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Molecular Farming: Biotechnological Approaches for Producing High-Value Plant-derived Pharmaceuticals

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Abstract: Molecular farming is a biotechnological method that involves using genetically modified plants to produce valuable medications. It has gained recognition as a revolutionary technique in the field. This novel approach utilizes the biosynthetic capacities of plants to generate intricate biomolecules, providing a scalable and cost-efficient substitute for conventional pharmaceutical manufacturing. This study article explores the several biotechnology methods used in molecular farming, focusing on the progress, difficulties, and future potential of this area.

Plants, with their ability to produce a wide range of secondary metabolites, offer a distinct opportunity for the creation of medications. Molecular farming exploits the inherent inclination of plants by inserting targeted genes to generate recombinant proteins, antibodies, vaccines, and other medicinal substances. Extensive research has been conducted on the utilisation of several plants,

including tobacco, maize, rice, and mosses. Each of these plants has unique benefits in terms of their ability to thrive in specific environmental circumstances, produce a large amount of biomass, and undergo post-translational alterations.

Transgenic plants are a key biotechnology method used in molecular farming. This method involves the incorporation of foreign genes into the genetic material of the plant, allowing the plant to produce the necessary medicinal proteins. Agrobacterium-mediated transformation and biolistic particle administration are frequently employed techniques for gene insertion. Agrobacterium-mediated transformation utilises the inherent capability of Agrobacterium tumefaciens to transfer DNA into plant cells, whereas biolistic particle delivery, sometimes referred to as the gene gun approach, includes the physical injection of DNA-coated particles into plant tissues.

Transient expression systems offer a viable method for quickly producing medications without the requirement of stable genetic integration. This approach frequently utilises viral vectors or agroinfiltration techniques, enabling rapid and abundant protein expression. Transient systems offer significant benefits for the rapid production of vaccines in response to newly emerging diseases, where time is of utmost importance.

Efficiently regulating gene expression is a crucial component of molecular farming. This involves choosing robust promoters, enhancers, and terminators to stimulate transcription at a high level, as well as optimising codons to improve translation efficiency in plant cells. In addition, directing recombinant proteins to certain organelles, such as the endoplasmic reticulum or chloroplasts, can enhance protein stability and increase protein accumulation.

The complexity of plant tissues and the existence of plant-specific pollutants make downstream processing and purification of plant-derived medications difficult. The implementation of purification techniques, such as affinity chromatography and the utilisation of plant-specific tags, has resulted in enhanced production efficiency and purity of the end product. Furthermore, the inclusion of regulatory factors and the implementation of stringent manufacturing standards (GMP) are crucial in guaranteeing the safety and effectiveness of medications generated from plants.

Molecular farming has extensive potential applications, including the generation of monoclonal antibodies, medicinal enzymes, and vaccine antigens. Significant achievements include the creation of ZMapp, a combination of monoclonal antibodies utilised in the treatment of Ebola virus, as well as the formulation of plant-derived vaccines for influenza and norovirus. These examples highlight the potential of molecular farming to tackle global health concerns.

Although molecular farming holds great potential, it encounters various obstacles. The commercial viability of plant-derived medications is heavily influenced by three essential factors: public perception and acceptance of genetically modified organisms (GMOs), intellectual property difficulties, and the necessity for stringent regulatory frameworks. Furthermore, the potential of

molecular farming systems to be scaled up and the economic viability of production are still subjects of continuing investigation.

To summarise, molecular farming is a groundbreaking method in the biotechnological manufacturing of medications. This technology utilises the innate capacities of plants to create a sustainable and adaptable system for manufacturing valuable medicinal chemicals. Ongoing progress in genetic engineering, optimisation of expression, and purification methods is anticipated to surpass existing constraints, therefore facilitating the mainstream acceptance of medications generated from plants. Molecular farming has the potential to greatly impact world healthcare by offering accessible and affordable cures for various ailments as the science advances.

Keywords: *Molecular Farming, Biotechnological Approaches, Plant-derived Pharmaceuticals, Recombinant Proteins, Genetic Engineering, Transgenic Plants, Agrobacterium-mediated Transformation, Transient Expression Systems, Downstream Processing, Vaccine Production.*

1. Introduction:

Molecular farming is a growing subject that combines plant biotechnology and pharmaceutical manufacture (1). It has gained considerable attention because of its potential to transform the creation of valuable therapeutic chemicals. This novel strategy utilises genetically modified plants as bioreactors to manufacture medications, providing an alternative to conventional manufacturing methods that depend on microbial or mammalian cell cultures (2). The emergence of molecular farming signifies a significant change in the production of biopharmaceuticals, motivated by the requirement for scalable, cost-efficient, and environmentally friendly solutions to address the increasing worldwide need for medical treatments (3).

The practice of using plants to produce therapeutic proteins originated in the early 1990s, when the first genetically modified tobacco and potato plants effectively generated recombinant proteins (4). Subsequently, the discipline has undergone rapid evolution, characterised by breakthroughs in genetic engineering techniques, expression systems, and downstream processing technologies. Plants provide various inherent benefits as production platforms, such as the capacity to carry out intricate post-translational alterations, minimal risk of contamination with human diseases, and the possibility of large-scale growing in open fields or controlled conditions.

Choosing appropriate plant species is a crucial factor in molecular farming (5). Widely utilised plants comprise tobacco (Nicotiana tabacum), maize (Zea mays), rice (Oryza sativa), and mosses (Physcomitrella patens), each providing distinct advantages. Tobacco is preferred for its abundant biomass production and recognised methods of modification, while maize and rice are advantageous since they are widely consumed crops, making it easier to incorporate them into existing agricultural systems (6). In contrast, mosses offer a steady and manageable setting for protein production, exhibiting little variations in glycosylation as compared to human proteins (7).

In molecular farming, genetic engineering commonly entails the incorporation of specific genes that encode therapeutic proteins into the genetic makeup of plants (8). The permanent incorporation of the foreign gene can be accomplished by stable transformation methods, such as Agrobacterium-mediated transformation or biolistic particle delivery. Transient expression systems, which do not entail genome integration, have become popular because they can rapidly produce recombinant proteins at high quantities (9). These methods commonly employ viral vectors or agroinfiltration techniques to introduce the desired genes.

Maximising the production and functioning of recombinant proteins requires the optimisation of gene expression (10). Strategies involve employing robust constitutive or tissue-specific promoters, optimising codons to facilitate translation, and targeting specific subcellular locations to optimise protein stability and accumulation. Moreover, the selection of promoters and enhancers is essential in promoting strong expression, whereas terminators guarantee effective termination of transcription and stability of the mRNA (11).

Plant-derived pharmaceutical production involves the manufacturing of various medicinal proteins, such as monoclonal antibodies, vaccines, and enzymes (12). Prominent instances encompass ZMapp, a combination of monoclonal antibodies employed for the therapy of Ebola virus, as well as diverse plant-derived vaccines developed for ailments including influenza and norovirus. These success stories demonstrate the capacity of molecular farming to effectively tackle pressing health issues by providing timely and cost-efficient solutions (13).
In spite of its optimistic prospects, molecular farming encounters certain obstacles that need to be resolved in order to attain economic feasibility (14). These factors encompass the way the general public views and the obstacles imposed by regulations on genetically modified organisms (GMOs), the intricacy of subsequent processing and purification, and the capacity to expand production systems. To acquire public trust and regulatory approval for plant-derived medications, it is crucial to adhere to good manufacturing standards (GMP) and build strong regulatory frameworks (15).
This study paper seeks to present a thorough and detailed examination of the present condition of molecular farming, including an analysis of the biotechnological methods employed, the progress achieved, and the obstacles faced (16). Through an examination of the possible uses and future paths of this area, we aim to emphasise the profound influence of molecular farming on the manufacturing of pharmaceuticals and worldwide healthcare. Molecular farming, achieved through ongoing research and collaboration, offers the potential to provide cost-effective and easily obtainable therapeutic solutions to cater to the need of various global populations (17).

2. Plant Systems Used in Molecular Farming:

Molecular farming utilises plants as bioreactors to produce valuable drugs (18). The choice of plant systems is essential for maximising yield, scalability, and cost-efficiency. This section examines the many plant species that are frequently utilised in molecular farming, along with the criteria used to pick them, and the benefits and constraints associated with each system.

2.1 Criteria for Selecting Plant Species

The selection of plant species for molecular farming is contingent upon various factors:

- Biomass Yield: Plants with high biomass production are desirable since they can generate a greater quantity of raw material for pharmaceutical extraction.

- Optimal Growing settings: Plants that may be readily cultivated under regulated settings or in open areas are beneficial (19).

- Genetic Transformation Efficiency: It is desirable to work with species that can be genetically manipulated and can effectively express foreign genes in a stable manner (20).

- Post-Translational Modifications: Plants that have the ability to carry out post-translational modifications similar to humans play a crucial role in ensuring the correct folding and functioning of recombinant proteins (21).

- Regulatory Acceptance: Species that have a proven track record of being safe for use in agriculture and eating are more likely to receive permission from regulatory authorities (22).

2.2 Plants that are frequently utilised

Tobacco (Nicotiana tabacum):

Advantages: -

- Exhibits high biomass output and demonstrates quick growth.

- Established genetic transformation protocols.

- Elevated levels of recombinant protein expression.

Disadvantages: -

- The presence of nicotine and other alkaloids can make the purifying process more complex (23).

- Public perception challenges arise as a result of its affiliation with smoking.

Maize (Zea mays):

Advantages:-

- Well-developed agricultural practices and infrastructure.

- The production of a large amount of biomass and the ability to increase production on a larger scale (24).

- Capacity to generate substantial volumes of medications derived from seeds.

Disadvantages: -

- Lengthy maturation period in comparison to certain other plant species.

- Regulatory issues pertaining to genetically modified (GM) crops.

Rice (Oryza sativa): -

Advantages: -

- Extensively grown essential crop with established agricultural systems.

- Thoroughly researched genetic makeup and techniques for altering it (25).

- Possibility of cultivating medications through seed-based manufacture for long-term stability.

Limitations: -

- Extended duration of growth cycle and possibility of contamination with food supplies.

- Involves the use of complex procedures to eliminate starches during the later stages of processing.

Mosses (Physcomitrella patens): -

Advantages: -

- Mosses, specifically the species Physcomitrella patens, offer a straightforward and consistent genetic system that allows for efficient homologous recombination (26).

- Capability to execute glycosylation processes that resemble those performed by humans. Regulating growth conditions within bioreactors.

Limitations: -

- Lower biomass productivity in comparison to higher plants.

- Production systems are not as well-developed and necessitate specialised facilities.

2.3 Benefits and Constraints of Each Plant System

Every plant system provides distinct advantages and encounters various obstacles. Tobacco is preferred due to its fast growth and high biomass production, which makes it well-suited for the

large-scale production of recombinant proteins (27). Nevertheless, the existence of poisonous alkaloids requires rigorous purification procedures. Maize and rice are beneficial because they are staple crops that may readily be incorporated into current agricultural systems. Their seed-based production processes provide enduring stability for pharmaceuticals, despite the considerable constraints posed by regulatory obstacles and the risk for contamination with food supplies.

Mosses offer a hopeful alternative because to their capacity to carry out post-translational alterations similar to humans and possess stable genetic systems (28). Bioreactors provide exact manipulation of environmental parameters, hence ensuring consistent output during their growth. Nevertheless, the reduced biomass productivity and the requirement for specialised cultivating facilities may restrict their capacity to be scaled up.

3. Genetic Engineering Techniques:

Genetic engineering plays a crucial role in molecular farming by allowing the incorporation of genes that code for specific medicinal proteins into the genomes of plants (29). This section provides an overview of the main genetic engineering techniques employed in molecular farming, which encompass stable transformation approaches and transient expression systems.

3.1 Methods for achieving stable transformations

Stable transformation refers to the process of incorporating foreign genes into the genetic makeup of a plant, which enables the plant to pass on the production of modified proteins to future generations. Agrobacterium-mediated transformation and biolistic particle delivery are two commonly employed strategies for steady transformation.

3.2 Agrobacterium-mediated transformation

Agrobacterium-mediated transformation is a process where DNA is transferred from the soil bacterium Agrobacterium tumefaciens to plant cells, utilising the bacterium's natural capacity to transfer genes. This procedure encompasses multiple crucial stages:

1. Gene Construct Preparation: The gene of interest is incorporated into a T-DNA section of a Ti plasmid, together with essential regulatory components including promoters and terminators (30).

2. Infection: The recombinant Ti plasmid is inserted into Agrobacterium tumefaciens, which is subsequently employed to invade plant tissues, usually leaf discs or callus cultures.

3. Integration and Regeneration: The T-DNA, which contains the desired gene, is introduced into the genome of the plant. The cells that have undergone transformation are carefully chosen and then developed into complete plants by a process of regeneration (31).

Advantages: -

Dicotyledonous plants (dicots) such as tobacco and potato exhibit high efficiency. - The technique is relatively easy and cost-effective.

The transgene is integrated in a stable and heritable manner.

Disadvantages : -

Reduced efficacy in monocotyledonous plants (monocots) such as maize and rice. Restricted to species that are vulnerable to Agrobacterium infection.

The possibility of suppressing genes and the impact of gene positioning on the expression of transgenes.

3.3 Biolistic particle delivery

It is a method used to deliver particles into cells or tissues by using a high-pressure helium gas to propel the particles.

Biolistic particle delivery, or the gene gun method, is a technique that involves the direct introduction of DNA into plant cells using high-speed microprojectiles. The procedure encompasses the subsequent stages:

1. DNA- Coated particles are prepared by applying DNA that encodes the gene of interest onto tiny gold or tungsten particles (32).

2. Particle Bombardment: The DNA-coated particles are propelled towards plant tissues using a gene gun, effectively piercing the cell walls and membranes.

3. Integration and Regeneration: The DNA becomes part of the plant's genetic material, and cells that have undergone transformation are carefully chosen and developed into complete plants (33).

Advantages: -

- Applicable to a diverse array of plant species, encompassing both dicots and monocots. Overcomes the constraints associated with Agrobacterium susceptibility.

- Enables the direct modification of chloroplast genomes, preventing the unintended spread of transgenes via pollen.

Disadvantages: -

- Reduced conversion efficiency in comparison to Agrobacterium-mediated techniques. There is a risk of tissue damage and the ability to regenerate is limited.

- Non-specific incorporation of transgenes can result in inconsistent amounts of gene expression and the suppression of gene activity (34).

3.4 Systems for the temporary production of proteins

Transient expression systems provide a fast alternative to stable transformation, allowing for the temporary and efficient production of recombinant proteins at high levels, without the requirement of integrating into the genome. These systems are especially valuable for efficiently generating proteins, such as in response to newly emerging diseases. Popular methods for temporary gene expression include the use of viral vectors and agroinfiltration.

3.5 Viral vectors

Plant viral vectors are genetically modified to transport and express genes from other organisms within plant cells (35). These vectors have the ability to invade plant cells and reproduce, resulting in significant amounts of production of recombinant proteins. Tobacco mosaic virus (TMV) and Cowpea mosaic virus (CPMV) are commonly used as viral vectors.

Advantages:-

- Efficient and expedited manufacturing of recombinant proteins within a short timeframe.

- Elevated levels of expression resulting from viral replication.

- Appropriate for mass production in industrial facilities.

Disadvantages:-

- Expression is limited in time, often lasting only a few weeks.

-There is a possibility of the rapid transmission of a virus and concerns regarding its impact on the environment (36).

-Restricted to proteins that do not hinder viral replication.

3.6 Agroinfiltration

Agroinfiltration is a technique that utilises Agrobacterium tumefaciens to temporarily transfer genes into plant cells (37). This method comprises the subsequent stages:

1. Culturing of Agrobacterium Strains: Agrobacterium strains containing the gene of interest are prepared.

2. Infiltration: The Agrobacterium suspension is introduced into plant tissues, usually leaves, through the use of a syringe or vacuum infiltration.

3. Gene Expression: The newly added genes exhibit a temporary period of activity, resulting in the production of the modified protein (38).

Advantages:-

- Quick and efficient production of genetically engineered proteins at a high level.

- Efficient and easily expandable procedure.

- Relevant to a diverse array of plant species.

Disadvantages:-

- Expression is ephemeral, usually enduring for a few weeks.

- Optimisation is necessary for each specific plant species and the protein being studied.

- There is a possibility of variation in the amounts of gene expression in various organs.

4. Optimization of Gene Expression

Maximising gene expression is a crucial element of molecular farming, guaranteeing the production of recombinant proteins at elevated levels and with the intended functionality (39). This section examines the several approaches employed to augment gene expression in plants, with a specific emphasis on promoters, enhancers, and terminators, codon optimisation, and subcellular targeting of recombinant proteins (40).

4.1 Promoters:

Promoters are particular DNA regions that initiate the process of transcription and are crucial in regulating the level and specificity of gene expression. The selection of a promoter is vital in order to attain elevated levels of expression for recombinant proteins in plants. Various types of promoters are utilised in molecular farming:

Constitutive promoters are responsible for maintaining uninterrupted gene expression in all tissues and during all phases of plant development. The Cauliflower mosaic virus (CaMV) 35S promoter is often utilised as a constitutive promoter owing to its robust and extensive functionality (41).

Tissue-specific promoters are responsible for regulating gene expression in particular tissues or organs, such as seeds, leaves, or roots. For instance, the seed-specific promoter derived from the phaseolin gene is employed to facilitate gene expression in seeds, hence promoting the stability and concentration of recombinant proteins in these tissues.

Inducible promoters are gene regulatory sequences that become active in response to certain environmental or chemical signals, enabling precise control over gene expression. A specific

instance is the ethanol-inducible promoter, which can be triggered by the administration of ethanol, allowing for accurate regulation of gene expression in terms of timing.

4.2 Enhancers:

Enhancers are specific DNA regions that enhance the transcriptional activity of promoters. These entities have the ability to operate in a manner that is not dependent on their position and can be found either before, after, or within the gene that they control. Enhancers function by promoting the interaction between transcription factors and the formation of the transcriptional apparatus (42). Utilising potent enhancers, such as the enhancer sequences derived from the CaMV 35S promoter, can greatly raise the levels of gene expression.

4.3 Terminators:

Terminators are specific sequences that serve as signals to indicate the completion of transcription. They play a crucial role in ensuring the stability and correct processing of mRNA. The nopaline synthase (NOS) terminator is commonly employed in plant transformation designs due to its high efficacy in facilitating transcription termination and polyadenylation of the mRNA (43). These processes are vital for maintaining mRNA stability and facilitating translation.

4.4 Codon optimization

It is the process of modifying the genetic code sequence in order to enhance the expression of a gene in a particular organism.

Codon optimisation entails altering the DNA sequence of the target gene to align with the host plant's preferred codon usage. Codon bias refers to the differing preferences of different organisms for specific codons that encode the same amino acid. Translation efficiency can be greatly enhanced by optimising codon use to match the quantity of tRNA in the host plant. This method encompasses the following:

Substituting infrequently utilised codons in the host plant with more commonly employed codons.

Preventing the formation of RNA secondary structures: Reducing sequences that have the potential to generate stable secondary structures in mRNA, which may impede the process of translation.

Preserving Amino Acid Sequence: Ensuring the protein's sequence of amino acids remains unaltered despite variations in the DNA sequence (44).

Codon optimisation can lead to increased protein expression, greater protein folding, and improved total output of recombinant proteins in plants.

4.5 Localization of Recombinant Proteins into Subcellular Compartments

Subcellular targeting of recombinant proteins includes directing them to specific compartments inside the plant cell, thereby improving their stability, accumulation, and usefulness. Distinct compartments offer distinct conditions that can enhance the synthesis of specific proteins.

Typical methods of targeting include:

Endoplasmic Reticulum (ER) Targeting: The ER creates a favourable environment for correct folding and post-translational modifications, such as glycosylation (45). Proteins can be directed to the endoplasmic reticulum (ER) by including a signal peptide at the N-terminus. Retention signals such as KDEL or HDEL can guarantee that proteins stay within the endoplasmic reticulum (ER), so avoiding their breakdown and improving their stability.

Chloroplast Targeting: Chloroplasts have the ability to collect substantial amounts of recombinant proteins as a result of their significant capacity for protein synthesis. Chloroplast targeting is accomplished by combining the gene of interest with a chloroplast transit peptide, which guides the protein to the chloroplast.

Vacuole Targeting: The vacuole functions as a storage organelle, and directing proteins to the vacuole can shield them from degradation in the cytoplasm (46). This is achieved by including vacuolar sorting signals within the protein.

Apoplast Targeting: The apoplast, also known as the extracellular space, can be utilised for the excretion of recombinant proteins. Proteins can be directed to the apoplast by including a signal peptide that guides secretion.

5. Downstream Processing and Purification

Downstream processing and purification are essential stages in molecular farming, with the goal of separating and purifying pharmaceuticals obtained from plants to meet the necessary requirements of purity, safety, and effectiveness (47). This section discusses the difficulties encountered in purifying medications generated from plants, as well as the latest advancements in purification methods. It also covers the precautions required to guarantee the safety and effectiveness of the final product.

5.1 Difficulties in the purification of pharmaceuticals generated from plants

Extracting medications from plant systems presents distinctive difficulties due to the intricate and varied nature of plant tissues. Some of the main difficulties are:

Plant tissues consist of many chemicals, including secondary metabolites, pigments, phenolics, and polysaccharides (48). These components can hinder the extraction and purification process of the desired recombinant protein.

Protease Activity:

Plants possess endogenous proteolytic enzymes that can break down recombinant proteins during the process of extraction and purification, resulting in decreased yield and compromising the integrity of the final product.

Protein expression can exhibit variability between plant species, tissues, and even within various regions of the same plant, which makes it challenging to establish standardised purification techniques

Scalability:

The task of expanding purifying procedures from a laboratory setting to an industrial scale, while ensuring consistency and efficiency, is particularly difficult for proteins that are produced in limited quantities.

Regulatory Compliance:

To guarantee that plant-derived pharmaceuticals adhere to strict regulatory criteria regarding their purity, safety, and effectiveness, it is necessary to implement strong and validated purification procedures.

5.2 Progress in Purification Methods

Affinity Chromatography: It is a method that takes advantage of the precise binding affinity between a desired protein and a ligand that is fixed to a chromatography matrix (49). One way to purify His-tagged proteins is by utilising affinity resins that have nickel or cobalt. Affinity chromatography provides a high level of specificity and purity, making it well-suited for the initial capture and concentration of recombinant proteins.

Protein A/G Chromatography: It is a regularly employed method for monoclonal antibodies purification. These proteins have a unique affinity for the Fc region of antibodies, which allows for their targeted extraction from plant extracts.

Hydrophobic Interaction Chromatography (HIC): It is a technique that separates proteins by exploiting their hydrophobic properties. By adjusting the salt concentrations, it is possible to selectively remove recombinant proteins from the chromatography column, therefore efficiently eliminating hydrophilic contaminants.

Ion Exchange Chromatography (IEX): It is a technique that separates proteins by using their electrical charge. By manipulating the pH and ionic strength of the buffer solution, specific proteins can be specifically attached to and released from the ion exchange resin.

Size Exclusion Chromatography (SEC): It is a technique that separates proteins by their molecular size. This method is very valuable for eliminating clusters and refining proteins to a state of uniformity, guaranteeing constant quality of the final product.

Two-phase extraction: It is a technique that separates proteins by utilising aqueous two-phase systems, which consist of polymers like polyethylene glycol (PEG) and dextran (50). It has practical applications in the purification of huge quantities and can be integrated with other chromatographic methods to achieve higher levels of purity.

Utilising a membrane as the basis Methods: Ultrafiltration and microfiltration membranes are employed to concentrate and purify plant extracts. Recent advancements in membrane technology have enhanced the efficiency of these procedures, resulting in decreased processing time and increased yield.

5.3 Ensuring the safety and effectiveness of products

Validating and ensuring the safety and effectiveness of pharmaceuticals produced from plants requires the implementation of many levels of validation and quality control measures:

Good Manufacturing Practices (GMP) refer to a set of guidelines that must be followed to guarantee that production processes are standardised, controlled, and recorded. This encompasses rigorous regulations on the sourcing of raw materials, the use of equipment, and the maintenance of the industrial environment.

Purity and potency testing is conducted on purified medications to ensure their quality, strength, and stability. Quantification and verification of the target protein's identification are accomplished using analytical techniques such as high-performance liquid chromatography (HPLC), mass spectrometry, and enzyme-linked immunosorbent assay (ELISA) (51).

Contaminant Elimination: It is vital to ensure the elimination of plant-specific pollutants, such as endotoxins, alkaloids, and secondary metabolites. This process entails the utilisation of sophisticated filtration, chromatography, and purifying techniques specifically devised to eradicate contaminants.

Functional experiments are performed to validate the therapeutic effectiveness of the recombinant protein by assessing its bioactivity. This may involve doing in vitro binding experiments, performing cell-based activity assays, and carrying out in vivo efficacy investigations.

Regulatory approval is required for plant-derived medications, and this approval is granted by agencies like the U.S. Food and Drug Administration (FDA) and the European Medicines Agency (EMA) based on certain standards. This process entails thorough documentation, rigorous clinical studies, and meticulous safety evaluations.

6. Applications of Molecular Farming

Molecular farming provides a flexible and expandable system for manufacturing a diverse array of valuable medications, utilising the biological synthesis skills of plants (52). This section examines the main uses of molecular farming, which involve producing monoclonal antibodies, creating vaccines, synthesising therapeutic enzymes, and showcasing noteworthy examples like ZMapp for Ebola and plant-based influenza vaccines.

6.1 Manufacturing Monoclonal Antibodies

Monoclonal antibodies (mAbs) are precise therapeutic proteins that are employed to treat a range of ailments, such as cancer, autoimmune disorders, and infectious diseases. Molecular farming offers a cost-efficient and easily expandable option for manufacturing monoclonal antibodies (mAbs) in contrast to conventional mammalian cell cultures.

Benefits:

Cost-effectiveness: Plant systems provide the advantage of being able to be grown on a larger scale at a lower cost compared to mammalian cell cultures.

Safety: Plants do not host human infections, hence minimising the danger of contamination. Scalability: The capacity to achieve a large biomass yield and expand production in open fields or greenhouses.

Examples:

ZMapp is a combination of three monoclonal antibodies that are created in Nicotiana benthamiana, a plant related to tobacco. It is utilised for the treatment of Ebola virus infection.

ZMapp exhibited effectiveness in decreasing death among infected patients during the 2014 Ebola epidemic.

Plant-based methods have been employed to generate monoclonal antibodies that specifically target the influenza virus, providing a fast reaction to newly developing strains.

6.2 Vaccine development

Vaccinations play a vital role in limiting the spread of infectious illnesses, and molecular farming presents a viable method for generating vaccinations that are both safe and effective (53). Plant-derived vaccines can be rapidly and efficiently manufactured, making them highly suitable for addressing pandemics and outbreaks.

Benefits:

Swift Manufacturing: Transient expression methods facilitate the expedited manufacture of vaccines, a crucial factor during outbreaks.

Scalability: The ability to cultivate plants in huge quantities enables the efficient and extensive manufacture of vaccines.

Safety: Decreased likelihood of exposure to human diseases and other detrimental substances.

Illustrations: Plant-based influenza vaccines, such as those derived from Nicotiana benthamiana, have demonstrated effectiveness in clinical studies. These vaccines can be swiftly manufactured in response to emerging influenza viruses.

6.3 Production of Medicinal Enzymes

Therapeutic enzymes are employed for the treatment of many metabolic abnormalities and diseases. Molecular farming allows for the efficient and expandable manufacturing of these enzymes at a reasonable cost (54).

Benefits:

Cost Reduction: The utilisation of plants for enzyme manufacturing might substantially decrease production expenses in comparison to conventional approaches.

Scalability: Scalibility refers to the capacity to achieve high biomass yield and cultivate plants on a wide scale.

6.4 Illustrations:

Glucocerebrosidase, an enzyme utilised for the treatment of Gaucher's illness, has been successfully grown in carrot cells using molecular farming techniques. Clinical testing have shown that it is both effective and safe.

Alpha-galactosidase, an enzyme utilised for the management of Fabry disease, has been effectively synthesised in tobacco plants (55).

7. Regulatory and Public Perception Challenges

Nanotechnology in medicine delivery encounters several regulatory and public perception obstacles during its development and deployment. These obstacles can have a substantial effect on the advancement and adoption of nanotechnology-based solutions.

The regulatory framework for nanotechnology in drug delivery is intricate and continuously developing. The FDA (Food and Drug Administration) in the United States and the EMA (European Medicines Agency) in Europe are regulatory authorities that have a vital role in establishing criteria and rules for approving nanomedicines (56). These laws guarantee the safety, effectiveness, and quality of pharmaceuticals that are based on nanotechnology.

1. Safety and Efficacy Evaluation:

Regulatory authorities want extensive data regarding the safety and effectiveness of nanomedicines. This encompasses preclinical investigations, clinical trials, and post-market monitoring. Specialised testing techniques are required due to the distinctive characteristics of nanoparticles, including their size, surface area, and reactivity.

2. Manufacturing Standards:

The manufacturing of nanomedicines must strictly comply with rigorous Good Manufacturing Practices (GMP). This involves guaranteeing the uniformity and integrity of the nanomaterials employed. Regulatory bodies conduct inspections of manufacturing plants to verify adherence to these criteria.

3. Labelling and transparency:

It is crucial for clearly indicating the use of nanomaterials in medication formulations (57). This fosters the development of trust between healthcare personnel and patients.

4. Standardisation of rules:

It is necessary to standardise rules across various countries in order to promote global trade and cooperation in nanomedicine research. Discrepancies in regulatory mandates can impede the progress and marketability of pharmaceuticals based on nanotechnology.

7.2 Perception and Acceptance of Genetically Modified Organisms (GMOs) by the Public

The adoption and success of nanotechnology, particularly in drug delivery, can be greatly influenced by the way it is seen and accepted by the public. Public opinion can be influenced by concerns of safety, ethical consequences, and environmental effect.

1. Safety Concerns: Public apprehensions over the potential toxicity and enduring consequences of nanoparticles can impede acceptance. Ensuring clear and open communication of scientific evidence that proves the safety of nanomedicines is essential in resolving these concerns.

2. Ethical Implications: The utilisation of nanotechnology in medicine raises ethical concerns that must be acknowledged, including matters of privacy, informed consent, and the possibility of misuse. Public engagement and conversation can facilitate the comprehension and alleviation of these challenges.

3. Education and Awareness: Enhancing public knowledge and comprehension of the advantages and potential drawbacks of nanotechnology in pharmaceutical delivery might facilitate the process of acquiring approval and support. Education campaigns and outreach programmes are crucial in this context.

4. Confidence in Regulatory Bodies: The confidence of the public in regulatory bodies and their capacity to guarantee the safety and effectiveness of nanomedicines is of utmost importance (58). Public confidence can be improved by implementing transparent and efficient regulatory mechanisms.

7.3 Issues related to intellectual property and the process of commercialising intellectual property.

The presence of intellectual property (IP) rights and the difficulties associated with commercialization pose substantial obstacles in the advancement and implementation of drug delivery systems based on nanotechnology.

1. Patent Protection: Obtaining patents for discoveries based on nanotechnology is essential for safeguarding intellectual property. Nevertheless, the newness and intricacy of nanotechnology can pose difficulties when filing for patents. Explicit criteria and assistance for obtaining patents for nanoscale innovations are crucial.

2. Licencing and Technology Transfer: Efficient licencing agreements and processes for technology transfer are essential for the successful transition of nanomedicines from the laboratory to the market (59). Cooperation among academic institutions, research organisations, and pharmaceutical businesses can expedite this process.

3. Market Competition: The presence of competitors in the pharmaceutical sector can affect the process of bringing nanomedicines to the market. Forming strategic alliances and collaborations can assist in effectively navigating the competitive landscape and attaining success in the market.

4. Cost and Accessibility: The exorbitant expenses associated with the development and

production of nanomedicines can restrict their availability to a wider population. It is essential to make significant efforts in order to decrease expenses and guarantee fair availability of these modern treatments, since this is vital for their general acceptance and use.

To ensure the successful integration of nanotechnology in drug delivery, it is crucial to tackle the regulatory, public perception, and commercialization problems associated with it. The cooperation of scientists, regulatory organisations, industry stakeholders, and the public can facilitate the development of novel and efficient nanomedicines.

8. Economic and Scalability Considerations:

The economic feasibility and ability to expand of molecular agricultural systems are essential considerations in determining their future acceptance and achievement (60). These factors impact the feasibility and practicality of producing high-value medications produced from plants on a large scale, as compared to traditional techniques of pharmaceutical production.

8.1 Economic efficiency of plant-based production

Plant-based production techniques provide numerous cost benefits compared to conventional methods:

1. Reduced Production Costs: Utilizing plants as biofactories for pharmaceuticals can offer a substantial cost advantage compared to conventional cell culture or microbial fermentation systems. Plants necessitate a reduced number of costly inputs, such as growing medium, fertilisers, and controlled environmental conditions.

2. Decreased Capital Expenditure: The infrastructure necessary for plant-based production, such as greenhouses or open fields, is typically less expensive than the advanced bioreactors and facilities required for microbial or mammalian cell cultures.

3. Scalability and Flexibility: Plants can be cultivated on a significant scale with relative simplicity, and the production capacity can be modified by expanding the cultivation area. This scalability offers significant benefits when it comes to addressing high demand or rapidly increasing production in response to pandemics or other pressing requirements.

4. Reduced Operational Expenses: Plant-based systems often incur lower operational expenses, encompassing labour, energy, and maintenance (61). In addition, plants can be genetically modified to directly produce the desired product, reducing the need for subsequent processing and purifying stages.

5. Sustainability: Plant-based systems exhibit greater sustainability and environmental friendliness, hence decreasing the carbon footprint linked to pharmaceutical manufacturing. This

sustainability can result in financial savings and be in line with the growing requirements of regulations and consumers for more environmentally friendly production practices.

8.2 The scalability of molecular farming systems.

The commercial success of molecular farming heavily relies on scalability.

1. Agricultural Expansion: The cultivation of plants on agricultural land enables a substantial increase in output capacity. Contemporary agricultural methods, such as precision farming, have the potential to maximise crop production and enhance efficiency.

2. Greenhouse and Vertical Farming: Controlled environment agriculture, such as greenhouses and vertical farms, allows for continuous production throughout the year, regardless of weather conditions (62). These systems have the capability to be expanded vertically, which allows for optimal use of space and increased production productivity.

3. Genetic stability and yield consistency: These are essential factors for achieving scalability in the production of pharmaceutical compounds. It is important to ensure that the desired compounds are consistently produced across successive generations of plants. Progress in plant breeding and genetic engineering can assist in accomplishing these objectives.

4. Harvesting and processing: These are crucial for expanding plant-based output. It is imperative to employ efficient procedures in order to scale up production. Implementing mechanised harvesting and automated processing technologies can enhance operational efficiency and decrease labour expenses.

5. Regulatory Compliance: Expanding molecular farming systems requires adhering to regulatory frameworks to guarantee compliance with safety, quality, and environmental norms. Efficient regulatory procedures can help smooth the shift from small-scale testing to large-scale manufacturing.

8.3 Contrast with Conventional Methods of Pharmaceutical Production

When contrasting plant-based molecular farming with conventional pharmaceutical production methods, certain crucial variables come into consideration:

1. Production Efficiency: Conventional techniques, such as microbial fermentation and mammalian cell cultures, provide optimal production efficiency and high yield of intricate compounds (63). Nevertheless, the utilisation of bioreactors, media, and controlled conditions necessitates substantial financial resources.

2. Cost Implications: Although traditional methods can generate significant outputs, they frequently entail increased expenditures for raw materials, infrastructure, and operational costs.

Conversely, plant-based systems can achieve comparable yields while incurring far lower expenses.

3. Rapid Time to Market: Conventional approaches may offer speedier development and production cycles as a result of well-established procedures and regulatory expertise. Plant-based systems may necessitate additional time for optimisation and expansion, while advancements in genetic engineering and agricultural techniques are diminishing these timeframes.

4. Product Purity and Quality: Maintaining a high level of purity and quality in medicines is of utmost importance. Conventional techniques provide accurate management of production conditions, leading to constant product quality. Plant-based systems must confront issues associated with the variability in plant growth and the extraction of compounds.

5. Regulatory Acceptance: Conventional pharmaceutical manufacturing techniques are firmly established and have clearly defined regulatory routes. Plant-based solutions are very recent and might encounter more rigorous examination and lengthier clearance processes as regulatory agencies adjust to these groundbreaking methods.

6. Environmental Impact: Conventional technologies exhibit a greater environmental imprint as a result of energy-intensive procedures and the production of waste. Plant-based systems are characterised by their higher sustainability and their ability to provide a greener alternative with a reduced environmental footprint.

9. Future Prospects and Innovations

The potential of molecular farming is highly promising as ongoing advancements in technology and creativity propel the industry forward. These advancements possess the capacity to tackle worldwide health obstacles and open up opportunities for novel study avenues and cooperative endeavours.

9.1 Advancements in Molecular Farming Technologies

Multiple state-of-the-art technologies are ready to completely transform molecular farming:

1. CRISPR and Gene Editing: CRISPR-Cas9 and other gene-editing techniques allow for accurate alterations to the genetic makeup of plants (64). This enables the precise incorporation or improvement of genes responsible for synthesising medicinal molecules, so enhancing both productivity and effectiveness.

2. Synthetic biology: It is the field that focuses on the deliberate creation and assembly of novel biological components, mechanisms, and structures. Synthetic biology can be employed in

molecular farming to design efficient pathways for the synthesis of intricate molecules, thereby augmenting the capacity of plants to function as biofactories.

3. Advanced plant breeding methods: Such as marker-assisted selection and genomic selection, expedite the creation of plant varieties that have high productivity, resistance to diseases, and tolerance to stressful conditions. These developments enhance the overall efficiency and dependability of molecular agricultural systems.

4.Metabolic engineering: It is a field that involves altering the metabolic pathways of plants in order to enhance the synthesis of specific chemicals. Through the optimisation of these pathways, scientists can improve the effectiveness and output of pharmaceutical manufacture in plants.

5. Nanotechnology: It can be utilised in molecular farming to enhance the transportation and durability of synthesised chemicals. Nanocarriers have the capacity to safeguard delicate molecules, improve their availability in biological systems, and facilitate precise transportation to particular tissues or cells.

Automation and precision agriculture are advanced technologies that can optimise the cultivation, harvesting, and processing of pharmaceutical plants. These technologies include robotic harvesting and precise agricultural techniques. These advancements enhance productivity, decrease labour expenses, and guarantee uniformity in product excellence.

9.2 Potential for Tackling Global Health Issues

Molecular farming offers the possibility to tackle numerous global health issues by offering economical and scalable methods for manufacturing crucial medications.

1. Vaccine Production: Utilizing plant-based systems enables the quick and cost-effective production of vaccinations, hence increasing accessibility for low-income countries. This strategy is of utmost importance during pandemics, as it allows for the rapid manufacturing and dissemination of vaccinations.

2. Therapeutic Proteins and Antibodies: Plants can be genetically modified to synthesise therapeutic proteins and monoclonal antibodies that are utilised in the medical treatment of various ailments, including cancer, autoimmune disorders, and infectious diseases. These biologics derived from plants can be manufactured at a lower cost and in greater quantities.

3. Molecular farming: It has the capability to generate nutraceuticals and functional foods that are fortified with vitamins, minerals, and bioactive substances. These items have the potential to mitigate malnutrition and enhance the general well-being of susceptible populations.

4. Enhancing Global Supply Chain Resilience: Molecular farming can strengthen the resilience of global supply chains by dispersing pharmaceutical production and utilising local agricultural resources. This approach reduces reliance on centralised manufacturing facilities and helps mitigate the effects of supply chain disruptions.

9.3 Prospects for Future Research and Opportunities for Collaboration

In order to fully harness the potential of molecular farming, it is imperative to pursue various research avenues and foster joint endeavours.

1. Enhancing Expression Systems Optimization: Research should prioritise the enhancement of plant expression systems to maximise the production, stability, and effectiveness of medicinal chemicals. This involves the creation of novel promoters, enhancers, and regulatory components.

2. Enhancing Downstream Processing: Advancements in downstream processing methods, including purification and formulation, are essential for guaranteeing the purity and effectiveness of medications generated from plants. It is crucial to develop purifying processes that are both cost-effective and scalable.

3. Resolving Regulatory Challenges: To ensure consistency and clarity in the regulation of plant-based pharmaceuticals, it is imperative for scientists, regulatory agencies, and industry stakeholders to work together collaboratively (65). This involves establishing criteria for evaluating the safety, effectiveness, and quality of a product or service.

4. Public Engagement and Education: It is crucial to actively include the public and provide them with information about the advantages and security of molecular farming in order to obtain acceptance and establish trust. Effective and transparent communication and outreach initiatives can help to clarify misunderstandings and garner backing.

5. Interdisciplinary Collaboration: Collaboration among many fields such as plant science, biotechnology, pharmacology, and engineering can foster innovation in molecular farming. Interdisciplinary research teams have the ability to tackle intricate difficulties and create comprehensive solutions.

6. International collaborations: Creating worldwide alliances and networks can enable the exchange of knowledge, transfer of technology, and development of capabilities. Cooperative endeavours can facilitate the expansion of molecular farming projects and guarantee fair and equal availability of plant-based medications on a global scale.

10. Conclusion

The investigation of molecular farming as an innovative method for manufacturing valuable medications derived from plants has brought attention to notable progress and prospects in the sector. This conclusion consolidates the main discoveries, examines the consequences for the pharmaceutical sector, and outlines a perspective for the future of molecular farming.

10.1 Key findings summary

1. Molecular farming provides a financially efficient and easily expandable option as compared to conventional techniques of pharmaceutical production. The use of plant-based systems is highly tempting due to their lower manufacturing costs, reduced capital expenditure, and scalability.

2. The effective execution of molecular farming necessitates traversing intricate regulatory frameworks and addressing concerns regarding public perception. It is essential to prioritise safety, effectiveness, and openness in order to obtain regulatory approval and earn public acceptability.

3. Technological advancements, including CRISPR, synthetic biology, enhanced plant breeding, metabolic engineering, nanotechnology, and automation, are propelling the development of molecular farming. These advancements improve the effectiveness, productivity, and excellence of medications generated from plants.

4. Molecular farming has substantial potential to tackle global health issues such as vaccine manufacturing, production of therapeutic proteins and antibodies, development of nutraceuticals, and creation of remedies for rare diseases. The capacity to generate cost-effective and expandable pharmaceuticals has the potential to enhance the availability of vital medications.

5. Ongoing research and interdisciplinary collaboration are crucial for maximising the efficiency of expression systems, enhancing downstream processing, tackling regulatory obstacles, and actively involving the public. Global collaborations can enhance the exchange of knowledge and transfer of technologies.

10.2 Implications for the Pharmaceutical Industry

1. Cost Reduction: Utilising plant-based production methods can result in substantial savings in the pharmaceutical manufacturing process due to its cost-effectiveness. This has the potential to enhance the affordability and availability of pharmaceuticals, particularly in economically disadvantaged areas.

2. Production Flexibility: The ability to scale up and adapt quickly in molecular farming enables rapid changes in production capacity. During health emergencies, the ability to quickly produce vaccinations and treatments can be highly advantageous.

3. Sustainability: Plant-based production techniques provide a more sustainable and ecologically conscious alternative to conventional approaches. Minimising the environmental impact of pharmaceutical manufacture is in line with the growing requirements from both regulators and consumers for eco-friendly production methods.

4. Innovation and Competition: Molecular farming is a groundbreaking innovation that is causing significant changes in the pharmaceutical business. Businesses who allocate resources to and embrace this technology have the potential to gain a competitive advantage by providing innovative medications produced from plants.

5. Regulatory Adaptation: The pharmaceutical industry must collaborate closely with regulatory organisations to establish and standardise protocols for the authorization of plant-derived medications. Cooperative endeavours can optimise the regulatory procedure and expedite market access.

10.3 Future Prospects of Molecular Farming

The future of molecular farming is promising, with various crucial factors influencing its advancement:

1. Incorporation of Cutting-Edge Technologies: The ongoing incorporation of cutting-edge technologies, including as gene editing, synthetic biology, and automation, will improve the efficiency and capabilities of molecular farming systems.

2. Global Collaboration: International cooperation and alliances will be essential for expanding molecular farming projects and guaranteeing fair availability of medications generated from plants. Sharing knowledge and transferring technology helps expedite advancement and tackle worldwide health inequalities.

3. Public Engagement and Education: Establishing public confidence and approval by means of open and informative communication is crucial. Interacting with communities and stakeholders helps cultivate a conducive atmosphere for the acceptance and implementation of molecular farming.

4. Regulatory Frameworks: Establishing unambiguous, uniform, and synchronised regulatory frameworks will be crucial for the commercialization of plant-derived medications. Regulatory organisations should collaborate with industry and researchers to develop rules that guarantee both safety and effectiveness, while also promoting innovation.

Implementing sustainable techniques in molecular farming will help create a more

environmentally friendly pharmaceutical sector. This encompasses the enhancement of resource utilisation, the reduction of waste, and the minimization of the ecological consequences of manufacturing procedures.

To summarise, molecular farming is a revolutionary method for manufacturing pharmaceuticals, providing cost-effective, scalable, and environmentally friendly options for creating valuable medications derived from plants. The progress in technology, capacity to tackle worldwide health issues, and cooperative endeavours are propelling the field ahead. Through ongoing innovation and strategic collaborations, molecular farming has the capacity to transform the pharmaceutical sector and enhance global health results.

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Different Biological Activities Especially Antioxidant Activity of Plant Based Functional Foods for Human Health

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Abstract: In recent years, the interest in plant-based functional foods with various biological activities, especially antioxidant properties, has grown exponentially due to their potential health benefits. Antioxidants play a crucial role in neutralizing harmful free radicals, which are reactive molecules that can cause cellular damage and contribute to various chronic diseases. Natural antioxidants are abundant in food and medicinal plants. These natural antioxidants, particularly polyphenols and carotenoids, have a variety of biological benefits, including anti-inflammatory, anti-aging, anti-atherosclerosis, and anticancer properties (Xu et al ., 2017). Fruits and vegetables are excellent sources of antioxidants because they contain a variety of antioxidant components. Fruits and vegetables have varying levels of antioxidant activity. Each fruit and vegetable contains a distinct type of antioxidant, and this might vary from species to species as well as climate to climate (Ravimannan et al ., 2017). The paper discusses the underlying principles of oxidative stress and the mechanisms by which antioxidants counteract its effects (Fang et al ., 2002). It delves into the various classes of antioxidants found in plant-based foods, such as polyphenols, carotenoids, flavonoids, vitamins (e.g., vitamin C and E), and trace minerals (e.g., selenium and zinc), explaining their diverse roles in protecting cells from oxidative damage (Peng et al., 2014). In this chapter we emphasize the vital role of plant-based functional foods as a source of natural antioxidants, contributing to the promotion of human health and well-being. Incorporating a diverse array of antioxidant-rich plant foods into the daily diet is crucial for supporting overall health and preventing chronic diseases.

Keywords: Plant-based functional foods, oxidative stress, polyphenols, carotenoids, flavonoids, vitamins, chronic diseases.

ANTIOXIDANT ACTIVITY : UNDERSTANDING THE ROLE IN HUMAN HEALTH

Antioxidants are molecules that neutralize harmful free radicals in the body. They play a crucial role in preventing oxidative damage to cells and tissues. Antioxidants help maintain cellular health and reduce the risk of chronic diseases such as cardiovascular disorders, cancer, and neurodegenerative conditions. There are two types of antioxidants: natural enzymatic antioxidants and non-enzymatic antioxidants. Superoxide dismutase and catalases are natural enzymatic antioxidants found mostly in peroxisomes. Natural and manufactured antioxidants include vitamin E, vitamin C, BHT, BHA, carotenoids, glutathione and derivatives, phenolic compounds, flavonoids, and alkaloids (Ravimannan et al ., 2017).
Reactive oxygen species (ROS) and reactive nitrogen species (RNS), such as superoxide, hydroxyl, and nitric oxide radicals, can damage DNA and cause lipid and protein oxidation in biological systems (Li et al., 2015). Normally, the antioxidant system in the human body can scavenge free radicals, thereby maintaining the balance between oxidation and anti-oxidation. Nonetheless, cigarette smoking, alcohol, radiation, or environmental contaminants cause the formation of excessive ROS and RNS, which upset the equilibrium of oxidation and anti-oxidation and result in several chronic and degenerative disorders (Wang et al., 2016).

THE IMPACT OF ANTIOXIDANTS ON HUMAN HEALTH

Antioxidants scavenge and neutralize free radicals, reducing their harmful effects on cells and tissues. They protect against oxidative damage and inflammation, promoting overall health and well-being. Consuming a diet rich in antioxidant-containing foods may reduce the risk of chronic diseases and support longevity.

INTRODUCTION TO PLANT-BASED FUNCTIONAL FOODS AND THEIR HEALTH BENEFITS:

Functional foods have gained significant attention for their potential to promote human health beyond basic nutrition. Among them, plant-based functional foods stand out due to their diverse biological activities and rich content of bioactive compounds. These foods go beyond meeting essential nutrient requirements and offer additional health benefits, making them valuable components of a balanced diet. One of the key areas of interest in plant-based functional foods is their antioxidant potential. Antioxidants protect cells from oxidative damage, which can lead to chronic diseases such as cardiovascular disorders, cancer, and neurodegenerative conditions. This chapter delves into the various biological activities exhibited by plant-based functional foods, with a primary focus on their antioxidant properties, to better understand their significance for human health.

Plant-Based Functional Foods	Biological Activities
Berries (e.g., blueberries, strawberries, cranberries)	High in antioxidants, including flavonoids and anthocyanins, protecting against oxidative stress and chronic diseases.
Nuts and Seeds (e.g., almonds, walnuts, chia seeds)	Rich in vitamin E and other polyphenols, supporting heart health and reducing inflammation.
Leafy Greens (e.g., spinach, kale, Swiss chard)	Abundant in lutein and other carotenoids, beneficial for eye health and antioxidant defense.
Spices and Herbs (e.g.,turmeric, cinnamon, rosemary)	Contain various phytochemicals, offering antioxidant and anti-inflammatory properties.
Whole Grains (e.g., quinoa, brown rice, oats)	Provide vitamins (e.g., vitamin E), minerals, and fiber, supporting overall health.
Legumes (e.g., lentils , chickpeas, kidney beans)	Rich in flavonoids and polyphenols, contributing to antioxidant and anti-diabetic effects.
Cruciferous Vegetables (e.g., broccoli, cauliflower, Brussels sprouts)	Contain sulfur compounds that enhance detoxification processes and provide antioxidant support.
Herbs and Teas (e.g., green tea, mint, basil)	Offer potent antioxidant activity and potential protective effects against chronic diseases.

Table no.1 : Plant-Based Functional Foods and Their Biological Activities

This table presents a selection of plant-based functional foods along with their respective biological activities. These foods are rich in various bioactive compounds such as antioxidants, polyphenols, carotenoids, and phytochemicals, which contribute to their beneficial effects on human health. The table highlights the specific biological activities of each functional food, including antioxidant properties, anti-inflammatory effects, support for heart health, eye health, and detoxification processes. Incorporating these plant-based foods into the diet can promote overall well-being and may help protect against oxidative stress and chronic diseases.

PLANT-BASED FUNCTIONAL FOOD PHYTOCHEMICAL COMPOSITION

Plant-based functional foods are high in phytochemicals, which are physiologically active molecules that provide a variety of health advantages. These bioactive chemicals contribute to the numerous biological activities of these foods, particularly their antioxidant activity, making them crucial components of a balanced diet.

BIOACTIVE COMPOUNDS IN PLANT FOODS: AN OVERVIEW

Phytochemicals are naturally occurring plant molecules that contribute to the brilliant colors, flavors, and fragrances of fruits, vegetables, nuts, seeds, and whole grains. These chemicals have gotten a lot of interest because of their potential health-promoting characteristics that go beyond simple nutrition.

Flavonoids, Phenolic Acids, and Anthocyanins are all polyphenols. Polyphenols are a type of phytochemical that is abundant in plant-based functional meals. They are divided into subclasses, which include flavonoids, phenolic acids, and anthocyanins (Pandey et al.,2009).
Flavonoids are one of the most investigated types of polyphenols, and they are found in a variety of plant diets. Quercetin (found in apples and onions), catechins (found in green tea), and anthocyanins (responsible for the red, purple, and blue colors in berries) are all examples of flavonoids. Flavonoids are powerful antioxidants that have been linked to a variety of health advantages, including cardiovascular protection, anti-inflammatory actions, and cancer prevention (Grosso et al., 2017).

Phenolic Acids: Another major subclass of polyphenols present in plant diets are phenolic acids. Ferulic acid (found in whole grains), caffeic acid (found in coffee), and chlorogenic acid (found in fruits and vegetables) are a few examples. These chemicals contain antioxidant action and have been demonstrated to benefit heart health, reduce inflammation, and regulate blood sugar levels (Suliman et al., 2016 ; Clifford et al.,2000)

Anthocyanins: Anthocyanins are flavonoids that give many fruits and vegetables their red, purple, and blue colors, such as berries, grapes, and red cabbage. Anthocyanins, in addition to creating brilliant colors, have strong antioxidant qualities and have been linked to enhanced cardiovascular health, cognitive function, and anti-cancer effects (He et al., 2010 ; Classidy et al., 2013).

BETA-CAROTENE, LYCOPENE, AND LUTEIN ARE CAROTENOIDS.

Carotenoids are another type of phytochemical present in plant-based functional meals that are responsible for the vibrant colors found in various fruits and vegetables. They are further classified into two types: carotenes (which include beta-carotene) and xanthophylls (which include lycopene and lutein).

Beta-carotene : Beta-carotene is a provitamin A carotenoid found in orange and yellow fruits and vegetables like carrots, sweet potatoes, and mangoes. It can be turned into vitamin A in the body, which is necessary for vision, immunological function, and skin health. Beta-carotene is also a powerful antioxidant that protects cells from oxidative damage (Krinsky et al.,2005 ; Pal et al., 2018).

Lycopene : It is a red carotenoid that can be found in tomatoes, watermelon, and pink grapefruit. It is well-known for its antioxidant action and has been associated with a lower risk of some malignancies, including prostate cancer. The capacity of lycopene to neutralize free radicals contributes to its possible health advantages (Rao et al.,2007 ; Yang et al 2001).

Lutein : It is a xanthophyll that is found in leafy greens such as spinach, kale, and collard greens, as well as egg yolks. It is critical for eye health, especially in the prevention of age-related macular degeneration. Lutein also has antioxidant capabilities, which help to protect the eyes from oxidative stress (Hammond et al., 2012 ; Ma et al., 2012).

VITAMIN C, VITAMIN E, AND OTHER NUTRIENTS:

Vitamins are necessary substances that play important roles in a variety of physiological processes. Plant-based functional foods are high in vitamins, particularly vitamin C and vitamin E, which act as antioxidants.

Vitamin C (Ascorbic Acid): Vitamin C is a water-soluble vitamin that may be found in a variety of fruits and vegetables, including oranges, strawberries, and bell peppers. It is a potent antioxidant that aids in the protection of cells from oxidative damage. Furthermore, vitamin C promotes immunological function, collagen formation, and iron absorption (Carr et al., 2017 ; Michels et al., 2013).

Tocopherols and tocotrienols (Vitamin E): Vitamin E is a fat-soluble vitamin found in nuts, seeds, vegetable oils, and leafy greens. It protects cell membranes from oxidative damage by acting as a lipid-soluble antioxidant (Azzi et al., 2006 ; Traber et al., 2011).
Other phytochemicals found in plant-based functional foods include terpenoids, phytosterols, and sulfur compounds, all of which contribute to their distinct health-promoting qualities.
Incorporating a varied range of plant-based functional foods into the diet ensures a high intake of these beneficial bioactive substances, which supports general health and lowers the risk of chronic diseases.

PLANT-BASED FUNCTIONAL FOODS: HEALTH IMPLICATIONS AND RECOMMENDATIONS

Plant-Based Diets for Health: Dietary Guidelines:

The relevance of plant-based diets in improving general health and well-being is emphasized in this chapter. It describes how eating more plant-based functional meals can deliver a variety of critical elements such as vitamins, minerals, fiber, and phytochemicals. The chapter emphasizes the possible health benefits of eating fewer processed and animal-based foods while eating more fruits, vegetables, whole grains, nuts, and seeds. It also investigates the advantages of plant-based diets in the prevention of chronic diseases such as cardiovascular disease, diabetes, and certain malignancies, as well as weight control and digestive health (Melina et al., 2016 ; Satija et al., 2017).
Including Antioxidant-Rich Foods in Your Daily Diet:

The emphasis in this part is on comprehending the importance of antioxidants in preserving cellular health and preventing oxidative damage. The chapter goes through a variety of plant-based functional foods that are high in antioxidants such vitamin C, vitamin E, flavonoids, carotenoids, and polyphenols. It includes simple recipes, meal planning suggestions, and innovative methods to add diversity to the diet, as well as practical recommendations and tactics for incorporating these antioxidant-rich foods into everyday meals. Furthermore, the chapter addresses the advantages of eating a variety of colored fruits and vegetables to acquire a broad spectrum of antioxidants for best health benefits (Pandey et al., 2009 ; Grosso et al., 2017 ; He et al., 2010).

Optimal Antioxidant Benefits from Plant-Based Functional Foods:

This chapter looks into the concept of balance in getting optimal antioxidant benefits from plant-based functional foods. It investigates the interaction of antioxidants and other nutrients in whole foods, emphasizing the need of eating a well-balanced diet to maximize their efficiency. The chapter also discusses lifestyle aspects such as physical activity, stress management, and proper sleep, which help to promote general health in addition to antioxidant-rich foods. It highlights the importance of moderation and mindfulness in food and lifestyle decisions for long-term health advantages (Traber et al., 2011 ; Lopresti et al., 2019 ; Grandner et al., 2014).

Bioactive Compounds in Plant Foods Have Synergistic Effects :

Plant-based meals are high in bioactive substances such as antioxidants, polyphenols, carotenoids, and vitamins, all of which contribute to their health-promoting characteristics. The possible synergistic effects of these bioactive chemicals when ingested together is one of their most intriguing aspects. The combined action of numerous components that results in a higher effect than the sum of individual effects is referred to as synergy.

The Impact of Plant Food Diversity on Antioxidant Potential:

Plant dietary diversity is critical for increasing the intake of numerous bioactive chemicals. Different fruits, vegetables, nuts, and grains have unique antioxidant and phytochemical combinations. Consuming a variety of these foods exposes you to a wide range of bioactive chemicals, resulting in a more robust antioxidant defense system. According to research, diets rich in plant diversity are connected with a lower risk of chronic diseases such as cardiovascular disease and certain malignancies, owing to the cumulative effect of bioactive substances acting together.

Dietary Patterns and Health Implications:

Combining various plant-based meals in dietary patterns can enhance the synergistic effects of bioactive substances. The Mediterranean diet, for example, which emphasizes fruits, vegetables, nuts, whole grains, and olive oil, is known for its antioxidant-rich profile and has been linked to a lower risk of heart disease and better longevity. Similarly, the traditional Japanese diet, which includes a range of vegetables, fish, and green tea, contains a balanced mix of bioactive components that promote overall health and longevity.

CONCLUSION

In conclusion, the chapter highlights the significance of plant-based functional foods with diverse biological activities, particularly their antioxidant properties, for human health. Antioxidants play a vital role in neutralizing harmful free radicals and protecting cells from oxidative damage, which is associated with various chronic diseases. The consumption of plant-based foods rich in antioxidants, such as polyphenols, carotenoids, flavonoids, and vitamins, has been linked to numerous health benefits, making them essential components of a balanced and nutritious diet.The chapter discusses the synergistic effects of bioactive compounds found in plant foods, emphasizing how different antioxidants work together to enhance their overall effectiveness in neutralizing free radicals. The interactions among these bioactive substances contribute to their collective health-promoting properties, providing additional support for the value of incorporating a diverse array of plant-based functional foods into the daily diet.

Furthermore, the chapter emphasizes the importance of plant food diversity in enhancing antioxidant potential. Each fruit and vegetable contains a unique combination of antioxidants, making it essential to consume a wide range of plant-based foods to obtain a comprehensive spectrum of bioactive compounds. Research indicates that diets rich in plant diversity are associated with a reduced risk of chronic diseases, underscoring the importance of incorporating a variety of antioxidant-rich foods in daily meals.

The review compiles the latest scientific evidence supporting the health benefits of consuming plant-based functional foods with high antioxidant capacity. These benefits encompass reduced risks of cardiovascular diseases, certain cancers, neurodegenerative disorders, and improved immune function, among others. It

reinforces the importance of promoting plant-based diets to support overall health and prevent chronic diseases.

In summary, the chapter underscores the vital role of plant-based functional foods as natural sources of antioxidants, contributing significantly to the promotion of human health and well-being. Incorporating a diverse array of antioxidant-rich plant foods into the daily diet is crucial for supporting overall health and preventing chronic diseases. By embracing plant-based functional foods with their myriad of bioactive compounds, individuals can harness the power of antioxidants to bolster their cellular health and enhance their quality of life.

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Role of Herbal Medicine in Cardiovascular Activities

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Abstract

Herbal medicine has gained substantial attention for its potential role in supporting cardiovascular health. This chapter explores the intricate interplay between herbal compounds and cardiovascular activities, shedding light on their mechanisms of action and therapeutic applications. With a historical backdrop of traditional herbal medicine, the prevalence of cardiovascular diseases serves as a compelling backdrop for the investigation. The chapter delves into the multifaceted mechanisms by which herbal compounds influence the cardiovascular system. Notably, herbs exhibit vasodilatory effects, contributing to blood pressure regulation, and harbor potent antioxidant and anti-inflammatory properties that collectively mitigate oxidative stress and inflammation within the cardiovascular milieu. Furthermore, certain herbs intricately modulate lipid metabolism, holding promise in the management of dyslipidemia. A thorough analysis of well-known herbal treatments clarifies each one's unique contributions to cardiovascular health. Hawthorn is revealed to be the champion of heart health, and garlic demonstrates its mastery of cholesterol reduction. Ginkgo Biloba is notable for its capacity to improve circulation, and turmeric demonstrates powerful anti-inflammatory properties. The chapter also looks at herbal medicine's potential as an intervention for regulating fluid balance, arrhythmias, and hypertension. Examined is the potential for resveratrol-rich plants and green tea to protect against heart disease. Along with considerations for safety, interactions, and future study, the symbiotic relationship between stress reduction, adaptogenic herbs, and heart health is also discussed in this article. This chapter concludes with a thorough examination of the crucial part herbal medicine plays in cardiovascular health. The complex interaction between herbal substances and circulatory functions, from mechanisms of action to clinical applications, shows promise for a more integrative and holistic approach to cardiovascular care.

Keywords: *Herbal medicine, cardiovascular health, mechanisms of action, vasodilation, blood pressure regulation, antioxidant, anti-inflammatory, lipid metabolism.*

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Introduction

Herbal Medicine and Cardiovascular Health

Historical Context of Herbal Medicine:

Herbal therapy has played a vital role in managing a variety of medical disorders throughout history, including cardiovascular diseases (CVDs). Herbal medicine has its roots in ancient civilizations when indigenous people gained a profound awareness of plant characteristics and possible advantages. Herbal treatments were frequently used to treat symptoms and improve general health. Traditional healers in many communities passed down their understanding of herbal remedies from generation to generation, weaving a rich tapestry of herbal knowledge. For instance, herbs have long been a crucial part of therapeutic regimens in Traditional Chinese Medicine (TCM) and Ayurveda, providing insights into the treatment of cardiovascular diseases.

Prevalence of Cardiovascular Diseases:

With cardiovascular diseases responsible for a significant portion of morbidity and mortality, they pose a serious threat to global health. Heart failure, stroke, coronary artery disease, and hypertension are a few of the conditions that jointly contribute to the rising prevalence of CVDs. The World Health Organization (WHO) reports that CVDs are the largest cause of death globally, accounting for a projected 17.9 million deaths per year (WHO, 2021). Researchers, medical professionals, and patients are all looking for complementary and alternative treatments as a result of the growing health issue.

Mechanisms of Action of Herbal Compounds on the Cardiovascular System

Vasodilation and Blood Pressure Regulation: It is known that herbal components have vasodilatory properties, which help to control blood pressure and promote cardiovascular health in general. Hawthorn ***(Crataegus spp.)*** has proven vasorelaxant characteristics through influencing endothelial nitric oxide generation, which results in better vascular tone. The synthesis and bioavailability of endothelial nitric oxide are both increased by ginkgo biloba extract, which has also been found to improve vasodilation.

Effects on Inflammation and Oxidative Stress: Herbal substances' anti-oxidant and anti-inflammatory effects are essential in reducing inflammation and oxidative stress in the cardiovascular system. Allicin, a sulfur component found in garlic ***(Allium sativum),*** has been linked to antioxidant activity and a decrease in vascular inflammation (Gorinstein et al., 2007). Turmeric ***(Curcuma longa)*** contains a compound called curcumin, which has been shown to have strong anti-inflammatory effects by inhibiting pro-inflammatory cytokines and modifying intracellular signaling pathways (Jurenka et al., 2009).

Modulation of Lipid Metabolism: Herbal therapies have also shown the ability to modify lipid metabolism, which may be advantageous for treating dyslipidemia. By preventing intestinal cholesterol absorption, plant sterols and stanols, which are frequently found in herbal sources, have been proven to lower low-density lipoprotein cholesterol levels (Demonty et al., 2009). Due to their high soluble fiber content and potential impact on cholesterol production, fenugreek (Trigonella foenum-graecum) seeds have also been investigated for their lipid-lowering benefits (Chevassus et al., 2010).

High blood pressure, often known as hypertension, is a significant risk factor for cardiovascular illnesses. Herbal medicines have been investigated as potential blood pressure management therapies, providing a more comprehensive approach to controlling this common illness.

Herbal Treatments for Blood Pressure Control: Some herbs have demonstrated potential for regulating blood pressure. Attention has been drawn to garlic ***(Allium sativum)*** because of its conceivable antihypertensive properties. Garlic contains a bioactive substance called allicin, which may help lower blood pressure by relaxing and dilating blood vessels (Ried et al., 2013). Another herb that has been linked to blood pressure-lowering benefits is hibiscus ***(Hibiscus sabdariffa)***, probably because of its diuretic effects and capacity to inhibit angiotensin-converting enzyme (Haji et al., 1999).

Clinical Research and Support: Clinical research has examined the effectiveness of herbal therapies in the treatment of hypertension. Garlic supplementation was linked to small drops in both systolic and diastolic blood pressure, according to a meta-analysis of randomized controlled studies (Ried et al., 2018). Furthermore, hibiscus tea has been shown in studies to significantly lower both systolic and diastolic blood pressure (Serban et al., 2015). While these results are encouraging, more investigation is required to determine the long-term efficacy and safety of herbal treatments for hypertension.

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Cardiovascular Activity	Role of Herbal Medicine	Examples of Medicinal Plants	Effects
Blood Pressure Regulation	Herbal remedies can help regulate blood pressure by promoting vasodilation, reducing arterial stiffness, and modulating the renin-angiotensin-aldosterone system.	*Hawthorn (Crataegus spp.)*	Vasodilation, improved blood flow.
		Garlic (Allium sativum)	Blood pressure reduction, vasodilation.
Cholesterol Management	Certain herbs possess lipid-lowering properties, aiding in the reduction of LDL cholesterol levels and improving lipid profile.	*Red Yeast Rice (Monascus purpureus)*	LDL cholesterol reduction.
		Fenugreek (Trigonella foenum-graecum)	Cholesterol-lowering effects.
Antioxidant Support	Herbal antioxidants combat oxidative stress, reducing damage to blood vessels and heart tissue.	*Green Tea (Camellia sinensis)*	Antioxidant protection, improved endothelial function.
		Turmeric (Curcuma longa)	Anti-inflammatory, antioxidant effects.
Antiplatelet Activity	Some herbs possess antiplatelet effects, reducing the risk of blood clot formation.	*Ginger (Zingiber officinale)*	Antiplatelet properties.
		Ginkgo (Ginkgo biloba)	Inhibition of platelet aggregation.
Cardiac Function	Herbal remedies may support cardiac muscle function and enhance cardiovascular performance.	*Hawthorn (Crataegus spp.)*	Improved cardiac contractility.
		Danshen (Salvia miltiorrhiza)	Cardiovascular protection, improved circulation.
Endothelial Health	Certain herbs promote endothelial health, enhancing blood vessel function and reducing endothelial dysfunction.	*Grapeseed Extract (Vitis vinifera)*	Endothelial protection, improved nitric oxide production.
		Garlic (Allium sativum)	Endothelial function improvement.

Table: Role of Herbal Medicine in Cardiovascular Activities
This table highlights the diverse contributions of herbal medicine to various cardiovascular activities. Herbal remedies have been recognized for their potential in regulating blood pressure, managing cholesterol levels, providing antioxidant support, influencing platelet activity, enhancing cardiac function, and promoting endothelial health

Herbal Approaches to Cholesterol Management
Elevated cholesterol levels contribute to atherosclerosis and cardiovascular risk. Herbal approaches targeting cholesterol reduction have gained attention as potential adjuncts to traditional therapies.

Cholesterol Reduction with Plant Sterols and Stanols: Studies have been done on the cholesterol-lowering potential of plant sterols and stanols, which are naturally occurring chemicals found in plants. These substances compete with cholesterol for intestinal absorption because of their structural resemblance. Plant sterols and stanols help reduce blood cholesterol levels by decreasing cholesterol absorption (Demonty et al., 2009). Some herbal extracts have showed potential in modifying lipid metabolism. These extracts also have lipid-lowering effects. The naturally occurring statins found in red yeast rice ***(Monascus purpureus)*** extract are known for their ability to reduce cholesterol. Red yeast rice extract has been shown to be effective in lowering levels of both total cholesterol and low-density lipoprotein cholesterol in clinical trials (Halbert et al., 2010).

Fluid balance management using natural diuretics
Cardiovascular health depends on efficient fluid balance control. The potential of some herbal medicines, also referred to as natural diuretics, to reduce fluid retention and encourage a healthy fluid balance has been investigated.

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Dandelion *(Taraxacum officinale)* and Fluid Retention: Dandelion has historically been used as a natural diuretic. Dandelion extract, according to studies, may increase salt and urine output, which would help to lessen fluid retention (Clare et al., 2009).

Nettle *(Urtica dioica)*, which has diuretic qualities, may improve fluid elimination and help maintain healthy kidney function. According to (Caesarone et al. 2010), it is thought to stimulate urine production without altering electrolyte balance.

Antioxidants from plants and heart protection

As oxidative stress plays a part in the development of cardiovascular disease, interest in the role of herbal antioxidants in cardioprotection is developing.

Heart health and green tea *(Camellia sinensis)*: Green tea includes catechins, strong antioxidants that may have positive effects on the heart. Major catechin epigallocatechin gallate (EGCG), which has been demonstrated to enhance endothelial function and lessen oxidative stress, supports heart health (Chacko et al., 2010).

Resveratrol-Rich Herbs and Endothelial Function: Resveratrol, which is present in a number of plants, including berries and grapes, has drawn interest for its anti-inflammatory and antioxidant properties. According to (Sahebkar et al.,2013), it could improve endothelial function, consequently enhancing cardiovascular health.

Herbal Medicine for Stress Reduction and Cardiovascular Health

Stress plays a significant role in cardiovascular health, and herbal medicine offers potential avenues for stress reduction, ultimately benefiting the cardiovascular system.

Adaptogenic Herbs and Cortisol Management: A group of herbs known as "adaptogens" aid the body in coping with stress and preserving physiological homeostasis. For instance, Rhodiola rosea has been investigated for its capacity to influence cortisol levels and improve stress resistance in order to modify the stress response (Olsson et al., 2009). According to (Chandrashekhar et al.,2012), ashwagandha *(Withania somnifera)* has also shown stress-relieving properties, possibly through cortisol regulation and neurotransmitter modulation.

Mind-Body Approaches and Their Impact on Heart Health: Mind-body practices, including meditation, yoga, and deep breathing exercises, have been associated with stress reduction and improvements in cardiovascular health.

Mindfulness Meditation and Stress Reduction: The practice of mindfulness meditation encourages present-moment awareness, which might help people feel less stressed. According to studies, therapies focused on mindfulness can lower blood pressure and enhance heart rate variability (Jain et al., 2007).

Yoga offers a holistic approach to stress reduction and cardiovascular health by fusing physical postures, breath awareness, and meditation. According to (Cramer et al., 2018), regular yoga practice has been associated to lower blood pressure, lowered stress hormone levels, and enhanced endothelium function.

Heart rate variability is a sign of cardiovascular health and stress resistance. Deep breathing techniques, such as the practice of coherent breathing, can increase heart rate variability. It has been demonstrated that coherent breathing, which uses slow, rhythmic breathing patterns, lowers tension and anxiety (Lehrer et al., 2000).

Case Studies and Clinical Applications

Case studies and clinical applications provide valuable insights into the real-world effectiveness of herbal interventions for cardiovascular health, showcasing patient experiences and outcomes.

Real-World Examples of Herbal Interventions:

Hawthorn for Heart Health: A case study involving a middle-aged individual with mild heart failure who incorporated hawthorn extract as an adjunct to conventional treatment. The study explores improvements in symptoms, exercise tolerance, and echocardiographic parameters (Pittler et al., 2003).

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Garlic and Blood Pressure Management: A clinical application detailing a patient with hypertension who integrated garlic supplementation into their regimen. Blood pressure measurements, before and after the intervention, demonstrate the potential antihypertensive effects of garlic (Ried et al., 2013).

Patient Experiences and Outcomes:

Personal Accounts of Stress Reduction: Patients share their experiences with mindfulness meditation and its impact on stress and overall well-being. Narratives describe reduced anxiety, improved sleep quality, and enhanced emotional resilience.

A Holistic Approach to Cholesterol Control: Individuals discuss their journey using herbal remedies like plant sterols and stanols in conjunction with lifestyle changes to manage cholesterol levels. Changes in lipid profiles and overall cardiovascular health are highlighted.

Incorporating Adaptogens for Stress Resilience: Patient testimonials explore the integration of adaptogenic herbs, such as ashwagandha, into daily routines. Improved stress management, increased energy levels, and enhanced mood are commonly reported outcomes.

Yoga and Heart Health: Patients share their progress in practicing yoga for stress reduction and cardiovascular well-being. Anecdotes reveal lowered blood pressure, enhanced flexibility, and a sense of calm and balance.

These case studies and patient narratives emphasize the multifaceted impact of herbal interventions on cardiovascular health. They illustrate the potential of herbal medicine to complement conventional treatments and enhance overall patient outcomes.

Conclusion

The exploration of herbal medicine's role in cardiovascular health unveils a captivating landscape of natural interventions that can complement conventional approaches. From historical roots to contemporary research, the chapters have delved into diverse aspects of herbal medicine's impact on the cardiovascular system.Herbal remedies offer a unique set of mechanisms to support cardiovascular health. Through vasodilation and blood pressure regulation, herbs like hawthorn, garlic, and Ginkgo Biloba exhibit their potential to promote optimal circulatory function. The antioxidant and anti-inflammatory effects of herbs such as green tea and turmeric contribute to reducing oxidative stress and inflammation, key factors in cardiovascular diseases. Moreover, herbal interventions extend to lipid metabolism modulation. Plant sterols, stanols, and extracts like red yeast rice emerge as promising tools for managing cholesterol levels, addressing a critical aspect of cardiovascular risk.In the realm of heart rhythm disorders, herbs like hawthorn and motherwort offer alternative pathways for arrhythmia management, while adaptogenic herbs and mind-body approaches present strategies for stress reduction. Patient experiences and case studies underscore the tangible impact of herbal interventions, offering real-world examples of improved cardiovascular outcomes and enhanced well-being. As the chapters have illuminated, the integration of herbal medicine into cardiovascular care is a dynamic and evolving field. While promising, it's essential to approach herbal interventions with a nuanced understanding, considering safety, interactions, and individual patient needs. By embracing the synergy between traditional herbal wisdom and modern scientific inquiry, healthcare practitioners can harness the potential of herbal medicine to provide holistic and personalized cardiovascular care.

In a world where cardiovascular diseases continue to pose significant challenges, the exploration of herbal medicine offers a beacon of hope, showcasing nature's intricate contributions to a healthier heart and a more vibrant life.

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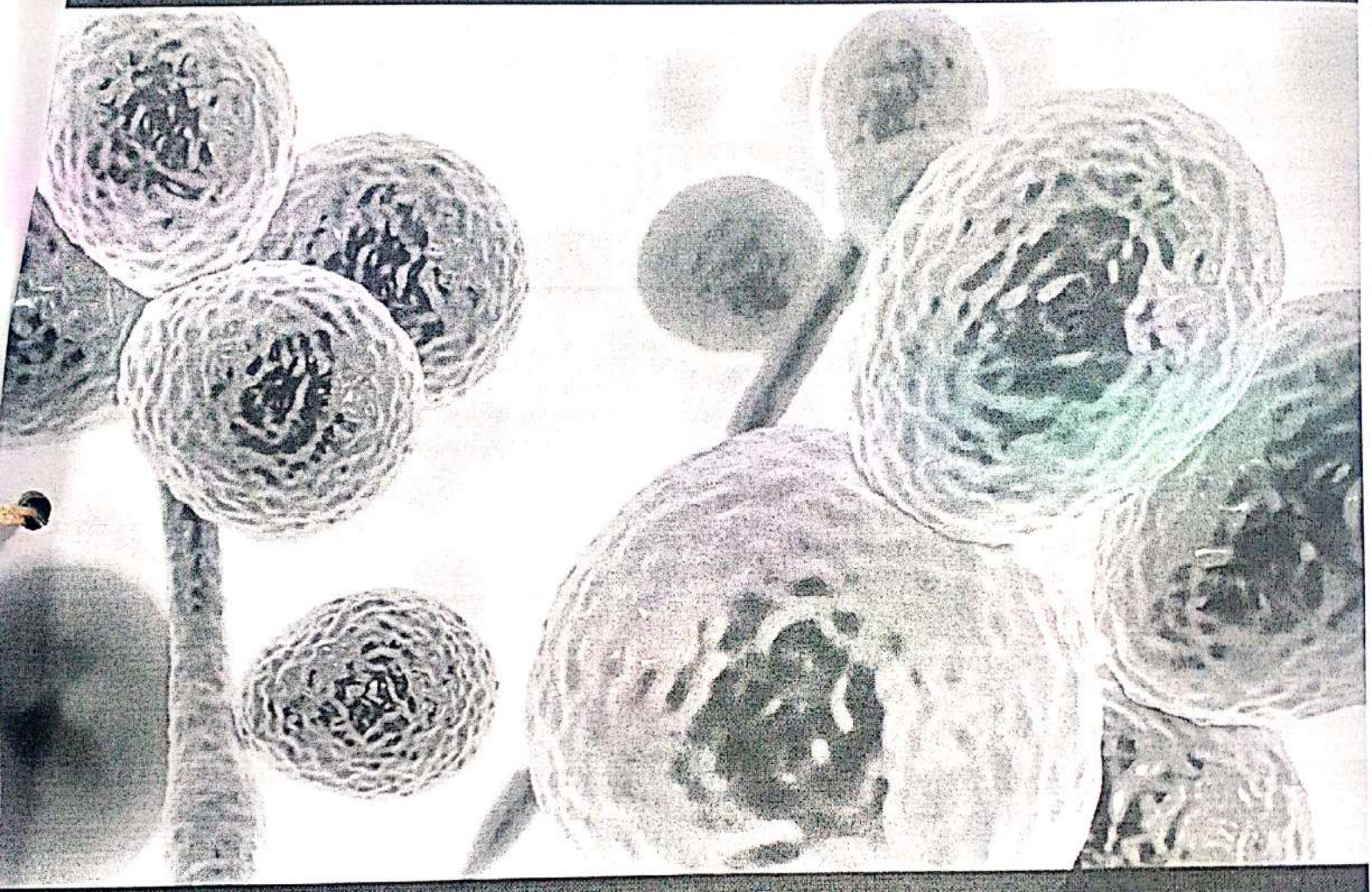

MICROBIOME-ASSISTED BIOREMEDIATION

Rehabilitating Agricultural Soils

Edited by
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CHAPTER 17

Potential use of microalgal metallothioneins and phytochelatins in bioremediation

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1. Bioremediation

The advancement in technology and improved living standard of human beings creates a need of large quantity of new materials as well as energies. These are responsible for the production of waste, results into environmental degradation and destruction of natural environmental components (Mani & Kumar, 2014; Saha et al., 2021). Rapid growth in industrialization, urbanization, mining, and use of pesticides and fertilizers for a prolong time are the primary sources of harmful and toxic pollutants such as heavy metals (HMs), pesticides, microplastics, hydrocarbons, etc. (Emenike et al., 2018; Guo et al., 2020; Rajendran et al., 2021; Xu et al., 2018). Bioaccumulation of these contaminants in food chain causes serious damage to the ecosystem (Zerizghi et al., 2020) and having harmful effects on human body, may lead to cancer, kidney diseases, atherosclerosis, hypertension, Alzheimer's diseases, cardiovascular diseases, etc. (Ahern et al., 2011; Bernhoft, 2012; Flora et al., 2012; Lee et al., 2017; Muszynska et al., 2015; Nawrot et al., 2006). The utilization of microbial source acting as an effective tool for remediation of environment contaminated with toxic organic pollutants and heavy metals (Liu et al., 2020). The bioremediation technique involves the use of microorganisms like microalgae and bacteria to detoxify, transform, or remove HMs and toxic pollutants from environment (Cepoi et al., 2022; Hadiani et al., 2018; Khan et al., 2019; Lopes et al., 2021). Nowadays, more preference is given to these biological-based strategies over other physicochemical approaches, because its implementation is easy and simple, applicable to large areas, more economic, reliable, and ecofriendly (Ashraf et al., 2019). According to the study, cleaning of metal-polluted soils and chemical treatment costs around 100–500 USD per ton, whereas for bioremediation, it costs around 15–200 USD per ton (Meier et al., 2012). Basically, bioremediation process is divided into "*in-situ*" and "*ex-situ*" strategies (Lombi & Hamon, 2005). In "*in-situ*" process, bioremediation takes place at the contamination site, whereas in case of "*ex-situ*," the excavation of these contaminants is performed from its original site and treated elsewhere (Das & Mukherjee, 2007). The "*in-situ*" bioremediation process includes bioventing, bio-

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sparging, bioaugmentation as well as biostimulation (Atlas & Phillip, 2005; Crivelaro et al., 2010; Sharma et al., 2012; Thapa et al., 2012). The "*ex-situ*" process includes the techniques like land farming, composting, biopiles, and use of bioreactors (Chatterjee et al., 2008; Chikere et al., 2011; Soccol et al., 2003; Wu & Crapper, 2009). Both the processes are based on the principles biodegradation, immobilization, biotransformation, removal, or decontamination of various environmental pollutants by using microorganism and plant sources (Abatenh et al., 2017). The chemical contaminants are used by microbes as an energy source and are metabolized into useable energy via redox reactions. The resulting metabolites and by-products are less harmful than original pollutants which are releasing back to the environment (Nester et al., 2001).

2. Heavy metals and their hazardous effects

Heavy metals are considered as most threatening environmental contaminants (Gustin et al., 2021). HMs are the elements with atomic number and density greater than 20 and 5 g/cm^3, respectively (Ali & Khan, 2018). These are categorized into three classes like toxic (a) HMs (e.g., Pb, Hg, Zn, Cu, As), (b) precious metals (e.g., Ag, Pt, Pd, Au), and (c) radionuclide HMs (Th, U, Ra, and Am) (Wang & Chen, 2009). HMs are also classified based on biological perspectives into essential as well as harmful elements. Essential metals or metalloids are micronutrients obtained from plant and animals such as Cu, Zn, Ni as well as Fe, but they can prove toxic above certain thresholds (Garcia-Garcia et al., 2016). On the other hand, toxic elements are nonessential metals, considered to be toxic even at low concentrations (Asad et al., 2019; Ashraf et al., 2019). Nonessential HMs are having serious toxicities toward microorganisms, plants, animals as well as human beings even at very less concentrations (Ali et al., 2019). HMs are not biodegradable, and its toxicity and accumulation in soil and environment attracted much attention worldwide (Kandziora-Ciupa et al., 2021). These can cause direct and indirect effect on the growth of plant like injury to the root, decrease in concentration of carotenoid, necrosis, chlorosis, inhibition of enzymatic activities, decrease in activities related to photosynthesis, and nutrient imbalance (Hasan et al., 2017; Lewis et al., 2001; Mascher et al., 2002; Sachan & Lal, 2017; Shaibur et al., 2009; Yadav, 2010). The bioaccumulation of HMs results into pass the food chains to human beings causing serious and adverse effects on health. HMs can enter the human body by ingestion, through food chain, drinking contaminated water, and contact with environmental contaminants. Its exposure for several years leads to the dangerous effect on the health of human beings (Kumar et al., 2019; Njoga et al., 2021). However, exposure to HM continues and arising in some regions (Järup, 2003). The industrial and domestic waste disposal containing HM threatens the aquatic organism and damage to aquatic ecosystem (De Filippis & Pallaghy, 1994). Hence, the treatment of water contaminated with HMs becomes a global issue and research area of interest for scientists and environmentalists. It becomes necessary to remove these contaminants from aquatic ecosystem as well as industrial wastewater in order to protect environmental as well as human health (Denouche et al., 2021). The use of traditional technologies (e.g., lime precipitation and ion exchange) to remove the HM is often expensive and ineffective (Wilde & Benemann, 1993). So, it becomes essential for searching the newer technologies for the remediation of HMs, which should be economic, effective, and consistent, shall reduce the heavy metal concentration up to significant, and promising approach to remove the HM contaminants (Fu & Wang, 2011; Sheng et al., 2004).

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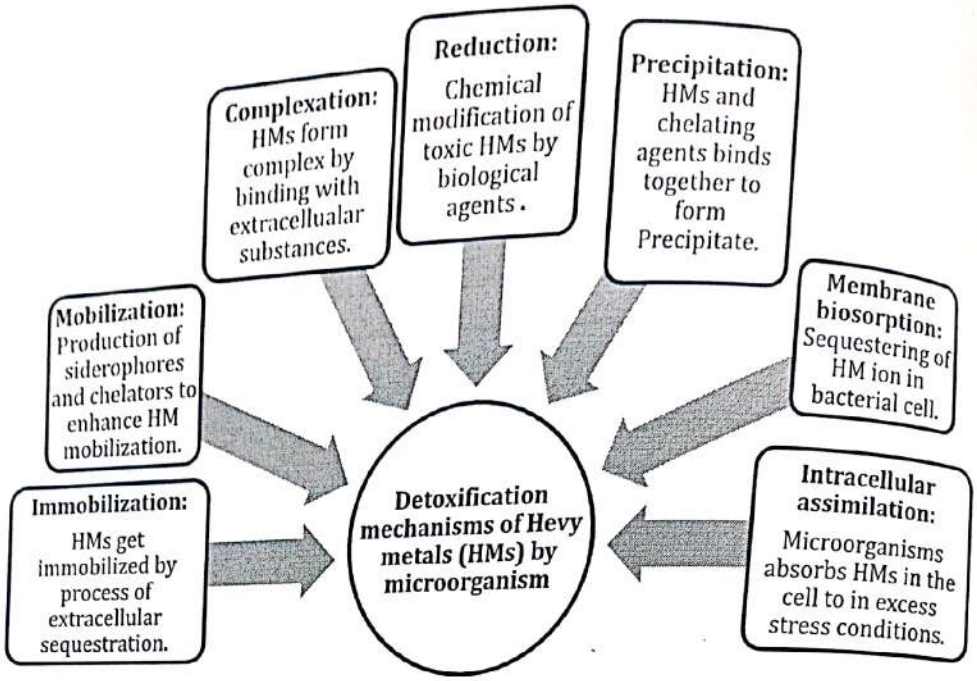

FIGURE 17.1

The mechanisms for detoxifications of heavy metals (HMs) from the soil using microorganisms.

3. Heavy metals detoxification mechanism

The HM accumulation in the cell leads to cell homeostasis disorders, causes damage to chloroplast and pigments, affects the structure and function of DNA, and finally the cell destruction takes place by the formation of reactive oxygen species (ROS) (Kumar et al., 2016). Microorganisms are playing important role in detoxification process which can precipitate, sequester, biosorb with change in oxidation states of different metals (Rizvi et al., 2020). The fundamental mechanism of detoxification of HM involves their chelation in the cytosol by certain ligands like metallothioneins (MTs), phytochelatins (PCs), organic acids, and amino acids which reduce the intracellular contents of HMs and their phytotoxicity (Haydon & Cobbett, 2007). The microbial conversion of toxic metals into less toxic takes place by using the microbial enzymes such as oxidoreductases, dioxygenases, and peroxidases (Saha et al., 2021). The mechanisms involving utilization of microorganism for detoxification of the HM from polluted soil is represented in Fig. 17.1.

4. Metallothioneins

MTs are metal-binding proteins characterized by Vallee et al. in the year of 1950. It is a product of mRNA translation, characterized as cysteine-rich protein with molecular weight (6–7 kDa). The induction of MTs in aquatic organism plays a role of significant biomarker for heavy metal toxicity as well as bioaccumulation (Stillmann, 1995; Won et al., 2008). MTs play a significant role in essential metal supply to the cells and carrying out the transport of harmful metals to other cell organelles (Capdevila & Atrian, 2011). Basically, MTs are small proteins (≤300 amino acids) consisting of some aromatic residues (<10%) and high amount (15%–35%) of cysteine, which coordinate metal ions

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(Ziller & Fraissinet-Tachet, 2018). MTs are classified into four types, having tertiary type of structure with metal-binding property is explained for type 4 plant MTs. Structurally type 4 plant MTs consist of cysteine-rich shorter N-terminal acting as domain for metal-binding and long C-terminal domain containing MTs (Leszczyszyn et al., 2013) along with shape having HM-MT complex varies as per total numbers of cations present in bound form (Bell & Vallee, 2009). MTs consist of 15 distinct families, and each family comprises evolutionary respective proteins present in organisms of similar taxonomic groups. The nine conserved motifs which are cysteine rich are present across various MT families like CCXCC, CXCXCXC, CCC, CCXC, CXCC, CXCXC, XCCX, CXC, and XXCXX. The eukaryotic MTs are identified majorly in plants, ciliates, fungi, and metazoan (Ziller & Fraissinet-Tachet, 2018). Most of the MTs obtained from eukaryotes of microorganisms are associated with ciliates (e.g., Paramecium, Tetrahymena), Apusozoa (Thecamonas), and parasitic Apicomplexa (e.g., Theileria, Babesia) or Amebae (Entameba), as well as six types of microalgal genera (Thalassiosira, Symbiodinium, Chlorella, and Aureococcus) include marine type of representatives (Balzano et al., 2020). MTs are the molecules that chelate the toxic metals like Cd, and thus reduce the cytotoxic, free metal ions concentration. Some of the MTs are involving in Zn as well as Cu homeostasis. The heavy metals like Pb, Cu, Zn, As, Cd, Au, and Ag are responsible for inducing the class III MT biosynthesis within several microalgae like *Stichococcus bacillaris*, *Stichococcus tenue*, and *Stichococcus subspicatus* (Perales-Vela et al., 2006; Robinson, 1989).

5. Phytochelatins

PCs are cysteine-rich peptides with metal-binding properties consisting three amino acids: glutamate, cysteine, and glycine, as well as sulfhydryl group of cysteine involves in metal sequestration (Danouche et al., 2021). PCs are also referred as class III MTs identified primarily in higher plants (Cobbett & Goldsbrough, 2002). PCs are synthesized from γ-glutamylcysteine and the synthesis is catalyzed by transpeptidase enzyme, PCs synthase, which needs posttranslational activation by heavy metals (Chen et al., 1997; Grill et al., 1989; Hayashi et al., 1991; Torres et al., 2008). The biosynthesis of glutathione (GSH) includes two reactions: γ-glutamylcysteine formation from cysteine and glutamic acid, the reaction catalyzes by enzyme glutamate-cysteine ligase (GCL) and glutamylcysteine ligation with glycine to form GSH, the reaction is catalyzed by GSH synthetase (GSHS) (Musgrave et al., 2013). In the final step, GSH binds to other glutamylcysteine units to form PCs. PCs are able to form a complex or chelates through thiol group present in cysteine residues side chain. HM cations can coordinate up to four sulfide groups from one or more PCs within HM-PC chelates (Hirata et al., 2005). Most of the metals and metalloids like Cu, Zn, As, Pb, and Cd can be helpful for the PC synthase activation both in vivo as well as in vitro. Earlier PC production is reported within freshwater algae as a response to heavy metals present in the mining water (Pawlik-Skowronska, 2001).

6. Use of microalgal metallothioneins and phytochelatins in bioremediation

MTs are known as a superrich cysteine family present in cytosol, which is characterized by low molecular weight gene-encoded proteins. These are metal-binding proteins having significant role for controlling the intracellular concentration of metals with regular level. The majorly known MTs from

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microalgae belongs to Chlorella Symbiodinium, Autococcus, Thalassiosira, Nannochloropsis, Ostreococcus genera (Balzano et al., 2020; Gaur & Rai, 2001). The microalgae that synthesize enzymatically PCs rather than MTs in response to metal exposure. The synthesis of PCs in microalgal strains is primarily identified in *C. fusca* on exposure to Cd(II) ions (Gekelat et al., 1988). From research, Hg–PCs are identified in *C. sorokiniana* with mercury exposure, and synthesis of PCs also found in Cu(II)-treated *Scenedesmus bijugatus* and Pb(II)-treated *S. bacillaris* (Gomez-Jacinto et al., 2015; Nagalakshmi & Prasad, 2001; Pawlik-skowron, 2002). Cd(II) is found to be a significant stimulator of PC synthase in Chlamydomonas species. PC synthesis is majorly induced by Zn present in Dunaliella species. The electron-dense material is found in vacuoles of green alga *Tetraselmis suecica* which is exposed to Cd(II) as well as diatom *Skeletonema costatum* that accumulated Cu(II) and Cd(II) (Abboud & Wilkinson, 2013; Nassiri et al., 1997; Perales-Vela et al., 2006; Wang et al., 2017). In other study, three microalgae isolated from *P. ambiguum*, *P. typicum*, and *S. quadricauda*, evaluated for the removal and tolerance of mercury, lead, and cadmium present in aqueous solutions. It is reported that cytoplasmic metal concentration is minimized by the formation of complex of metal ion with PCs in the form of metallo-iron, metallo-sulfur, or metallo-phosphate chelates in the cytosol. These are carried into the vacuoles, where acidic pH displaces the metals and allows peptides to return to the cytosol. This mechanism is referred as cellular protection or detoxification mechanism (Shanab et al., 2012).

7. Factors responsible for affecting bioremediation

The prime factor responsible for affecting bioremediation is site characteristic, and other factors viz. pollutant bioavailability, amount of moisture, nutrient availability, pH, temperature, and amount of water also affect the bioremediation efficiency (Leong & Chang, 2020). The type of contaminants and the extent at which it is present in the location or site affect bioremediation. It can be managed by sufficient prior investigation (Abatenh et al., 2017). The high temperature is responsible for the destruction of bacterial cell metabolic activities and can affect the bioaccumulation process. However, pH 6.5–8.5 is considered maximum potential bioremediation (Abatenh et al., 2017; Javanbakht et al., 2014). Within cold environment, nutrient supply in required quantity increases the microbial metabolic activities that results into rise in the rate of bioremediation. Moisture is also responsible for affecting pollutant metabolism rate by influencing osmotic pressure of aquatic sites (Couto et al., 2014). In case of plant-based bioremediation, the factors for the selection of suitable plant include the root system, above-ground biomass, and plant growth. For the growth and metabolism of microorganisms, the water activity values should be 0.9–1.0, and most number of bacteria can grow with upper limit values of water activity (Azubuike et al., 2016; Sharma, 2019). The bioavailability of contaminant is controlled by different process like diffusion, desorption, sorption, dissolution, etc. It can be managed by the application of complexing agents like ethylene diamine tetraacetic acid (EDTA), citric, acetic, and malic acid that form chelates with HMs with increase in bioavailability (Sarwar et al., 2017).

8. Strategic approaches in remediation

The first strategic approach in bioremediation is the use of immobilized microalgae and metals. It is one of the significant approaches in detoxification and metal recovery process. It is reported that

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the total removal of Cu(II) by calcium alginate gel immobilized *C. vulgaris* is higher than that of agarose *C. vulgaris* system (Aksu, 1998; Hameed & Ebrahim, 2007). In order to increase the specificity toward HM and microalgal metal-binding capacity, the transgenic approach is developed for the use of microalgae for the treatment of heavy metals in wastewater as well as sediments. It is characterized by enzymatic overexpression of which metabolic residues or products enhance the effect of heavy metal-associated stress, heavy metal-binding proteins on the surface as well as in the transgenic cells cytoplasm (Rajamani et al., 2007). Another approach in remediation is metal desorption; algae are used as characteristic biological adsorbents in different restoration processes. The metal that is sorbed on microalgal biomass is desorbed by using solution used for desorption and by which allowing the reuse of biomass in multiple cycles of sorption–desorption (Lu et al., 2006). Recycling of microalgal biomass is also a strategic approach in remediation in which flocculating agent chitosan is used for microalgal recovery. The gel entrapment by the use of synthetic polymers like polyacrylamides, polyurethanes, or natural polysaccharides like agar, alginate is also recommended (Monteiro et al., 2012).

9. Metallothioneins and phytochelatins in heavy metal phycoremediation

Phycoremediation is a type of bioremediation, related to the utilization of algae for removing or mitigation of toxic pollutants (John, 2003). In this process, the HMs are removed from polluted water as well as sediments by using microalgal ability to get incorporated into the metal cations from surroundings. HM uptake process is driven with the use of electrochemical affinity which starts with the adsorption of metal. Electrochemical affinity occurs within metal cations and groups of cell wall polymers that are polar in nature. The dead microalgal biomass can also be used which prevents the risk of contamination of ecosystem, particularly suitable for polluted environments in which the inhibition of microalgal growth takes place (Kumar et al., 2015; Arıca et al., 2005). The accumulation and intracellular transport of HMs in the particular organelles are regulated with use of MTs, PCs, and different heavy metal-binding molecules like polyphosphates. The biosorption rate of HM can be enhanced by adjusting the physicochemical conditions like pH, temperature to which microalgal substrates as well as HMs exposure takes place; as increase in the bioaccumulation of HMs, the scientist expressed recombinantly import-storage systems that consist of primary active transporters and secondary carriers and channels (Diep et al., 2018).

10. Current developments in bioremediation and other applications

Bioremediation is one of the promising and innovative techniques of waste management which use living organism for the removal or neutralization of contaminants (Mosa et al., 2016). Phytoremediation is the efficient, cost-effective, solar-powered, and green alternative technology which is also called as green remediation, botanoremediation, or agroremediation related to use the plant to transform, reduce, extract or immobilization of contaminants present within soil, sediment as well as groundwater (McGrath et al., 2001; Ullah et al., 2015). Another technology of bioremediation includes phytoextraction, phytostabilization, phytovolatilization, phytotransformation, and phytofiltration. Phytoextraction is also called as phytoaccumulation which is related to the use of hyperaccumulating

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plants which are responsible for the uptake of metal from soil with the use of its roots and accumu them in its aerial part (Oladoye et al., 2022). Phytostabilization is also an emerging technology refers to use plant to immobilize soil contaminants through adsorption on or precipitation in root (DalCorso et al., 2019). Phytovolatilization is related to the uptake of toxic soil contaminants by pla and its transformation into the volatile products, followed by their discharge in environment (Ali et a 2013). Phytotransformation or phytodegradation is restricted to eliminate the organic contaminants heavy metals are nonbiodegradable (Singh et al., 2018). Phytofiltration technique consists the proce of elimination of organic as well as inorganic pollutants from the water with aid of plant roots (rh zofiltration), plant shoots (caulofiltration), or seedlings (blastofiltration) (Hakeem et al., 2020). The nanoparticles are having special characteristic that includes improved process of catalysis and adsorption with increased reactivity. Recently the microorganisms and its extracts are proved to be promising, ecofriendly catalysts for engineered nanomaterial. The combination of nanotechnology and bioremediation is called as nano-bioremediation which is more ecofriendly, safe, more economic, and green (Hidangmayum et al., 2022).

11. Future technologies in bioremediation

Biotechnological interventions which primarily include the genetic engineering, for example, various steps which are rate limiting in known pathways of metabolism can be altered and genetically manipulated in order to increase the rate of biodegradation or by the introduction of completely newer pathways of metabolism in microorganism for high amount of HMs accumulation. The study related to hologenomics of microorganisms from plant source which assists for the manipulation of microbial niches helps to increase in resistance against the harmful contaminants. Though there are various technologies available for bioremediation, there is need to develop more suitable ecofriendly technology for the treatment of the multistressed and multimetal-contaminated soil (Saha et al., 2021). Metagenomic perspectives shall also be focused on microbial evolution during the process of bioremediation (Raklami et al., 2022).

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Biometric Length Weight Relationships of the Pool Barb *Puntius sophore* (Hamilton 1822) (Cyprinidae) from Ujani Wetland of Maharashtra, India

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

The present study explains biometric Length weight relationships (LWRs) of *Puntius sophore* (Hamilton 1822) from the Ujani wetland of Maharashtra, India. A total 213 specimens collected from local fish market of Bhigwan during February 2022 to January 2023. Individual fish measurements of the total length (TL, cm), standard length (SL, cm) and fresh total body weight (Wt. g) were measured using a digital caliper and a weighing machine respectively. Puntius sophore, scientifically classified as an ornamental fish belonging to the Cyprinidae family, is renowned for its striking chromatic attributes, diminutive dimensions, and adaptability to constrained aquatic habitats. Despite its modest size and ossified structure, this species possesses nutritional significance. Puntius sophore boasts a wide geographic distribution encompassing India, Pakistan, China, and select regions within Southeast Asia. Due to limited manpower, we sourced specimens from the market. In the study area, the species was collected using traditional fishing methods,

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such as the "jhaki jal" (cast net) and "tar jal" (square lift net). The slope of the log-transformed linear regression (b) values are 2.8085, The b value exponent for study species is significantly lying within the recommended value of 2.5 – 3.5, while the coefficient of determination (R^2) is 0.82 indicated the proper fitness of the fish in concern of growth and health of the study species. Fulton's condition factor (K) value for present study is greater than 1, indicates fish in healthy environment. The result provides baseline information for the sustainable management and conservation of the studied species.

Keywords: Morphometry; length weight; wetland; conservation; Bhima river

1. INTRODUCTION

"The Western Ghat of India is rich in fish diversity and most of the species recorded are endemic to the Western ghat" [1,2]. "There are about 1047 Indian freshwater fish species has been reported so far from Indian waters, which have been reported so far, with 216 fish species found in the state of Maharashtra" [3,4]. "In Pune district 80 species of fishes belonging to 10 orders, 16 families" reported by [5]. "Bhima river, the tributary of river Krishna is one of the important river of Maharashtra. The Ujani dam is terminal dam on Bhima river situated at Village Ujani. Ujani is the largest freshwater fishing co-operative in state Maharashtra" [6]. "The Bhima river consists of 60 fish species belonging to 6 orders, 15 families and 36 genera" [7]. "The species *Cyprinus carpio, Oreochromis mossambica, Hyporhamphus limbatus, puntius ticto, Labeo rohita, Catla catla, Cirrhinus mrigala* etc. are found to be common while fishing" [4]. "Pool barb *Puntius sophore* (Hamilton 1822) is a small indigenous fish (SIF) member of the family Cyprinidae" [8]. "This species *Puntius sophore* is widely distributed throughout the Indian sub-continent including India, Nepal, Bhutan, Bangladesh and Pakistan" [9]. "This is important target species of fisherman's, having different variety of fishing gears. Due to the fishing pressure this species is declining rapidly. *Puntius sophore* (Hamilton 1822) is the major source of the micronutrients and protein, they eat whole. It is very popular food item and it is also used in aquarium" [9–11].

"In fish biology, the morphological parameters like length and weight are the important primary trait in every individual" [12]. "For examining the health of the fish, the relationship between length and weight is a useful parameter" [13]. "In the length weight relationship (LWR), Convert length data from field studies into weight data because weight data measurement in the field is time-consuming and difficult. Moreover, LWRs and Conditional factor also important to study the fisheries and relationship between length and weight, these are important for study of the biomass production in fishes, useful for comparing life history and morphological aspects of populations inhabiting different regions" [6,14–17].

Due to insufficient knowledge about basic biology of fishes from Ujani reservoir, it is decided to carry out at least some studies on basic biology of *Puntius sophor Length-Weight Relationship (LWR), Growth estimation and Length at maturity of Eleutheronema tetradactylus in the Chilika Lagoon, Indiae*. Therefore, the present study is carried out to prepare basic database on length weight relationship and condition factors of *Puntius sophore,* which has never been attempted earlier from this ecosystem.

2. METHODOLOGY

In total 213 specimens of *Puntius sophore* (Fig. 3) were collected from February 2022 to January 2023 from fish market of Bhigwan. The fish market located at Village Bhigwan, Pune, Maharashtra and is well connected by national highway, which receives the fish supply from Bhima river. After collection, specimens were preserved in 10% formalin solution and brought to the research laboratory for identification and measurements. Fishes were identified based on [18,19]. Measurements of total length (TL), and standard length (SL) were done by using digital caliper (Mitutoyo, Japan) to the nearest 0.1cm accuracy and Weight (W) were measured using weighing machine closest 0.1 gm correctness (CONTECH – CB Series) (Table 1). Length weight relationships was estimated by the common formula: $W = aLb$ [20], where, 'L' is the total length (cm), 'W' is the body weight (g), 'a' is the intercept and 'b' is the slope of the log-transformed linear regression, r^2 is the coefficient of determination to estimate the goodness of fit. Calculation of Fulton's condition factor (K) by $K = 100\ W / L^b$, Where, 'K' is condition factor 'W' is weight of fish 'L' is length of fish And, 'b' is exponent from LWR [21].

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3. RESULTS AND DISCUSSION

The sample size (n), Range of total length (TL), standard length (SL), Weight range, intercept (a value), slope (b value) and r^2 the coefficient of determination of *Puntius sophore* were estimated and expressed in the Table 1. Maximum standard length and weight for the *Puntius sophore* were 8.4 cm and 14.9 g respectively. The intercept (a value) and the slope (b value) was found to be 0.0389 and 2.8085 respectively (Fig. 1). The b value exponent for both species is significantly lying within the recommended value of 2.5 – 3.5 [20,22].

The b value observed in this study is 2.80, it was found lower than the previous study [9,23]. Factors like mesh size, sampling gear, fishing pressure, gonadal maturity, sex, geographical an environmental factor, sampling season, length range used, diet, stomach fullness might be responsible for variations in the "b" value of fishes [24–26]. However, because these factors were not taken into account in the preliminary investigation, it is possible that the observed variances in LWRs characteristics are the results of a single factor or the combined effects of many factors. As per the previous studies, the value of the parameter b of *Puntius sophore* in present investigation is within the expected range of 2.5–3.5 [20]. Similarly, a value of the present investigation was higher than the all discussed two reports [9,23].

The R^2 value in the present study was found to be greater than 0.80, This shows that the model is properly adapted for Ujani dam water, showed good growth of the fish and revealed that the fish is living in excellent condition [6,27]. The Fulton's condition factor (K) value recorded for present study was 1.424±0.176 (Table 2). K value greater than 1 showed that Fishes in their environment were healthy and in good shape. The condition factor (K) provides information on the physical and biological conditions, as well as alterations brought on by feeding practices and parasite illnesses etc. [28] (Fig. 2).

Table 1. Length weight relationship parameter of *Puntius sophore*

Parameter	Puntius sophore
N	213
TL range (cm)	6.4 - 10.3
TL (Mean±SD)	8.21 ±0.79
SL range (cm)	5.3 - 8.4
SL (Mean±SD)	6.61 ±0.65
W (g)	3.97 - 14.9
W (Mean±SD)	8.07 ±2.47
a value	0.0389
b value	2.8085
R^2	0.82

(N: Number of samples, TL: Total Length, SL: Standard Length, W: Body weight, SD: Standard deviation, a: Intercept, b: Slope, R^2: coefficient of determination)

Table 2. Fulton's condition factor (K) calculated for *Puntius sophore*

Period	CF	SD
Jan	1.406	0.181
Feb	1.478	0.139
Mar	1.456	0.152
Apr	1.344	0.139
May	1.487	0.317
Jun	1.370	0.185
Jul	1.442	0.140
Aug	1.418	0.147
Sept	1.420	0.200
Oct	1.367	0.131
Nov	1.462	0.161
Dec	1.436	0.130
Overall	1.424	0.176

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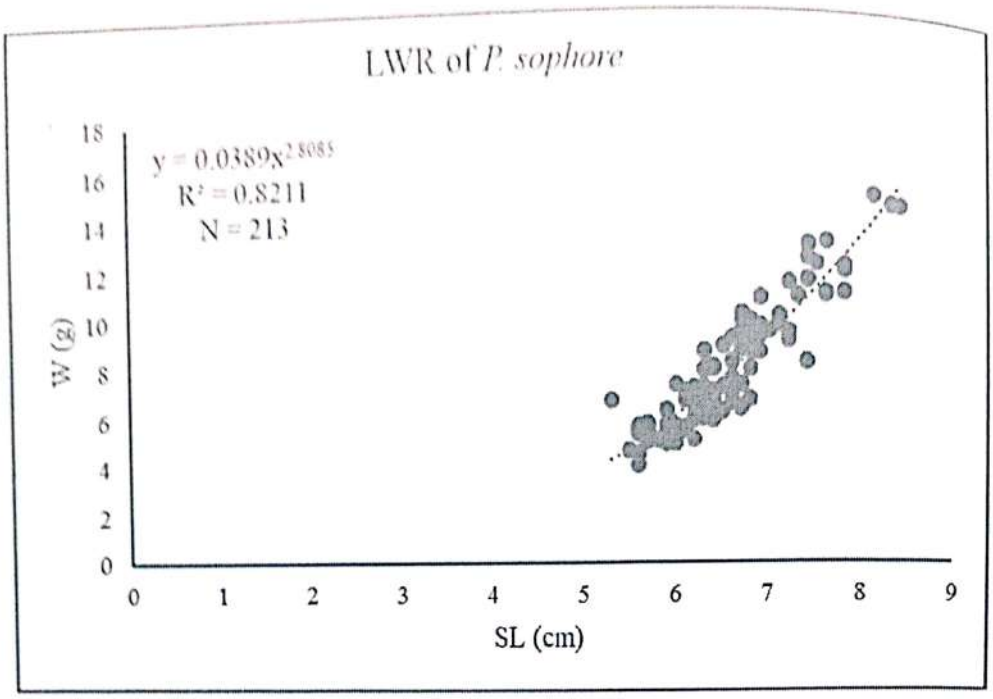

Fig. 1. Graph showing standard length vs body weight scattered plot

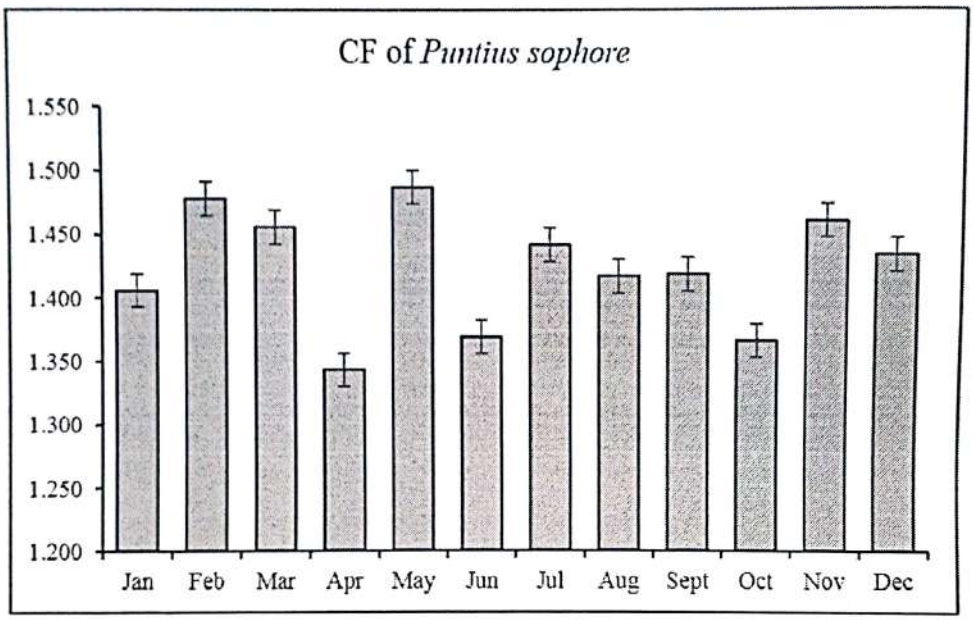

Fig. 2. Graph showing Fulton's condition factor (K) distribution in study period

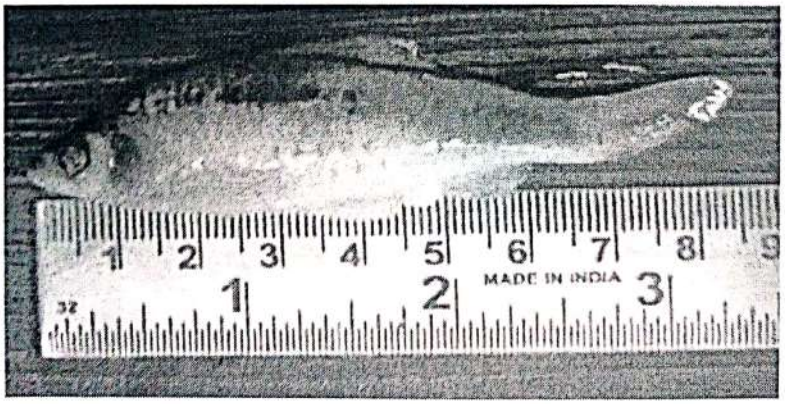

Fig. 3. Photograph of *P. sophore*

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4. CONCLUSION

The present investigation provides the baseline information on the length –weight relationships in *Puntius sophore* from Ujani Dam. These freshwater fish species would be important for monitoring their populations and operative implementation of protection of species and other conservation policies.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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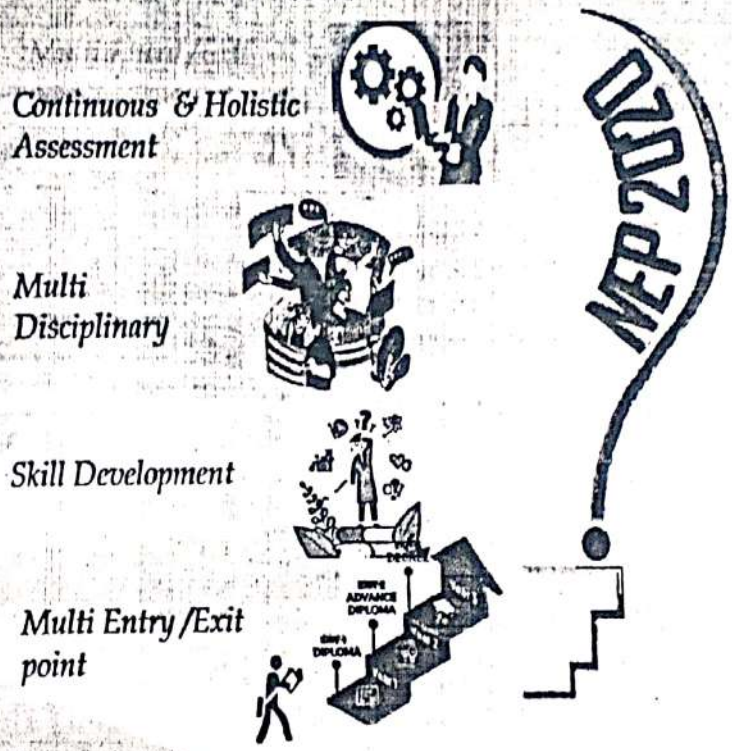

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NEP 2020 : Roadmap for Students

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Abstract-

National Education Policy was created keeping in mind the rich tradition of ancient Asian Santana Indian knowledge. In Indian philosophy, the pursuit of knowledge, wisdom and time is always considered as the highest goal of human beings. Today we have gone through three national education policies and now planning to implement NEP 2020 policy. In 1968 the National Education Policy, which was implemented by the government, was based on the Kothari Commission recommendations. That policy had free and compulsory education to all the students up to the age of 14, In that importance was given to teacher training and qualification, three language formula, equal opportunity for education for all as well as 10+2+3 structure. In 1986 Rajiv Gandhi implemented new education policy. It provided equal educational opportunities to all the students. First time in this education policy women, Scheduled Castes and Tribes were also taken into consideration. It Established district education and training institutes, and implementation of 10+2+3 pattern across the country, it ensured enough availability of food as well as healthy environment in schools. First time in India most of the open universities and distance learning institutes were opened. In 1992 when P.V. Narasimha Rao was the Prime Minister of India, once again education policy was updated. In 1992 Provision was made to open at least one Open University in every state. It was decided that Common Entrance Tests must be conducted for admission of professional and technical courses throughout India. The 'National Education Policy 2020' focus mainly on mainstreaming of out of school children through open school system It targets to give education to the students as per their interest.

Key Words : Education policies, Format, knowledge, Language formula, stream of education.

NEP 2020-

Union Cabinet approved the new education policy (National Education Policy 2020). Many changes have been made in this from school education to higher education. Central committee under the chairmanship of Prime Minister Narendra Modi have finalized this. This new education policy 2020 emphasizes on providing equal education for all from pre-school to secondary level. Also, efforts will be made through this new education policy to bring the children back into the stream of education, who are away from education.

10+2 pattern has been cancelled in the new education policy. Till now the school curriculum in our country was following 10+2 pattern. But now the method of education has been changed. Now the syllabus will be as per the pattern 5+3+3+4. It means first part will be from primary to fifth class. Second part from sixth to eighth class and fourth part from ninth to twelfth class. If we will learn this pattern i.e. 5+3+3+4, we will come to know that education is divided in various stages.

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Foundation Stage:

The children below three years will study in Anganwadi's. After that for the next two years the children will be in Foundation Stage. Then for the next two years the children will study in primary and secondary school. A new syllabus will be prepared for these five years. It will have more emphasis on activity-based learning. It will include children between the ages of three and eight years. In this way the first stage of education will be get completed by the child.

Second Stage:

In this phase education will be given to third to fifth standard students. During this stage, children will get education of science, mathematics, art etc. It will include children between the ages of eight and 11 years.

Third Stage:

It will cover studies of class six to eight standard. This will include children between the ages 11 to 14 years. The priority will be given to Skill development especially in this stage.

Fourth Stage:

The study from class 9th to 12th will be divided in two stages in NEP. There will also be a facility to choose the subject as per child's interest. This system was popular in the past education patterns also.

Initially there was no form of pre-schooling in government schools. The syllabus from 1st to 10th was normal. But now this has been changed. After 11th we were allowed to choose any subject, we wanted. Government thinks that this will help the students to learn those subjects, in which they have interest. But if we think about it from a teacher's perspective, it is not that much fruitful. The institutions may not arrange different faculties for different subjects. It will create lots of chaos in the mind of student as well as parents.

Vocational education imparting professional knowledge from 6th standard onwards

Dr. Kasthurirangan who headed the committee that made the new educational policy said, now children will be given professional education from sixth standard. Internships will also be offered at the local level. It will impart vocational and skill development education. This new education policy will not create unemployed people. The children will be given the professional education required for employment in the school itself.

Currently there are different regulatory bodies for different courses in higher education, instead (except for law and medical disciplines) there will be a single regulatory body. Like America, a National Research Institute will be established in India to give importance to researchers and improve their quality not only science but also research in sociology will be financially supported. The standard of higher education in the country will be taken to international level. It will increase communication with students from foreign quality educational institutions and educational exchange can also take place.

In the new education policy, though 10th and 12th board exams will be conducted, its importance will be reduced. These exams can be conducted twice in a year Instead

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of memorizing and writing answers, the exam will be based on daily useful knowledge. Subjects from different branches like science and art can be studied together. Thus, interdisciplinary education will begin. Flexibility has also been introduced in higher education and interdisciplinary subjects can be studied together in colleges and universities. Education can be stopped at any stage. The marks of that education will be retained and further education can be taken after some time. For students who want to do research, there will be a 5-year course. After that there will be no need to do M.Phil. One can directly take admission for PhD.

Conclusion-

The Union Ministry of Education has set a target of starting at least one multidisciplinary interdisciplinary college in every district by 2030. Until now, the degree was taken from a single subject, now the degree will be completed by taking subjects from multiple disciplines simultaneously. Not only universities but also colleges will have multi-disciplinary courses so the fees will be fixed accordingly. Similar conditions are to be fixed for charging fees of government as well as private educational institutions. Fees will be fixed within that framework and a maximum limit will also be placed on the levy. The progress book is to be evaluated by students, fellow students and teachers themselves without just giving marks and teacher's comments. Based on that, it can be decided that the life skills of the students can be developed.

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Review Article

Cutting-Edge Biotechnological Progress in The World of Edible Flowers

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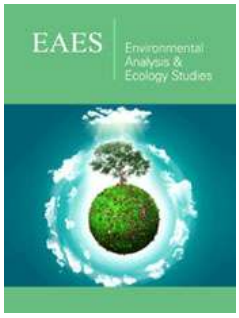

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Abstract

The floriculture industry in developing countries has grown significantly due to improved production methods and rising demand for unique, resilient flowers. Biotechnological methods like micropropagation and genetic modification are crucial for enhancing ornamental plants, including traits such as floral morphology, color, fragrance, stress resistance, and post-harvest longevity. This review emphasizes the importance of biotechnology in creating commercially desirable varieties and understanding the chemical composition of edible flowers. Edible flowers, with historical significance and health benefits, are gaining renewed interest. Advances in biotechnological methods like mutation breeding, molecular markers, genetic engineering and genome editing offer promise in meeting global demand for nutritious food options through enhanced edible flowers, highlighting the need for ongoing research and innovation.

Keywords: Edible flowers, Advance biotechnological tools, Nutritional composition, Genetic engineering, Floriculture industry

Introduction

Edible flowers possess a rich history of consumption and documentation worldwide, spanning ancient civilizations like Greece, Rome, medieval Europe and Asian countries such as China and Japan [1,2]. Over time, globalization and heightened consumer awareness have rekindled interest in edible flowers due to their potential to enhance human well-being and health. Research has spotlighted their bioactive compounds, including natural pigments, essential oils and antioxidants, elucidating their health-promoting effects and folk medicinal uses. The common phytochemicals in edible flowers are depicted in (Table 1). In response to consumer preferences for natural, functional and healthy food products, edible flowers have gained considerable attraction in the market which led to the evaluation of several species such as chrysanthemum, hibiscus, lavender, marigold and rose for their potential benefits [13,14]. Approximately 180 flower species have been identified as suitable for human consumption, edible flowers offer more than just aesthetic enhancement; they present a safe and nutritious option. These blossoms play a crucial role as functional ingredients in food along with their aroma and have potential health advantages when included in range of dishes and beverages like teas, wines, fruit juices etc. [15,2]. Beyond culinary appeal, their extensive historical use in traditional medicine underscores their medicinal properties.

Table 1: Common phytochemicals in edible flowers.

Edible Flowers	Phytochemicals	Reference
Marigold, Rose, *Calendula, Chrysanthemum*	Carotenoids (Lutein, β-carotene, Flavoxanthin, lycopene, zeaxanthin, etc)	Varzakas and Kiokias [3]; Wan et al. [4]; Pavelkova et al. [5]
Rose, *Hibiscus, Calendula, Chrysanthemum*	Anthocyanins (Cyanidin 3,5-diglucoside, pelargonidin 3,5-diglucoside, peonidin 3-O-glucoside, etc)	Grajeda-Iglesias et al. [6]; Wan et al. [7]; Kumari et al. [8]
Rose, *Calendula*, Marigold, Lavender, *Hibiscus*, Daylily, *Chrysanthemum*	Flavonoids (Quercetin, myricetin 3,5-di-O-glucoside, kaempferol 3,7-di-O-rhamnoside, etc)	Cendrowski et al. [9]; Cao et al. [10]; Wan et al. [4]
Rose, Lavender, *Chrysanthemum, Calendula, Daylily*, Marigold	Phenolic acid (Gallic, Caffeic, Caftaric, Chlorogenic, Chicoric, Coumaric, Sinapic and Ferulic, etc)	Ryu et al. [11]; Krzymińska et al. [12]

As a niche market, edible flowers cater to a diverse range of consumers seeking natural and bioactive components in their diet, further highlighting their significance in contemporary food culture. In the present scenario, there is a global demand for novel traits in ornamental plant products, including improved anatomical attributes, floral colors, pigments, stress tolerance, disease resistance and enhanced secondary metabolites with health benefits and medicinal values [16,17]. Research and advancements in biotechnology Figure 1 have paved the way to enhance edible flowers, ensuring their safety and augmenting their valuable traits for diverse purposes, including industrial applications, promising a future for these blossoms.

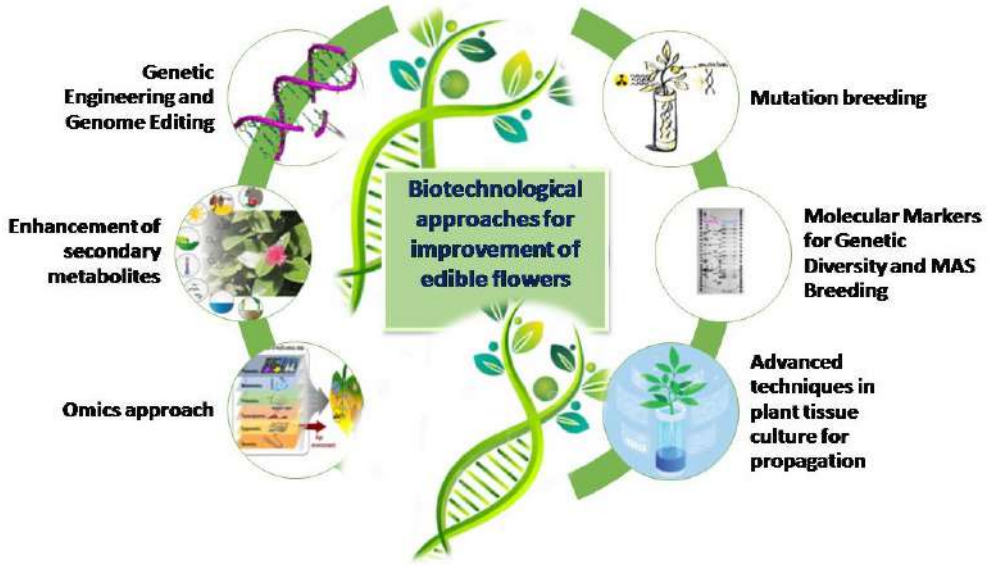

Figure 1: Biotechnological approaches for improvement of edible flowers.

Biotechnological Approaches Employed for Improving Specific Traits in Edible Flower Crops

Mutation breeding

Mutation breeding has been a fundamental approach in developing new plant varieties, especially in ornamental plants. Traditional breeding methods, although reliable, are laborious and time-consuming compared to mutation breeding. This technique involves the use of UV radiation, ionizing radiation and chemical mutagens like EMS and Sodium Azide to induce mutations. It has significantly enhanced breeding efficiency. Mutation breeding revolutionized ornamental plant breeding, accelerating the development of novel traits, particularly flower colors. This method is pivotal in satisfying the floriculture industry's demands for unique attributes. Various techniques, including gamma radiation optimization and chemical mutagen selection, have yielded promising results in plants like carnations, *dianthus*, *chrysanthemums*, roses and more. These methods have shown potential in creating new cultivars and enhancing characteristics like flower color and plant architecture. Research institutions have actively registered number of new mutant lines of *dianthus*, *chrysanthemums*, roses, marigold, Jasmine, tuberose, aster, gladiolus and many more, ensuring the continuous innovation of ornamental plant varieties [18-29] DFR Annual Report, 2022-23). Mutation breeding methods are pivotal for the growth and innovation of the ornamental plant industry, enabling the creation of desirable traits to meet local and export market demands.

Molecular markers for genetic diversity and MAS breeding

Molecular markers have emerged as valuable tools for genetic improvement in ornamental plants, offering insights into genetic diversity and aiding in various applications such as Marker-Assisted Selection (MAS). Various molecular techniques like SSR, ISSR and SNP have been effectively utilized to assess genetic diversity, determine parentage and identify specific traits.

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These markers have been employed in genetic studies of different ornamental species, revealing unique alleles and providing essential information for plant breeding program [30]. For example, SSR markers have been used to distinguish different rose varieties and evaluate genetic diversity in *chrysanthemums* [31,32] Additionally, GWAS studies have linked specific genes to traits like flower type and shape in *chrysanthemums* [33]. Agarwal et al. [34] identified the polymorphic nature of SCoT markers and established genetic diversity among different Rosa germplasms. *Rosa hybrida's* genetic fidelity was affirmed with RAPD and ISSR markers [35] and SSR markers differentiated between cultivated and wild rose species [36,37] constructed the first individual maps of rose populations, linking them with 824 SNPs and 13 SSR bridge markers. In carnations, molecular markers unveiled the genetic basis of resistance to *Fusarium oxysporum*, with a sequence-specific PCR-based SCAR marker developed [38]. SSR markers differentiated carnation varieties [39], while RAPD markers assessed genetic fidelity of *in vitro* regenerated plants [40]. Marigold research employed molecular markers for investigating male sterility [41] and assessing genetic diversity in genotypes. In *Lilium* species, ISSR and AFLP markers confirmed genetic stability and variations in regenerants and progeny [42,43]. ICAR-DFR is working on unique fingerprints for marigold, rose and *chrysanthemum*, employing SRAP, ISSR, and SCoT markers, with a specific focus on variety-specific markers in *chrysanthemums* (Unpublished data).

Advanced techniques in plant tissue culture for propagation

The floriculture industry, driven by the demand for high-quality ornamental plants and flowers, consistently seeks new varieties with improved traits, including plant architecture, vase life, keeping quality, color, and disease resistance [16,17]. Ornamental horticulture encompasses a wide range of plants used in various applications, such as home gardening, landscaping and cut flower production, contributing significantly to the industry [44,45]. Tissue culture technology has brought about a revolution in the floriculture sector, particularly through large-scale propagation using *in vitro* cloning. Tissue culture has proven invaluable in generating genetic variability, enhancing plant health and expanding germplasms available to breeders. This technology has successfully incorporated specific traits through gene transfer, resulting in new genetic variations within breeding lines [36]. Various *in vitro* techniques, such as protoplast culture, organ culture and meristem culture, have been employed to produce haploid lines and Somaclonal variation in Table 1, offering advantages over traditional methods in terms of time and mass multiplication [17]. In addition to mass production, tissue culture has enabled pathogen elimination from planting materials and the production of uniform, disease-free plantlets for large-scale cultivation. These techniques have also facilitated the rapid multiplication of chimeric-mutant plants obtained through mutagenesis [16]. *In vitro* techniques have significantly reduced the time required for developing new varieties and have facilitated the rapid dissemination of planting materials over large areas [46]. (Table 2) has summarized the tissue culture techniques employed for edible flower species. ICAR-DFR has developed efficient regeneration protocols for indigenous *chrysanthemum* varieties, which are particularly valuable for multiplying chimeric flowers induced by physical mutagens. The institute has also established regeneration and direct organogenesis protocols for marigold varieties, allowing for the development of transgenic and genome-edited plants (Unpublished data).

Table 2: Summary of tissue culture techniques employed for edible flower species.

Species/Cultivars	Explant	Response	References
Organogenesis			
Chrysanthemum spp.	Shoot tips, Nodal explants and leaf	Multiple shoot, root and plant formation	Jahan et al. 2021
Gerbera jamesonii	Shoot tips, floral buds, leaf, petioles and petals	Multiple shoot root and plant formation	Winarto B & Prama Yufdy M 2017; Akter et al. 2012
Hemerocallis fulva	Stem tissue	Callus and shoot formation	Matand et al. 2020
Hibiscus rosa sinensis	Nodal explants with axillary bud	Multiple shoot root and plant formation	Metwally et al. 2016
Jasminum sambac	Young leaves, stems and petioles	Callus and shoot formation	Farzinebrahimi et al. 2014
Dianthus caryophyllus	Axillary buds	Multiple shoot root and plant formation	Ahmadian et al. 2017
Nelumbo nucifera	Immature cotyledon and embryo and meristem and embryos	Callus induction and Multiple shoo, root and plant formation	Deng et al. 2020 and Yu et al. 2015
Rhododendron arboretum	Nodal explants	Multiple shoot root and plant formation	Mao et al. 2018
Rosa spp.	Axillary buds	Multiple shoot root and plant formation	Attia et al. 2012 and Baig et al. 2011
Tagetes erecta and *Tagetes patula*	Nodal segments, shoot tip	Multiple shoot root and plant formation	Kumar et al. 2018, Majumder et al. 2014
Soma clonal variation			
Chrysanthemum spp.	Adventitious shoots from two explant types, leaves and internodes	Eeckhau et al. 2020 and Zalewska et al. 2011	

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Gerbera	Capitulum	Bhatia et al. (2009)
Carnation	Leaf base explants	Esmaiel et al. (2012)
Somatic embryogenesis		
Rosa spp.	Nodal stem segment	Li et al. 2002 and Kim et al. 2003
Haploid development		
Chrysanthemum spp.	Anther, Ovule	Khandakar et al. 2014 and Wang et al. 2014 and Gao et al. 2010
Carnation	Anther	Nontaswatsri et al. 2007
Lily	Anther	Arzate-Fernandez et al. 1997
Marigold	Anther	Kurimella et al. 2021
Gerbera	Ovule	Cappadocia et al. 1988

Genetic engineering and genome editing for edible flower crops

Genetic manipulation techniques have emerged as powerful tools to overcome limitations of traditional breeding methods in the ornamental plant industry. Genetic engineering allows the introduction of desired genes into ornamental plants, providing the ability to modify traits such as color, fragrance, disease resistance and flower architecture. *Agrobacterium*-mediated plant genetic transformation is a widely used method for gene transfer due to its simplicity and adaptability (Table 3). Through genetic engineering, it is possible to enhance the quality and traits of ornamental plants for both aesthetic and practical purposes. This approach offers a promising way to develop new cultivars with novel flower colors, improved post-harvest longevity and other desired characteristics, contributing to the advancement of the ornamental plant industry described below.

Table 3: *Agrobacterium*-mediated stable gene transformation in edible flower plants.

Species	Exogenous	Explant	Methods	Gene *A. tumefaciens* strain	Transformation Efficiency	Phenotype of Transgenic Plant	Ref
Rosa hybrida	GFP	Leaf	Somatic embryogenesis	GV3101	5~6%	Green fluorescence observed	Liu et al. 2021
Rosa chinensis	GUS	Somatic embryos	Somatic embryogenesis+Shoot regeneration	EHA105	ND	GUS positive	Vergne et al. 2010
Tagetes erecta	GFP	Flower	Floral dipping	EHA105	ND	Green fluorescence observed	Cheng et al., 2019
Tagetes erecta	GUS	Leaf	Shoot regeneration	LBA4404	ND	GUS positive in leaves of transgenic plants	Narushima et al., 2017
Chrysanthemum	Artemisinin biosynthesis genes	Leaf	Shoot regeneration	CBE21	0.17~0.33%	Artemisinin production	Firsov et al., 2020
Chrysanthemum	RsMYB1	Leaf	Shoot regeneration	GV3101	1%	Improved resistance to herbicides	Naing et al., 2016
Chrysanthemum	cry1Ab	Leaf	Shoot regeneration	LBA4404	ND	Improved insect resistance	Shinoyama et al., 2002
Lilium 0-	GUS	Meristematic nodular calli	Shoot regeneration	EHA101	11.10%	Stable expression of GUS gene	Abbasi et al., 2020
Lilium	GUS	Filament-derived calli	Shoot regeneration	EHA101	ND	GUS positive	Hoshi et al., 2004
Gerbera hybrida	GMYB10	Leaf	Shoot regeneration	C58C1	ND	Activation of Anthocyanin Biosynthesis	Elomaa et al., 2003

Flower colour: Plant flower colors depend on anthocyanins, water-soluble pigments that bring vibrant hues to fruits, flowers and leaves. These pigments, derived from six anthocyanidins, are pivotal in genetic and molecular research [47]. Anthocyanin creation involves a series of enzymatic reactions within the flavonoid biosynthetic pathway, encompassing phenylalanine, phenylpropanoid, flavonoid and anthocyanin metabolism. In the realm of genetic manipulation for flower color, *Petunia hybrida* with its well-studied genetics and transformability, stands out as a valuable model for engineering flower color [48]. *Chrysanthemum*, known for its diverse flower colors, has been genetically engineered to intensify cyanidin content for vibrant red petals.

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However, achieving blue flower color through the introduction of a pansy F3′5′H gene remains a persistent challenge [49]. Moon carnations and roses have been successfully engineered to display violet and blue flower colors, respectively. Introduction of *petunia* genes F3′5′H and DFR into white carnation mutants resulted in violet hues through co-pigmentation. Similarly, roses were modified to produce delphinidin-based anthocyanins, leading to blue and magenta flower colors via specific gene introduction [50]. Transient transformation experiments in Lilium plants have demonstrated the alteration of flower color through the overexpression of key genes for instance, overexpressing the Phalaenopsis F3′5′H (Ph F3′5′H) gene shifted the color from pink to pale purple, with further deepening of the purple color achieved by co-expressing PhF3′5′H and Hyacinth DFR (HyDFR) genes [51]. Genome editing has emerged as a potent tool for modifying flower color across various plant species. Understanding anthocyanin biosynthesis and related genes offers exciting possibilities for creating unique flower colors, greatly impacting the ornamental plants industry with visually captivating varieties.

Floral scent: Floral scent plays a vital role in attracting pollinators, protecting plants from herbivores and pathogens and facilitating reproductive processes. The scent is a complex mixture of compounds, including fatty acid derivatives, benzenoids, phenylpropanoids and terpenoids. Understanding the intricate role of floral scent in plant biology offers opportunities to improve crop yields and enhance the visual and olfactory appeal of flowers [52,53]. Genetic engineering offers a solution to impart fragrance to modern cut-flowers, addressing the decline of natural scent due to selective breeding for other traits. A breakthrough involved isolating the S-Linalool Synthase (LIS) gene from *Clarkia breweri*, a sweet-scented California plant. By introducing the LIS gene into carnations, linalool production was successfully enhanced, showcasing the potential of genetic manipulation to enhance floral scents [54]. Transcription Factors (TFs) are key players in fragrance biosynthesis, regulating various pathways that lead to the production of volatile compounds. They control processes like the shikimate pathway, regulated by TF ODORNT1 (ODO1), specifically expressed in *petunia* petals. While some pathways are well understood, the regulation of terpenoid pathways remains unclear. The successful introduction of the PAP1 transcription factor from Arabidopsis into rose flowers resulted in heightened production of specific scent compounds, emphasizing the potential of genetic engineering to enhance floral fragrances and revolutionize the floral industry [55].

Biotic and abiotic stress resistance: Plants are susceptible to a wide range of environmental stresses viz., abiotic (e.g., radiation, salinity, drought) and biotic (e.g., pathogens, herbivores) that impair growth and productivity [17]. These stresses trigger diverse plant responses, altering gene expression, metabolic processes and physiological attributes. Research on stress tolerance in edible flower crops has made progress in understanding and improving their responses, exemplified by transgenic carnations with enhanced resistance to Fusarium wilt disease and caffeine-producing chrysanthemum plants exhibiting resistance to fungal attacks [56,57]. The abundance, organization and expression patterns of LlWRKY genes were studied in Lilium, indicating their potential role in both abiotic and biotic stress tolerance [58]. Genetic transformation methods, like *Agrobacterium*-mediated transfer of specific genes, have been instrumental in conferring resistance against viruses and pests, enhancing crop resilience. Additionally, the role of critical transcription factors such as ZIP, WRKY and NAC in stress response pathways has been demonstrated, paving the way for targeted approaches to enhance stress tolerance in ornamental plants [59,60]. Overall, employing biotechnological strategies holds promise in mitigating environmental stress effects and improving the productivity and stress resilience of ornamental plants.

Keeping quality and post-harvest quality management: Ornamental plants are integral to the horticulture industry and preserving their quality and freshness is commercially important. Ethylene and bacterial infections accelerate flower wilting, necessitating resistance. Genetic engineering offers a cost-effective solution by reducing ethylene-induced senescence [61]. Targeting ethylene-related genes enhances vase life and quality in flowers. Successful genetic modifications, as seen in carnations, illuminate this potential [62]. Additionally, optimizing tissue-specific ethylene insensitivity, demonstrated in transgenic petunias, is crucial for commercial viability. In roses, various genes and transcription factors have been implicated in the ethylene response, providing opportunities to manipulate floral senescence and extend flower life. In conclusion, genetic engineering focused on ethylene pathways holds promise for enhancing the shelf life of ornamental plants, ensuring better quality and commercial value. Understanding regulatory mechanisms and gene expression patterns in ethylene response pathways is pivotal for developing enduring ornamental plants.

Enhancement of industrially important pigments, essential oils and secondary metabolites: Highlighting the nutraceutical potential of edible flowers, underscoring their richness in nutrients, phytochemicals and the subsequent health benefits, these flowers demonstrate a broad range of medicinal attributes, including anti-diabetic, anti-cancer, anti-anxiety, anti-inflammatory, antimicrobial, diuretic and immunomodulatory effects [63,64]. Also, flower essential oils are highly valued for their aromatic appeal and pharmacological properties enriched with active constituents. These oils possess antimicrobial, antioxidant and anti-pest properties, crucial for food preservation, cosmetics and medicine [65,66]. Biotechnological advancements show potential in optimizing essential oil yield and composition, exemplified by studies focusing on lavender as a key example [67-69].

Omics approaches: Crop improvement endeavors aim to develop climate-smart crops with heightened stress tolerance, improved nutritional value and superior agronomic traits. The integration of "omics" technologies-genomics, transcriptomics, proteomics and metabolomics-has been pivotal in identifying pivotal genes, proteins and metabolic pathways governing desired traits, facilitating marker-assisted breeding in major crops. Additionally, harnessing natural variation in crop wild relatives and underutilized species is crucial.

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Conclusion

Edible flowers are highly valued for their functional properties, adding appeal and nutritional benefits to food products. With growing consumer demand for natural and healthy food options, there's a significant opportunity to use biotechnological tools to enhance the quality and yield of edible flowers to meet global demands. Progress has been notable in enhancing key traits through mutation breeding and tissue culture techniques. Despite genome sequencing progress, the application of genome editing in edible ornamentals is still evolving. There's a need to extend transgenic, genome editing and omics technologies to enhance the nutritional and bioactive properties of valuable edible flowers.

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RESEARCH ARTICLE

Potential assessment of *Chrysanthemum* flowers from various cultivars as sources of natural antioxidants and bioactive compounds

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Abstract *Chrysanthemum* blossoms are renowned for their aesthetic appeal and have gained recognition as potential contributors to nutraceuticals, cosmeceuticals, and pharmaceuticals, benefitting human health. This study assessed 22 Indian *Chrysanthemum* cultivars for phytochemicals and antioxidants. This study also presents the first quantitative determination of total saponin content in *Chrysanthemum morifolium*. The phytochemical profiles categorized the cultivars into three groups by hierarchical cluster analysis. The correlations among biochemical compounds was established by statistical correlation analysis which underscored the importance of anthocyanins and phenolic compounds in antioxidative attributes of cultivars. Also, variation in carotenoid content unveiled astaxanthin, zeaxanthin, mutatochrome, canthaxanthin, neoxanthin, violaxanthin, and auroxanthin as potential biomarkers in differentiating cultivars. The cultivars viz., Bidhan Protima, Mauve Sarah, Silk Brocate, Diamond Jubilee, and Mahatma Gandhi displayed remarkable levels of phenolic compounds, tannins, saponins, and carotenoids, emphasizing their superior antioxidant capacity. The variety in the phytochemical composition including phenolic content (0.0008–0.0231 mg/g), flavonoid content (10–555 mg/g CE), anthocyanin content (0.3–65.4 mg/L), saponin content (5.5–15%), tannin content (4.13–66.5 mg/g TAE), carotenoid content (0.02027–0.07214 mg/g), alkaloid content (220–680 mg/ml) and antioxidant potential of the *C. morifolium* cultivars studied featured their potential as sources of bioactive compounds for various applications. The research elucidates the rich phytochemical diversity in Indian *Chrysanthemum* cultivars, establishing them as priceless assets for pharmaceutical and nutraceutical industries with potential advantages for human health.

Keywords *Chrysanthemum* · Antioxidant acitivity · Phenols · Carotenoids · Alkaloids · Tannins

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Abbreviations

Biological and chemical	
CE	Catechin equivalent
DE	Dry extract
DPPH	2,2-Diphenylpicrylhydrazyl
FRAP	Ferric reducing ability of plasma
GAE	Gallic acid equivalent
MY	Malvidin-3-glucoside
TFC	Total flavonoid content
TPC	Total phenol content
Trolox	6-Hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid
Statistical	
HCA	Hierarchical cluster analysis
PCA	Principal component analysis
PLS-DA	Partial least squares-discriminant analysis
VIP	Variable importance in projection

Introduction

Chrysanthemum, a member of the Asteraceae family, boasts a vast array of cultivars worldwide, with *C. morifolium* Ramat being the most significant, encompassing over 2300 varieties, including more than 800 originating from India (Kalia 2015). This flowering plant is extensively cultivated for diverse purposes, such as cut and loose flowers, pot culture, exhibitions, and landscaping, and it ranks among the top ten globally traded cut flowers (Darras 2021). Beyond its aesthetic appeal, *Chrysanthemum* is a repository of potential health benefits within its delicate petals (Coyago-Cruz et al. 2023). *Chrysanthemum* flower extract has garnered attention due to its rich composition of bioactive compounds, encompassing antioxidants, flavonoids, phenolic compounds, and beta-carotene. Primary carotenoids found in *Chrysanthemum* flowers include lutein, zeaxanthin, β-cryptoxanthin, 13-cis-β-carotene, α-carotene, trans-β-carotene, and 9-cis-β-carotene (Park et al. 2015), conferring a multitude of health advantages and positioning *Chrysanthemum* flower extract as a subject of interest in natural health remedies. Foremost, the antioxidant properties of the extract are noteworthy, with flavonoids and phenolic compounds combating harmful free radicals, thereby reducing oxidative stress and the risk of chronic diseases (Tian et al. 2019). Notably, a study by Cao et al. (2020) identified catechin as the predominant phenolic compound in *Chrysanthemum* flowers, featuring its antioxidative potential. The extract particularly in the form of tea, is known to have calming effect. Extracts from *Chrysanthemum* flowers may provide a number of health advantages, including antioxidative and anti-inflammatory properties, stress relief, and vision enhancement (Wang et al. 2018). Similarly, *Chrysanthemum* flower extract is associated with digestive health, potentially alleviating indigestion symptoms and possessing mild diuretic properties that support a healthy urinary system. In terms of cardiovascular health, the extract exhibits potential in regulating blood pressure, making it relevant for individuals managing hypertension (Shahrajabian et al. 2019).

Chrysanthemum morifolium stands out for its liver-calming and eye-brightening properties, addressed in traditional medicine for its effectiveness in dispelling liver fire. Renowned for detoxification, it holds a prominent place in both culinary and herbal practices, exemplifying the dual role of nourishment and therapeutic application (Long et al. 2022).

Chrysanthemum flowers offer a wealth of bioactive compounds, including phenolic acids, flavonoids, and lignans found in *C. morifolium* Ramat (Han et al. 2019). In *C. morifolium*, flavonoids like luteolin-7-glucoside and quercitrin are prevalent, along with volatile compounds such as β-humulene and ledene oxide-(I). *Chrysanthemum* exhibits diverse pharmacological properties, including anti-inflammatory, antibacterial, anticancer, and antioxidant effects, owing to its rich array of flavonoids, amino acids, sesquiterpenoids, vitamins, and chlorogenic acids (Duh et al. 1999; Lin and Harnly 2010; Chinese Pharmacopoeia Commission 2015; Cui et al. 2018; Yuan et al. 2020). Other reported health benefits of *Chrysanthemum* flowers include their antipyretic, sedative, and antiarthritic properties (Lal et al. 2020). These flowers have been integral to traditional Chinese medicine

for millennia, particularly Juhua. Its traditional uses include alleviating respiratory infections, eye ailments, headaches, hypertension, and sore throat. It is one of the commonly cited medicinal flowers in the Chinese pharmacopeia that has been traditionally recognized for its dietary and healthcare benefits. Originating in China, Juhua has been consumed for more than 3000 years, with flower tea being especially popular in traditional Chinese medicine (TCM) and healthcare practices (Yuan et al. 2020; Sharma et al. 2023). Overall, plant-derived products like *Chrysanthemum* are perceived to have fewer adverse effects compared to synthetic medications.

Flowers as human food are underrated despite recent use for flavour and visual appeal. Various investigations have explored the diverse uses of flowers in food, nutraceutical products and herbal medicines. Gulkand, a value-added food product derived from rose petals, is celebrated for its laxative properties and its effectiveness in soothing sore throats and enlarged tonsils (Hegde et al. 2022). Likewise, Alim-un-Nisa et al. (2018) created candies enriched with lutein from *Tagetes erecta* extract, indicating the potential for flowers to be used in innovative food products. Bahuguna et al. (2018) reported that fresh red *Hibiscus rosa-sinensis* flowers are a rich source of nutrients like vitamin C and β-carotene and formulated a fresh red Hawaiian from hibiscus and evaluated for its nutraceutical properties. *Chrysanthemum morifolium* flowers have found extensive use in food, herbal tea, and medicine owing to their delightful taste and fragrance, appealing colours, and medicinal properties (Sharma et al. 2023).

Given the medicinal significance of *C. morifolium* flower extract, this study aims to compare the qualitative and quantitative content of phenolics, anthocyanins, flavonoids, tannins, carotenoids, alkaloids, and saponins, alongside their antioxidative properties, utilizing spectrophotometric methods across twenty-two distinct Indian *Chrysanthemum* cultivars. Additionally, it seeks to identify potential biomarkers through variable importance in projection (VIP) plots from Partial Least Squares Discriminant Analysis (PLS-DA) for cultivar differentiation. Establishing statistical correlations among biochemical compounds in various *Chrysanthemum* cultivars, further provides understanding for the further improvement of *Chrysanthemum* cultivars.

Materials and methods

Collection of flowers and extracts preparation

The flowers of 22 Indian *Chrysanthemum* cultivars (Table 1) were collected from the research field of ICAR-Directorate of Floricultural Research in Pune during the November–December flowering period. The petals were shade dried for 3–4 days at room temperature (20–25℃). These petals were pulverized to a fine powder of particle size 75–80 µm using a disc pulveriser. This petal powder was used for the estimation of different phytochemical compounds.

Quantitative phytochemical assays

Estimation of total phenolic content

Total phenolic contents were determined using the Folin–Ciocalteu method following Al-Duais et al. (2009) with slight modifications. A 0.5 g dried flower sample was extracted with 20 mL of 80% methanol. Subsequently, an aliquot of 1 mL from the extract was taken in a test tube, and 2.9 mL of 1 N Folin and Ciocalteau's phenol reagent was added, followed by 0.5 mL of distilled water and each tube was shaken. In each tube 2 mL of a 20% sodium carbonate solution was added before being incubated for 90 min at room temperature in the dark. The absorbance was measured at a wavelength of 760 nm. The total phenolic contents were expressed as milligrams of gallic acid equivalent (GAE) per gram.

Estimation of total flavonoid content

The aluminum trichloride method outlined by Zhishen et al. (1999) was used to determine the flavonoid content. A 1000 µL aliquot of the extract was mixed with 150 µL of a 5% NaNO2 solution. This mixture was allowed to stand for 6 min, after which 150 µL aluminium trichloride (10%) was added and left to incubate for 5 min, followed by addition of 1000 µL of 1 N NaOH, and the final solution volume was adjusted to 1500 µL with distilled water. The absorbance was measured in spectrum mode at 510 nm after 15 min incubation. The total flavonoid

Table 1 Details of *Chrysanthemum* cultivars, parentage and flower colour used in this study

Sr. no	Name	Parentage	Color	Flower	Sr. no	Name	Parentage	Color	Flower
1	Autumn joy (Ajoy)	UK	Pink		12	Diamond Jubilee	UK	Yellow orange	
2	Bidhan Agnidev	UK	Red		13	HYDC 42	LC	Pink	
3	Bidhan Agnisikha	OSB 52	Red		14	HYDC 56	STW	White	
4	Bidhan Gold	MBJ	Yellow		15	Koka Kinjan	UK	Yellow	
5	Bidhan Lalima	OPS	Red		16	Mahatma Gandhi	UK	Pink	
6	Bidhan Monami	OPS	Red		17	Mauve Sarah	UK	Pink	
7	Bidhan Protima	OPS	Red		18	Mini Jessie	UK	Orange	
8	Bidhan Purna	OSB 52	Yellow		19	PAU B-43	UK	Pink	
9	Bidhan Rajat	OSB 52	White		20	Punjab Anuradha	UK	Yellow	
10	Bidhan Sabita	UK	Orange		21	Silk Brocade	UK	Pink	
11	Big Violet	UK	Purple		22	Vasantika	UK	Yellow	

UK unknown; *OPS* OP selection; *OBC 52* open selection of BCC 52; *MBJ* mutant of bidhan jayanti; *LC* local collection; *STW* selection from cv. terry white

contents were expressed as milligrams of catechin equivalent (CE) per gram of extract.

Estimation of total carotenoid content

The total carotenoid content was determined using the method outlined by Kamalambigeswari and Rebecca (2016). The concentrations of specific carotenoids were determined by utilizing the λ_{max} values from Britton's (1995) compilation, employing the following formula:

$$\text{Concentration of carotenoids } (\mu g) = \frac{\left[A \times Y(\text{ml}) \times 10^6\right]}{\left[A^{1\%}(\text{cm}) \times 100\right]}$$

$$\text{Concentration of carotenoids } (\mu g/g) = \frac{\left[\text{Concentration of carotenoids}(\mu g)\right]}{\left[\text{Weight of sample } (g)\right]}$$

where A-absorbance, Y-volume (ml), $A^{1\%}$ (cm) = Absorption coefficient for a carotenoid (absorbance at a specified wavelength in a 1% solution within a spectrophotometer cuvette with a 1 cm light path) which exhibits significant variability when different solvents are used.

Estimation of total anthocyanin content

Total anthocyanin contents were determined using a modified spectrophotometric differential pH method (Rapisarda et al. 2008; Scalzo et al. 2008). Sample (0.1 ml) was mixed with pH 1.0 (24 ml 0.2 N KCl and 76 ml 0.2 N HCl) and pH 4.5 (40 ml 1 M sodium acetate, 24 ml 1 N HCl, 36 ml water) buffers. After homogenization, the supernant was collected following two centrifugation cycles, 5000 g for 10 min at 4 °C. Absorbance at 500 nm and 700 nm was measured with a spectrophotometer in spectrum mode. Total anthocyanin contents (C) were determined using the equation:

$$C(\text{mg } MY/L) = \frac{\left[(Abs_{520} - Abs_{700})pH\ 1.0 - (Abs_{520} - Abs_{700})pH\ 4.5\right] \times 463.39 \times DF \times 1000}{\varepsilon \times L}$$

here 463.39 is the molecular mass of malvidin-3-glucoside; ε is its molar extinction coefficient at 520 nm in the pH 1.0 solution which is 28000; DF is the dilution factor, and L is the path length of the cuvette. Results were expressed as milligrams of malvidin-3-glucoside (MY) equivalents per litre (mg MY/L) of flower extract.

Estimation of total tanwnin content

The total tannin contents were determined using a modified Folin–Denis method (Polshettiwar et al. 2007). A 0.5 g sample of dried flowers was extracted in 3.5 ml of distilled water. Subsequently, 0.5 ml of Folin–Denis reagent and 0.5 ml of a 35% Na_2CO_3 solution were added. The volume was adjusted to 4 ml with distilled water, and the absorbance was measured at 700 nm after 30 min of incubation. The total tannin content was reported as milligrams of tannic acid equivalent per gram of the extract.

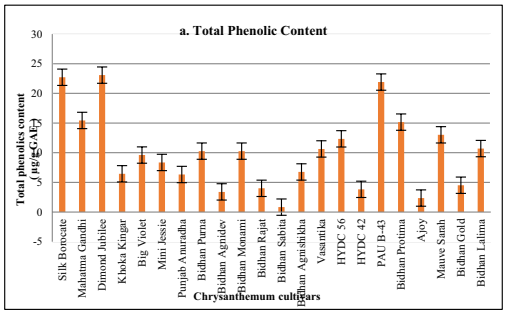
Estimation of total alkaloid content

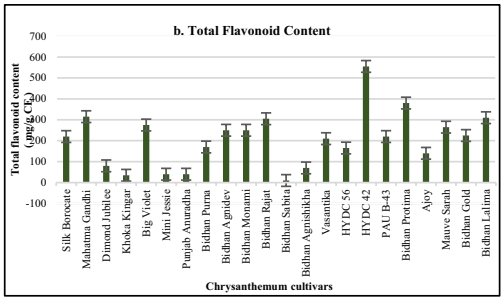
Alkaloid quantification followed the modified titrimetric method of Debnath et al. (2015). Three grams of powdered flower material were mixed with 20 ml of n-butanol, stirred into a slurry, and left overnight at room temperature. After centrifugation (6000 rpm, 15 min), the supernatant volume was adjusted to 50 ml with n-butanol. For the assay, 10 ml of the supernatant mixed with 10 ml of 0.1 N HCl, was shaken vigorously for 2–3 min, forming two layers: the lower one containing neutralized alkaloids and the upper layer with n-butanol. The lower layer (10 ml) was collected, added with 2–3 drops of methyl red, and titrated with 0.1 N NaOH until the colour changed from red to pale yellow. This process was repeated three times, using 10 ml of fresh supernatant each time. The total alkaloid contents were calculated as milligram weight per volume of extract (mg/mL), with the equivalence of 1 ml of 0.1 N HCl ≡ 0.0162 g of alkaloid.

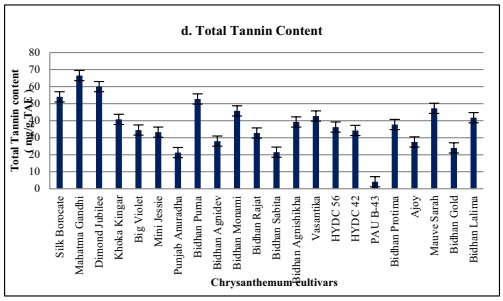
Estimation of total saponin content

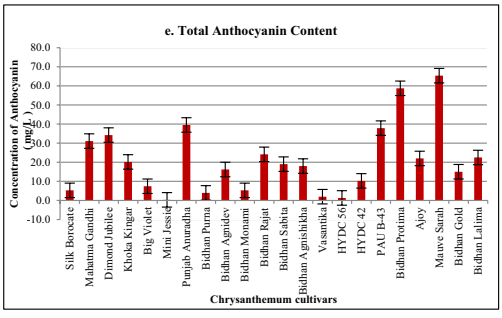
To prepare the sample for estimation, 20 g of floret powder were mixed with 200 ml of 20% ethanol and heated at 55 °C with continuous stirring for 4 h. After filtration, the residue was re-extracted using another 200 ml of 20% aqueous ethanol. The combined extracts were concentrated to 40 ml at 90 °C. The concentrated solution was then subjected to

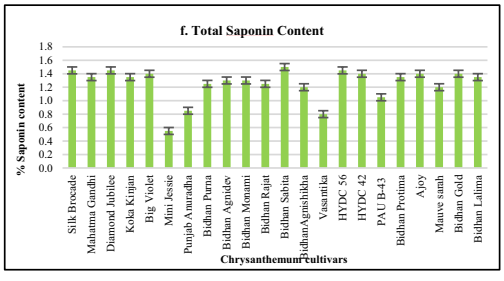
Phytochemical estimation of 22 Indian *Chrysanthemum* cultivars

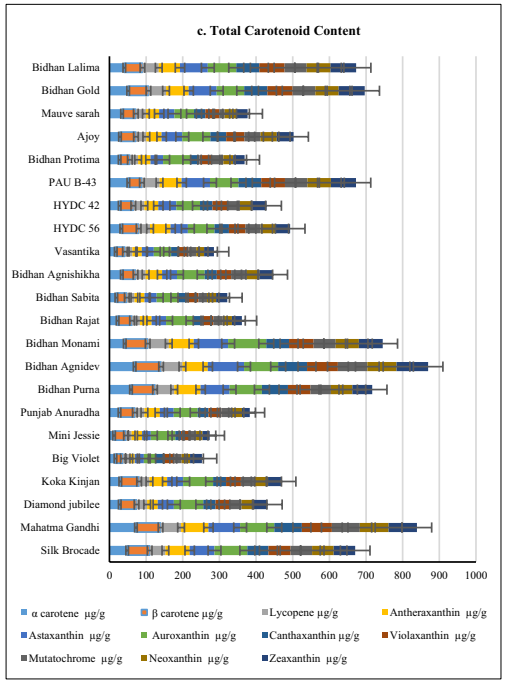


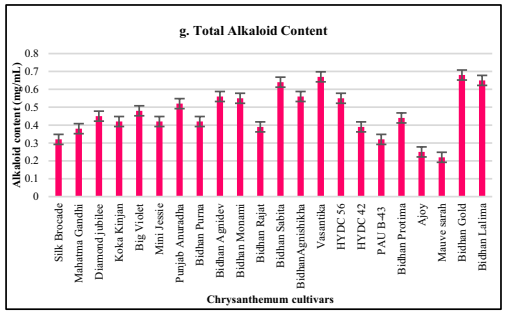


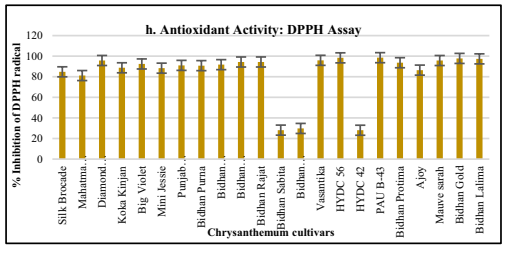


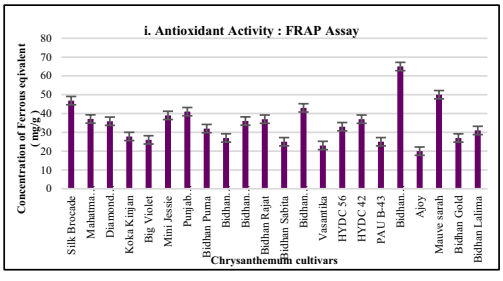












◂**Fig. 1** Phytochemical content of 22 *Chrysanthemum* cultivars: **a** Total phenolic content, **b** Total flavonoid content, **c** Carotenoids content, **d** Total tannin content, **e** Total anthocyanin content, **f** Total saponin content, **g** Total alkaloid content, **h** Percent inhibiting capabilities of floret extracts of *Chrysanthemum* cultivars by DPPH assays, **i** Fe^{3+} reducing abilities of floret extracts of *Chrysanthemum* cultivars by FRAP assays

liquid–liquid extraction with 20 ml of diethyl ether, followed by two purification cycles. After adding 60 ml of n-butanol to the aqueous phase, two washes were performed using 10 ml of 5% aqueous sodium chloride. The remaining solution was heat-dried until a constant weight was achieved, and the saponin content percentage was calculated following the method by Obadoni and Ochuko (2002)

Anti-oxidant assays

DPPH assay: comparable scavenging methods Floret extracts were assessed for DPPH radical scavenging ability using an adapted method from Brand-Williams et al. (1995). DPPH solution (0.07 mg/mL) was mixed with varying concentrations of methanolic extracts (2.5–100.0 µg/mL) and a control solution containing methanol and DPPH (Abs control) was prepared. After vigorous mixing, incubation at room temperature for 60 min in the dark, and measurement of absorbance at 517 nm. The percentage of DPPH radical scavenging was calculated using the formula:

$$\%\text{Inhibition} = \frac{Abs_{(control)} - Abs_{(test)}}{Abs_{(control)}} \times 100$$

Plotting percentage inhibition against sample concentration in µg/mL, we determined the IC_{50}, representing the concentration reducing DPPH absorbance by 50%.

FRAP assay: comparable reducing methods The FRAP assay quantifies the conversion of ferric iron (Fe^{3+}) to ferrous iron (Fe^{2+}) in the presence of antioxidants using a previously described method (Suarez et al. 2010). Fresh FRAP reagent was prepared by combining 5.0 mL of TPTZ (10 mM in 40 mM HCl), 5.0 mL of $FeCl_3$ (20 mM), and 50 mL of sodium acetate buffer (300 mM, pH 3.6). The FRAP assay was conducted at 30 °C in a water bath. To initiate the assay, 3 mL of the FRAP reagent was thoroughly mixed with 0.1 mL of each sample. The reaction mixture was allowed to incubate at 30 °C for 30 min. Absorbance was then measured at 593 nm. The results were expressed as milligrams of ferrous equivalent per gram of dry floret powder (mg/g).

Statistical analysis

Statistical analysis was carried out employing MetaboAnalyst 5.0 software to investigate associations among diverse phytochemicals in distinct cultivars and their interrelationships within the dataset. Additionally, a dendrogram was constructed using the Euclidean distance matrix and Ward's minimum variance method to cluster the 22 *Chrysanthemum* cultivars based on observed dissimilarities in their quantitative phytochemical assays. To assess trait variability, Principal Component Analysis (PCA) was applied to evaluate the contributions of individual traits to the overall variation among genotypes. To ensure data comparability, auto scaling techniques, as outlined by Seisonen et al. (2016), were applied to mitigate unit-related differences for each quantified compound. PCA was executed using the quantified content of selected biochemical compounds as variables. In the quest to identify marker compounds, VIP plots of metabolites were employed within the framework of PLS-DA.

Results and discussion

Phytochemical and antioxidant potential evaluation

Environmental factors and cultivation practices can significantly influence secondary plant components. To mitigate these influences on phytochemical content, we sourced flowers from 22 *Chrysanthemum* cultivars grown on the same farm and harvested during the same season.

Total phenol and flavonoid contents

The phenolic content exhibited a considerable range, spanning from 0.83 µg/g GAE–23.08 µg/g GAE among the 22 *Chrysanthemum* cultivars (Fig. 1a). Among these cultivars, Diamond Jubilee displayed the highest total phenol content (TPC), followed by Silk Brocade and PAU B-43, while Bidhan Sabita had the lowest TPC. On the other hand, the total

flavonoid content (TFC) among the same 22 *Chrysanthemum* cultivars ranged from 10 to 555 mg/g CE (Fig. 1b). The highest TFC was recorded in HYDC-42 (555 ± 1.1 mg/g CE), followed by Bidhan Protima (380 ± 1.1 mg/g CE). This content obtained is greater than that found in *Chrysanthemum indicum* flower where total concentration of the detected flavonoids was 137.29 ± 1.13 mg/g (Wu et al. 2010). Yet, the lowest TFC was observed in Bidhan Sabita (10 ± 1.1 mg/g CE) (Table 2). A correlation analysis revealed a robust relationship between phenol and flavonoid content (r = 0.38, n = 22).

In our study, Diamond Jubilee (0.0231 ± 0.0003 mg/g) characterized by its deep yellow colour, exhibited the highest phenolic content, followed by Silk Brocade (pink) (0.0227 ± 0.0025 mg/g) and PAUB43 (pale purple) (0.0219 ± 0.0003 mg/g). These findings align with research on total flavonoids and phenolic acids in flowers with purple or pink petals and/or petaloid discs. Conversely, red or white-petaled flowers typically displayed lower levels of flavonoids and phenolic acids (Ryu et al. 2019). The role of flavonoids in influencing flower colours has been extensively

Table 2 Phytochemical estimations of 22 Indian *Chrysanthemum* cultivars

Cultivar	Phenolic content (mg/g)	Flavonoid content (mg/g CE)	Anthocyanin content (mg/L)	Saponin content (%)	Tannin content (mg/g TAE)	Carotenoid content(mg/g)	Antioxidant activity FRAP (mg/g)	Alkaloid content (mg/mL)
Silk Borocate	0.0227 ± 0.0025	220 ± 24.2	5.3 ± 0.538	14.5 ± 1.89	54 ± 9.18	0.06133 ± 0.01	46.86 ± 7.029	320 ± 48
Mahatma Gandhi	0.0154 ± 0.0003	315 ± 1.1	31.1 ± 2.42	13.5 ± 1.82	66.5 ± 0.702	0.06718 ± 0.0078	37.1 ± 3	380 ± 37.5
Dimond Jubilee	0.0231 ± 0.0003	80 ± 1.1	34.3 ± 2.42	14.5 ± 1.82	60 ± 0.702	0.04582 ± 0.0078	35.9 ± 3	450 ± 37.5
Khoka Kingar	0.0064 ± 0.0003	35 ± 1.1	20.2 ± 2.42	13.5 ± 1.82	40.75 ± 0.702	0.05137 ± 0.0078	27.8 ± 3	420 ± 37.5
Big Violet	0.0096 ± 0.0003	275 ± 1.1	7.4 ± 2.42	14 ± 1.82	34.5 ± 0.702	0.02027 ± 0.0078	26 ± 3	480 ± 37.5
Mini Jessie	0.0084 ± 0.0003	40 ± 1.1	0.3 ± 0.22	5.5 ± 1.82	33.25 ± 0.702	0.03265 ± 0.0078	39 ± 3	420 ± 37.5
Punjab Anuradha	0.0063 ± 0.0003	40 ± 1.1	39.5 ± 2.42	8.5 ± 1.82	21.25 ± 0.702	0.04179 ± 0.0078	41 ± 3	520 ± 37.5
Bidhan Purna	0.0103 ± 0.0003	170 ± 1.1	4 ± 2.42	12.5 ± 1.82	52.75 ± 0.702	0.06553 ± 0.0078	32 ± 3	420 ± 37.5
Bidhan Agnidev	0.0034 ± 0.0003	250 ± 1.1	16.2 ± 2.42	13 ± 1.82	28 ± 0.702	0.07214 ± 0.0078	27 ± 3	560 ± 37.5
Bidhan Monami	0.0103 ± 0.0003	250 ± 1.1	5.3 ± 2.42	13 ± 1.82	45.75 ± 0.702	0.06255 ± 0.0078	36 ± 3	550 ± 37.5
Bidhan Rajat	0.004 ± 0.0003	305 ± 1.1	24.2 ± 2.42	12.5 ± 1.82	32.75 ± 0.702	0.03933 ± 0.0078	37 ± 3	390 ± 37.5
Bidhan Sabita	0.0008 ± 0.0003	10 ± 1.1	19 ± 2.42	15 ± 1.82	21.5 ± 0.702	0.02865 ± 0.0078	25 ± 3	640 ± 37.5
Bidhan Agnishikha	0.0068 ± 0.0003	70 ± 1.1	18 ± 2.42	12 ± 1.82	39.25 ± 0.702	0.03744 ± 0.0078	43 ± 3	560 ± 37.5
Vasantika	0.0106 ± 0.0003	210 ± 1.1	2 ± 0.22	8 ± 1.82	42.75 ± 0.702	0.02506 ± 0.0078	23 ± 3	670 ± 37.5
HYDC56	0.0157 ± 0.0060	165 ± 98.47	1.3 ± 3.24	14.5 ± 7.80	36.25 ± 30.66	0.04736 ± 0.0403	33 ± 19.40	550 ± 254.01
HYDC42	0.0038 ± 0.0003	555 ± 1.1	10.3 ± 2.42	14 ± 1.82	34.25 ± 0.702	0.0372 ± 0.0078	37 ± 3	390 ± 37.5
PAUB43	0.0219 ± 0.0003	220 ± 1.1	37.9 ± 2.42	10.5 ± 1.82	4.13 ± 0.702	0.03695 ± 0.0078	25 ± 3	320 ± 37.5
Bidhan Protima	0.0152 ± 0.0003	380 ± 1.1	58.7 ± 2.42	13.5 ± 1.82	37.75 ± 0.702	0.02782 ± 0.0078	65 ± 3	440 ± 37.5
Autumn joy (Ajoy)	0.0024 ± 0.0003	140 ± 1.1	22 ± 2.42	14 ± 1.82	27.5 ± 4.675	0.04356 ± 0.0078	20 ± 3	250 ± 37.5
Mauve Sarah	0.013 ± 0.0003	265 ± 1.1	65.4 ± 2.42	12 ± 1.82	47.25 ± 0.702	0.03761 ± 0.0078	50 ± 3	220 ± 37.5
Bidhan Gold	0.0045 ± 0.0003	225 ± 1.1	15.1 ± 2.42	14 ± 1.82	24 ± 0.702	0.05534 ± 0.0078	27 ± 3	680 ± 37.5
Bidhan Lalima	0.0107 ± 0.0003	310 ± 1.1	22.5 ± 2.42	13.5 ± 1.82	41.75 ± 0.702	0.0495 ± 0.0078	31 ± 3	650 ± 37.5

Values are given in mean ± standard deviation

investigated across plant species. It is noteworthy that flavonoid glycosides play a role in the formation of purple pigments and protection against radiation damage (Winkel-Shirley 2002). Furthermore, the biosynthetic pathway of phenolic compounds is intertwined with anthocyanins, as demonstrated by the accumulation of anthocyanins in a purple sweet potato cell line that produces caffeoylquinic acids (Haslam 1998). Several investigations support the idea that darker-coloured fruits or flowers often possess higher antioxidant capacities due to elevated levels of phenolic compounds (Kumari et al. 2022). Previous research by Sugawara and Igarashi (2009) demonstrated significant variations in flavonoid components among four *C. morifolium* cultivars, emphasizing the impact of cultivar selection. Similarly, Ma and Wako (2017) reported distinct disparities in phenolic content among popular *Chrysanthemum* cultivars in Japan. Other investigations have explored the complex relationship between flower colour and secondary metabolites and pigment composition (Suzuki et al. 2007; Jia et al. 2008; Tanaka et al. 2008).

Total carotenoid contents

The study of 22 *Chrysanthemum* cultivars identified 11 distinct carotenoids (Fig. 1c), including β-carotene, α-carotene, lycopene, antheraxanthin, astaxanthin, auroxanthin, canthaxanthin, violaxanthin, mutatochrome, neoxanthin, and zeaxanthin. Among these, Mahatma Gandhi, Bidhan Agnidev, and Bidhan Purna cultivars exhibited the highest α-carotene and β-carotene levels, while Mini Jessie and Big Violet had the lowest concentrations of these carotenoids. Notably, Bidhan Agnidev showed the highest content of all other carotenoids. Additionally, Mahatma Gandhi had the highest antheraxanthin content, while Mini Jessie had the lowest levels of α-carotene, lycopene, violaxanthin, neoxanthin, and zeaxanthin. Big Violet displayed relatively low amounts of β-carotene and antheraxanthin, and Mauve Sarah had the lowest mutatochrome content. These carotenoid variations result from complex interactions with other natural pigments in the petals and are influenced by factors such as petal colour, cultivar, and species.

Carotenoids are a group of organic compounds composed of C40 isoprenoid units, potentially containing epoxy, hydroxy, and keto functional groups. They impart yellow, red, or orange colours to flowers. The carotenoid composition in flower petals is species-specific, unlike the relatively consistent carotenoid profiles in the green tissues of most plants. Non-green tissues exhibit varying qualitative carotenoid compositions, with xanthophyll accumulation in many plants contributing to yellow hues in their flowers. For example, a study on yellow petal *Chrysanthemum* found lutein, β-carotene, and violaxanthin initially present, with lutein becoming the dominant carotenoid over time (Kishimoto et al. 2006).

A heatmap revealed that Bidhan Agnidev, Mahatma Gandhi, PAU-D-11, Bidhan Gold, Bidhan Lalima, Bidhan Manomi, Bidhan Purna, and Silk Brocate cultivars exhibited the highest presence of all 11 identified carotenoids, forming a distinct cluster (Fig. 2). In contrast, Big Violet, Mini Jessie, Bidhan Sabita, and Vasantika had lower carotenoid content and were grouped separately. Notably, Bidhan Agnidev showed the highest presence of all carotenoids, while Vasantika had the lowest total carotenoid content.

Furthermore, carotenoids including astaxanthin, zeaxanthin, mutatochrome, canthaxanthin, neoxanthin, violaxanthin, and auroxanthin (Fig. 3) were identified as potential biomarkers for distinguishing between *Chrysanthemum* cultivars, based on VIP scores exceeding 1 in the PLS-DA. Numerous phytochemicals, among them carotenoids, have been explored as potential remedies for various diseases. It has been reported that the intake of carotenoids (lycopene, beta-carotene, α-carotene) can reduce the risk of developing many chronic diseases like age-related cataracts, cardiovascular disease or cancer (Mayne 1996; Tapiero et al. 2004; Metibemu and Ogungbe 2022).

Total anthocyanin content

In our investigation, we observed that the Mauve Sarah cultivar (65.4 ± 2.42 mg/L) exhibited the highest anthocyanin content (Fig. 1e), followed by Bidhan Protima (58.7 ± 2.42 mg/L) and Punjab Anuradha (39.5 ± 2.42 mg/L), whereas Mini Jessie displayed the lowest anthocyanin levels of 0.3 ± 0.22 mg/L (Table 2). Furthermore, our findings indicate a close correlation between anthocyanin content and the antioxidant potential of the cultivars, as evidenced by the Pearson's r values presented in Table 4. These results align with numerous prior investigations, which have

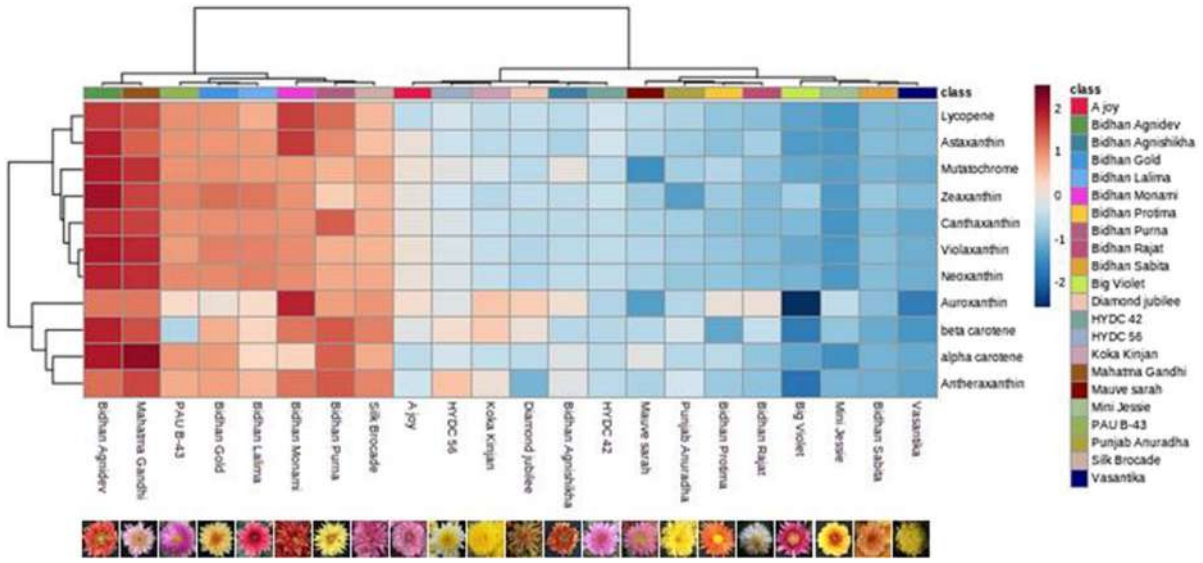


Fig. 2 Heatmap for 11 carotenoids identified in 22 *Chrysanthemum* cultivars

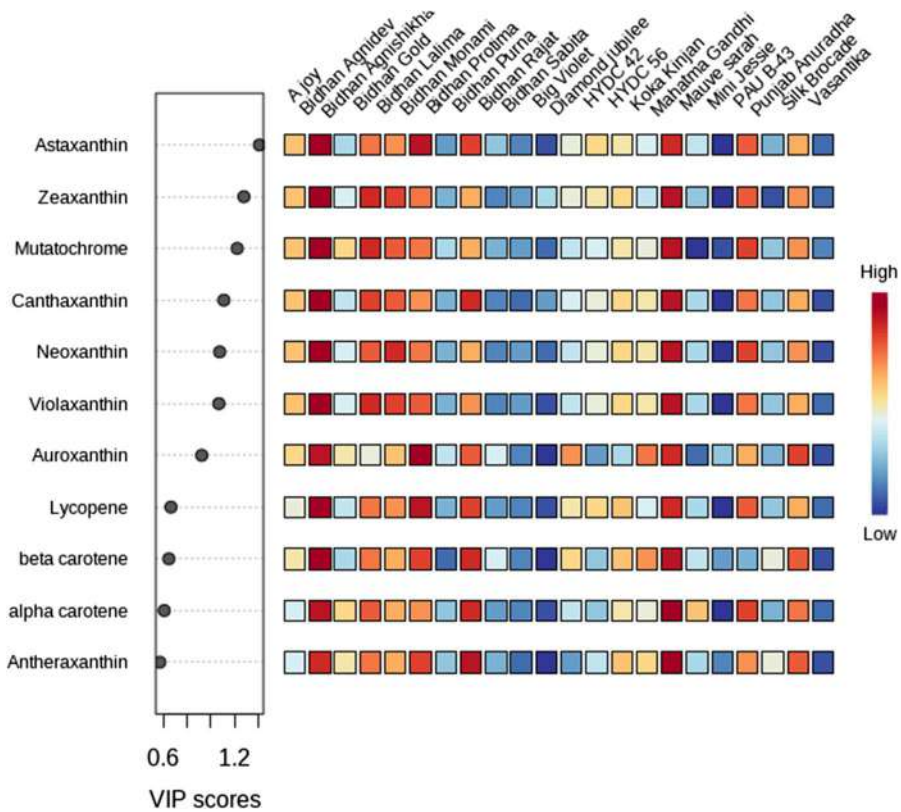


Fig. 3 VIP scores obtained through Partial Least Squares Discriminant Analysis (PLS-DA) for the carotenoids obtained in 22 *Chrysanthemum* cultivars

consistently demonstrated that edible flowers are replete with diverse bioactive constituents, prominently including flavonoids, particularly anthocyanins, as well as polyphenols and other compounds (Pires et al. 2018). In a study of *Chrysanthemum* cultivars (*Dendranthema grandiflorum* Ramat.) flower, the anthocyanin content was studied from low level variety Yes Nuri 0.46 ± 0.28 mg/gm DW to high level variety Magic 18.00 ± 0.84 mg/gm DW (Park et al. 2015). Anthocyanins exhibit potent antioxidant activity by scavenging free radicals, activating antioxidant enzymes, and chelating metal ions. Their diverse health benefits include anticancer, antimicrobial, anti-inflammatory, and anti-neurodegenerative properties, aiding in the prevention of diseases such as cancer, Alzheimer's, and cardiovascular diseases, as well as managing conditions like diabetes (Yazhen et al. 2019; Thornthwaite et al. 2020). They are also utilized in various health products like sunscreens, creams, mouthwashes, and shampoos, offering anti-wrinkle and moisturizing effects, and are commonly used as food additives in products like lactic acid milk and cakes (Yazhen et al. 2019; Mahesh et al. 2019).

Total tannin content

Among the 22 cultivars, the cultivar Mahatma Gandhi (66.5 ± 0.702 mg/g TAE) has displayed the highest tannin content, followed by Diamond Jubilee cultivar (60 ± 0.702 mg/g) and Silk Borocate (54 ± 9.18 mg/g) (Fig. 1d). In contrast, PAU B-43 had the lowest tannin content of 4.13 ± 0.702 mg/g TAE (Table 2). When a similar study of qualitative and quantitative analysis of phytochemicals in extracts of *Centella asiatica* L. was conducted (Ranjan and Kumar 2020), it was found that ethanol extract of flowers had the highest concentration of total tannins (12.25 mg/g), followed by petroleum ether, acetone, and benzene extracts (11.55, 10.35, and 10.35 mg/g respectively). Methanol and distilled water extracts contained relatively lower amounts of total tannins (9.25 mg/g and 9.45 mg/g respectively). Tannins are widely distributed in plants as protectant against grazing animals. They are also said to work as an antiseptic and are used to treat numerous illnesses. They are typically concentrated in delicate plant parts, such young leaves and flowers, and their concentrations differ between plant species, parts, and environmental factors (Huang et al. 2018). Plants like *Hibiscus rosa-sinensis* and *Limonium delicatulum* showed higher tannin content in aqueous and methanolic extracts of stems and leaves during the flowering stage (Medini et al. 2014). Similar findings were made with extracts from the golden flamboyant plant's leaves and flowers (Muthukumaran et al. 2016). Tannins, analysed on a molecular level, were found to exhibit diverse medicinal effects including scavenging of superoxide anions, antitumor properties, and anti-plasmin activity. Additionally, they demonstrated fundamental actions such as binding to proteins and exhibiting antioxidant properties (Okuda and Ito 2011).

Total alkaloid content

In the analysis of 22 dried *Chrysanthemum* floret samples, the highest alkaloid content was identified in Bidhan Gold (680 ± 37.5 mg/mL), closely followed by Vasantika and Bidhan Lalima (Fig. 1g). The lowest total alkaloid content was observed in the Mauve Sarah cultivar (220 ± 37.5 mg/mL) (Table 2). The potential of *Chrysanthemum* as a source of biologically active compounds, including insecticidal pyrethroids and their derivatives from *C. cinerariaefolium*, has been extensively examined for insect control. Additionally, perennial *Chrysanthemum* flower extracts have been found to be abundant in alkaloids (Husain and Kumar 2015). Galanthamine, a bioactive alkaloid, was identified in 97 out of 100 ornamental cultivars of *Narcissus*, predominantly in leaves or bulbs. Among these cultivars, *Narcissus hispanicus* leaves exhibited the highest content at 0.46% of dry weight, while the 'Yellow Wings' Sanguinine cultivar bulbs contained 0.14% (Torras-Claveria et al. 2013). In our investigation, several cultivars demonstrated superior alkaloid content compared to others, with Bidhan Gold, Vasantika, and Bidhan Lalima exhibiting alkaloid content up to 0.6 g. In a study examining alkaloids in the fresh aerial parts of *Chrysanthemum trifurcatum*, it was noted that the presence of alkaloids in the extract may contribute to its analgesic activity (Salem et al. 2019). Alkaloids have been recognized for their anti-inflammatory, analgesic, and antioxidant properties (Mutiah et al. 2021). In the present investigation, significant amounts of alkaloids were obtained in extract of Bidhan Gold, Vasantika, and Bidhan Lalima flowers. Further research into efficient alkaloid extraction from these flowers could

potentially offer a cost-effective and consistent source of this secondary metabolite for the pharmaceutical industry.

Total saponin content

In the case of the 22 *Chrysanthemum* cultivars under investigation, the saponin content exhibited a range from 0.6 to 1.5% (Fig. 1f). Among these cultivars, Silk Brocade (14.5 ± 1.89%), Diamond Jubilee (14.5 ± 1.82%), Bidhan Sabita (19 ± 2.42%), and HYDC 56 (14.5 ± 7.80%) displayed the highest saponin percentages, while the Mini Jessie cultivar (5.5 ± 1.82%) had the lowest saponin content (Table 2). To the best of our knowledge, this study represents the first quantitative determination of total saponin content in *C. morifolium*. Saponins, which are surface-active chemicals, find extensive applications in the food, cosmetics, and pharmaceutical industries and also play significant roles in plant ecology (Guçlu-Ustunda and Mazza 2007). As suggested by Qi et al. (2011), saponins are key components of traditional folk medicines, such as the ginsenosides produced by *Panax* species. Although saponins constitute one of the largest families of plant natural compounds, there is limited understanding of their biological mechanisms. They are typically believed to play significant roles in protecting plants from pathogens, pests, and herbivores due to their antimicrobial, antifungal, anti-parasitic, insecticidal, and antifeedant properties (Augustin et al. 2011; Morrissey and Osbourn 1999; Osbourn et al. 2011; Sparg et al. 2004).

Anti-oxidant assays

In this study, we comprehensively evaluated the antioxidant activity of *Chrysanthemum* florets using two distinct methods: DPPH and FRAP assays.

DPPH assay

We assessed DPPH radical scavenging activity and IC_{50} values for 22 *Chrysanthemum* flower extracts, as detailed in Table 3 and Fig. 1h. The extracts exhibited varying inhibitory potential, ranging from 28% (observed in HYDC 42 and Bidhan Sabita) to 98% (PAU B43). Notably, the cultivar Diamond Jubilee, with the highest phenolic content, displayed the second-highest DPPH radical scavenging activity (96%). This can be attributed to the presence of hydroxyl groups in phenolics, known for their antioxidant properties. Conversely, cultivars like Bidhan Sabita and HYDC 42, with lower total phenolic content, exhibited reduced DPPH radical scavenging activity (28.18%). These results align with prior research, demonstrating a positive correlation between phenolic content and antioxidant activity (Kumari et al. 2022).

Table 3 % Inhibition of DPPH radical and IC_{50} value of *Chrysanthemum* floret extracts

Sr. no	Samples	Inhibition%	IC_{50} value (µg/mL)
1	Silk Brocade	84.82	28.2
2	Mahatma Gandhi	81.18	25.61
3	Diamond Jubilee	95.83	20.36
4	Koka Kinjan	88.73	44.93
5	Big Violet	92.45	21.93
6	Mini Jessie	88.36	48.13
7	Punjab Anuradha	91.07	27.24
8	Bidhan Purna	90.81	28.31
9	Bidhan Agnidev	91.78	47.87
10	Bidhan Monami	94.35	25.21
11	Bidhan Rajat	94.38	29.37
12	Bidhan Sabita	28.16	79.7
13	Bidhan Agnishikha	29.8	84.57
14	Vasantika	95.98	37.68
15	HYDC 56	98.4	28.67
16	HYDC 42	28.05	76.05
17	Pau B-43	98.55	31.87
18	Bidhan Protima	93.64	29.61
19	Autumn joy (Ajoy)	86.46	35.87
20	Mauve Sarah	95.8	29.03
21	Bidhan Gold	97.84	38.34
22	Bidhan Lalima	97.4	15.03

The cultivars, Bidhan Agnidev (3.4 µg/g GAE) and Bidhan Rajat (4.0 µg/g GAE), despite of lower phenolic content, still demonstrated significant radical scavenging abilities of 92% and 94%, respectively. This suggests the presence of other bioactive compounds in these cultivars, extending beyond phenolics, consistent with findings in phytochemical and antioxidant research of Bird of Paradise and other ornamental plants (Bungihan and Matias 2013).

We further assessed antioxidant properties using IC_{50} concentrations, representing the extract amount required to scavenge 50% of the DPPH radical. The results, summarized in Table 3, showed that Bidhan Lalima had the lowest IC_{50} value (15.03 µg/mL), followed by Diamond Jubilee (20.36 µg/mL) and Big Violet (21.93 µg/mL), indicating their high antioxidant potential. Conversely, Bidhan Agnishika, with the highest IC_{50} value of 84.57 µg/mL, represented the lowest antioxidant potential.

FRAP assay

The FRAP assay revealed that Bidhan Protima exhibited the highest reducing power at 65 mg/g ferrous equivalent (Table 2), followed by Silk Brocade at 46.86 mg/g and Mauve Sarah at 50 mg/g. The cultivar Autumn joy (Ajoy) displayed the lowest reducing power, registering only 20 mg/g ferrous equivalent (Fig. 1i). These findings are consistent with research indicating that red-coloured rose cultivars typically have elevated phenolic content and increased antioxidant activities (Kumari et al. 2022). Bidhan Protima, with the highest reducing power, also ranked second in total flavonoid content (380 mg/gm CE). Silk Brocade exhibited the third-highest reducing capacity and ranked second in total phenolic compound content (22.72 µg/gm GAE). In an earlier investigation comparing the antioxidant capacities of extracts from 30 different flowers of *C. morifolium*, an antioxidant capacity of 168.39 ± 0.64 µmol Trolox/gm DW was reported (Chen et al. 2018). Subsequently, recent research has revealed substantial antioxidant effects in vitro and in vivo through the use of aqueous extracts from *C. morifolium* flowers (Wang et al. 2016).

Statistical analysis

Correlation between phytochemicals

The Pearson's correlation coefficients presented in Table 4 unveil robust associations among the phytochemical contents. A significant correlation exists between antioxidants and anthocyanins (r = 0.44), as well as between antioxidants and both phenols (r = 0.40) and tannins (r = 0.43) based on the Pearson's correlation coefficient. Furthermore, flavonoid content demonstrated a moderate relationship with the presence of saponins (r = 0.27) and antioxidant activity (r = 0.27). Whilst tannin content exhibited close correlations with phenols (r = 0.45), saponins (r = 0.40), and antioxidants (r = 0.43). Remarkably, a strong relationship was observed between saponins and carotenoids content, with a Pearson's correlation coefficient of 0.58.

Cluster analysis

Based on the Euclidean distance similarity index, a dendrogram was constructed, revealing an initial division of cultivars into two major clusters (Fig. 4). The first major cluster comprised cultivars Silk Brocade, Mauve Sarah, Bidhan Protima, Diamond Jubilee, and Mahatma Gandhi, which exhibited the highest levels of all biochemical compounds, including antioxidants, assessed in this study. The second major

Table 4 Linear correlation coefficients (r) between different phytochemicals in flowers of *Chrysanthemum* cultivars obtained by Pearson's analysis

	Anthocyanin	Flavonoids	Phenols	Antioxidants	Alkaloids	Tannins	Carotenoids	Saponins
Anthocyanin	1	0.099621	0.21677	0.44062	−0.36834	−0.09726	−0.1633	0
Flavonoids	0.099621	1	0.10923	0.27565	−0.08489	0.16941	0.098597	0.27772
Phenols	0.21677	0.10923	1	0.40238	−0.17235	0.45721	0.20175	0.15899
Antioxidants	0.44062	0.27565	0.40238	1	0	0.4367	0.19206	0.26019
Alkaloids	−0.36834	−0.08489	−0.17235	0	1	0.077179	0.25386	0.29952
Tannins	−0.09726	0.16941	0.45721	0.4367	0.077179	1	0.49668	0.40205
Carotenoids	−0.1633	0.098597	0.20175	0.19206	0.25386	0.49668	1	0.58365
Saponins	0	0.27772	0.15899	0.26019	0.29952	0.40205	0.58365	1

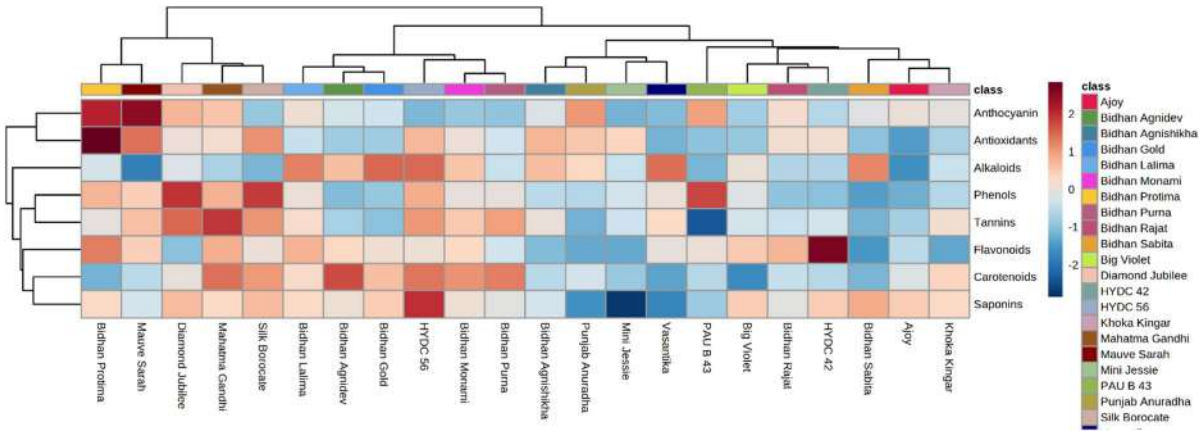


Fig. 4 Chemo metric analysis of *Chrysanthemum* cultivars: Hierarchical cluster analysis (HCA)–clustering and heatmap obtained on cluster analysis of *Chrysanthemum* cultivars based on their phytochemical content studied

cluster included the remaining cultivars, further subdivided into five sub-clusters. In this cluster, cultivars such as Bidhan Lalima, Bidhan Agnidev, Bidhan Gold, HYDC-56, Bidhan Monami, and Bidhan Purna shared similar characteristics, producing a moderate range of biochemical compounds, with a notable emphasis on carotenoid production. Bidhan Agnishikha, Punjab Anuradha, Mini Jessie, and Vasantika formed another sub-cluster, demonstrating the presence of most studied phytochemicals at lower levels, along with moderate contents of antioxidants. Cultivars PAU-B-43, Big Violet, Bidhan Rajat, and HYDC 42 represented a sub-cluster with lower content of most phytochemicals, except for saponins and flavonoids. Finally, the last sub-cluster consisted of Bidhan Sabita, Autumn joy (Ajoy), and Khoka Kingar, which exhibited a moderate range of saponin content and lower levels of other biochemical compounds.

Principal component analysis

To assess the data generated from all conducted assays in this study, Principal Component Analysis (PCA) was employed, with data being normalized through auto-scaling. The application of PCA resulted in the generation of two visual representations: scores and loading plots. Variables that cluster together denoted strong positive correlations among them. The scores plot (Fig. 5a) provided a visual representation of the distinctions among accessions, with each test being plotted on a graph where the first two principal components constituted the axes. PC1 explained 32.5% of the total variance, while PC2 elucidated 22.8%, summing up to 55.3%. Further analysis utilizing a bi-plot (Fig. 5b) unveiled the presence of tannin, saponin, carotenoid, and alkaloid in the fourth quadrant. On the other hand, flavonoid, phenol, antioxidant, and anthocyanin were located in the positive first quadrant.

The Variable Importance in Projection (VIP) score, obtained through Partial Least Squares Discriminant Analysis (PLS-DA), identified phenols, saponins, and alkaloids as biomarkers crucial for distinguishing among *Chrysanthemum* cultivars (Fig. 6).

Conclusion

In this study, we conducted a thorough analysis of phytochemical composition across flowers of 22 Indian *Chrysanthemum* cultivars, covering flavonoids, phenolic acids, anthocyanins, carotenoids, saponins, and tannins. Notably, significant variations in phytochemical composition were observed among the cultivars. Our investigation revealed a strong correlation between antioxidant activity, phenol, and anthocyanins content, showing their substantial contributions to antioxidant properties. The cultivars HYDC-42, Bidhan Rajat, and Bidhan Protima exhibited noteworthy flavonoid content, while extracts from Mahatma Gandhi, Silk Brocade, and Mauve Sarah displayed highest antioxidant properties. Vasantika, Bidhan

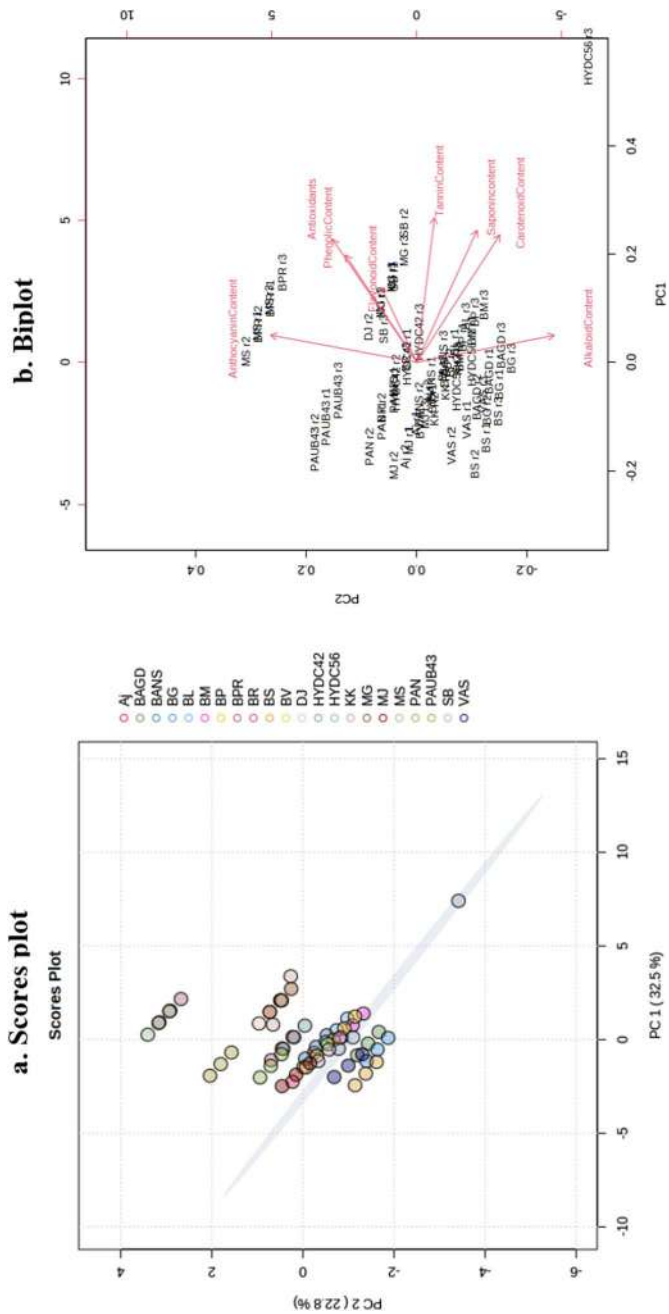


Fig. 5 Chemo metric analysis of *Chrysanthemum* cultivars: principal component analysis of data obtained by phytochemical analysis of 22 *Chrysanthemum* cultivars: **a** Scores plot and **b** Biplot for total phenolic content, total flavonoid content, total anthocyanin content, total saponin content, total tannin content, total carotenoid content, total antioxidants and total alkaloid content where the *Chrysanthemum* cultivars are denoted as SB-Silk Borocate, MG-Mahatma Gandhi, DJ-Diamond Jubilee, KK-Khoka Kingar, BV-Big Violet, MJ-Mini Jessie, PAN-Punjab Anuradha, BP-Bidhan Purna, BAGD-Bidhan Agnidev, BM-Bidhan Monami, BR-Bidhan Rajat, BS-Bidhan Sabita, BANS-Bidhan Agnishikha, VAS-Vasantika, HYDC56-HYDC56, HYDC42-HYDC42, PAUB43-PAUB43, BPR-Bidhan Protima, Aj-Ajoy, MS-Mauve Sarah, BG-Bidhan Gold, and BL-Bidhan Lalima

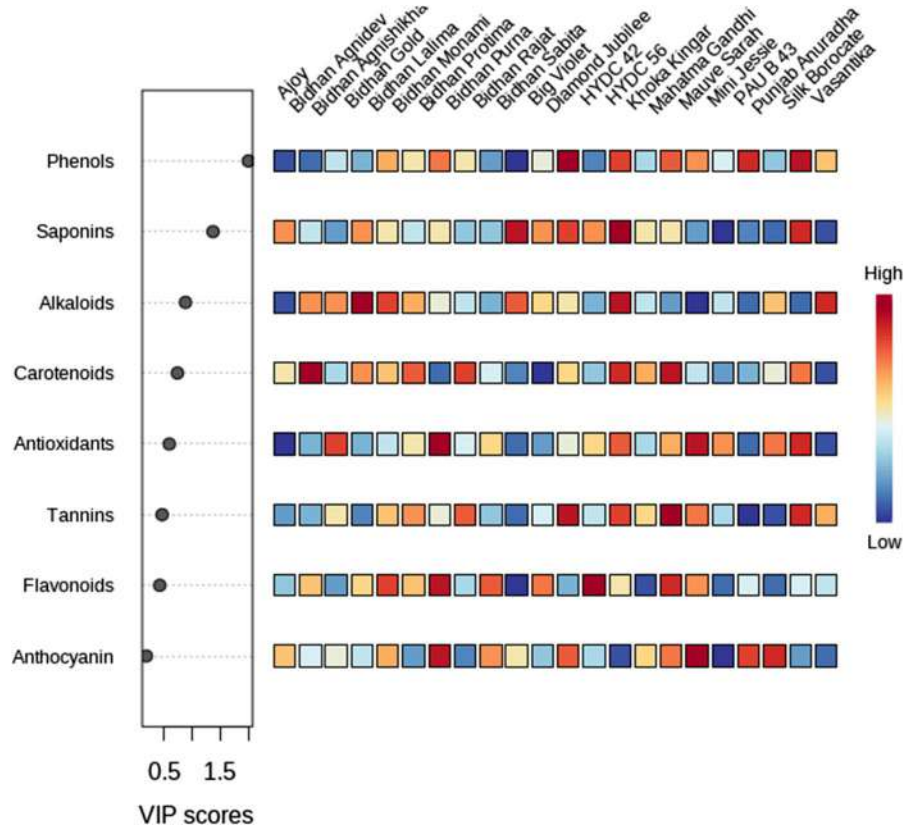


Fig. 6 VIP scores obtained through Partial Least Squares Discriminant Analysis (PLS-DA) for the different phytochemicals obtained in 22 *Chrysanthemum* cultivars

Gold, and Bidhan Lalima showcased high alkaloid production, and Bidhan Protima, Mauve Sarah, Diamond Jubilee, and Punjab Anuradha demonstrated significant anthocyanin production. These findings suggest the potential of these *Chrysanthemum* cultivars as dietary supplements for combating oxidative damage caused by free radicals. Furthermore, our results imply that these distinctive biochemical compounds can serve as valuable markers for classifying and identifying *Chrysanthemum* cultivars for future breeding programmes. Additionally, our findings highlight the suitability of *Chrysanthemum* cultivars with substantial content of specific bioactive phytochemicals for applications in functional foods, pharmaceuticals, and horticulture.

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Data availability Data will be made available on reasonable request.

Declarations

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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DETERMINING FACTORS INFLUENCING THE ADOPTION OF E-LEARNING PRODUCTS AT HIGHER EDUCATION IN INDIAN MARKET- A LITERATURE REVIEW.

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Abstract:
The aim of these study is to analyze the factors influencing the adoption of e-Learning products in higher education in Indian market. Despite the increasing research on e-learning, there is lack of systematic literature analysis. Therefore, this study conducted systematic literature review to identify the various factors that affect the adoption of e-learng products in India.
A Systematic Approach followed and 15 relevant articles published between 2010 and 2022 were selected for analysis. The finding of the selected studies indicate that various factors significantly influence the adoption the adoption of e-learning products in higher education in Indian Market. These Factors include individual, social and organizational aspects as well as demographics, ease of use and perceived usefulness of e-learning product.
The study also identified limitation in existing literature and proposed future research direction for e-learning product in higher education. These drawbacks and future research directions can be served as a guidance for enhancement in e-learning products in higher education.
Overall, this study contributes for understanding the factors influencing adoption of e-learng products in India and provides insights for researchers and practitioners in this field.

Introduction:
E-learning denotes the use of digital or electronic media for learning and teaching purposes. A popularity of e-learning has been increasing steadily, with a growing number of providers and users. The of internet has increades all over globe and improved access to technology have fuelled the development of e-learning platforms.The pandemic situation of Covid-19 has further accelerated the embracing of online education, as lockdown measures necessitated the shift to e-learning as the primary mode of instruction. While the threat of COVID-19 has diminished, online education continues to attract new audiences (Lockee, 2021).
In India, the e-learning industry is expanding its market presence and targeting a broader audience for its courses. The demand for e-learning has increased significantly, leading many online learning platforms, like BYJU'S to offer free access to their services. Even before the pandemic, there was already substantial growth in the adoption of educational technology. E-learning plays crucial role in the academic development of any nation.
Existing literature indicates that various factors including individual, social and organizational aspects, as well as demographics, organizational impact, the perceived usefulness, social infuences and ease of use of course influenced the adoption of e-learning in.
However, the significance of issues related to adoption of e-learning in India has not been fully acknowledged. Previous studies have not explicitly focused on determining the influencing factors that impact the adoption of e-learning products in Indian higher education market or explored a perceptions of e-learning adoption in India.

Objective:

1. To examine and understand different factors influencing the adoption of e-learning products in higher education.
2. To examine and understand the user perception in selecting e-learning products.

Literature Review

The literature review provides a summary of previous research conducted on particular topic.It involves examining published books,journals ,articles and other relevant sources related to a specific topic.The literature review provide background for further research.

Zhang et al. (2010) investigated perception and attitude of peoples towards adopting e-learning in China. The researchers utilized Rogers innovation adoption theory and analyzed 33 factors of perceived innovative attributes using the analytic hierarchy process (AHP). A questionaire was administrated 160 undergraduate students in China to examine the relationship between perceived innovative features and the intention of adopting e-learning in China.

Punnoose (2012) explored the factors influencing students intention and determinants that different factors to use e-learning.The study considered variables such as personal characteristic, beliefs, attitudes, behavioral intention and actual behavior, utilizing the Technology Acceptance Model (TAM). The questionnaire-based data collection involved 249 masters degree students in Thailand, and the findings indicated that students with prior e-learning experience showed stronger intention to use e-learning in the future.

King and Boyatt (2015) conducted a study at the University of Warwick to examine the factors influencing the adoption of e-learning in organizations for professional development and continuing education. The study identified organisational infrastructure, staff attitudes,skills and perceived student expectations as influential factors. Effective implementation required an institutional strategy that provided necessary and sufficient resources and guidance for e-learning.

Koloseni and Mandari (n.d.) highlighted the importance of developing e-learning policies in higher learning institutions that consentrate on improving effort expectancy that focus on improving effort expectancy, awareness of the benefits of e-learning systems, encouraging social pressure, and promoting behavioral intention among students. The study also identified the role of personal traits and learners'perceptions using the Technology Readiness Index (TRI) and Unified Theory of Acceptance and Use of Technology (UTAUT). Data were collected through questionnaires distributed via Google Forms, emails, and social media platforms, resulting in 275 responses.

Elango et al. (n.d.) identified the quality dimensions of e-learning and analyzed the strengths and weaknesses of the e-learning system. The study collected data through questionnaires administered to 112 undergraduate students of online programs from the United Arab Emirates (UAE) and Oman. Course relevance, delivery effectiveness, instructor support, web usage, and course compliance were crucial for imparting qualitative education through e-learning.

Chahal and Rani (2022) investigated the factors influencing students& behavioral intentions and actual usage of e-learning, exploring the mediation effects among hidden constructs. The study employed the Technology Acceptance Model (TAM) and tested an explanatory structural model. Personal innovativeness, self-efficacy, and social factors were found to play essential roles in adopting e-learning among higher education students. The study collected data through a quantitative questionnaire-based online survey with a sample size 570.

Duggal (2022) explored various factors affecting the acceptance of e-learning, including performance expectancy, effort expectancy, social influence, facilitating conditions, and more. The study collected data through surveys administered via email, social networking websites, university forums, and in-person interactions, with a sample size of 331 Indian students selected using random sampling. Infrastructure dependability, course design and content effectiveness, and students' computer competency were the top three factors influencing e-learning acceptance in India.

Ansong et al. (2017) investigated the determinants of e-learning adoption at the University of Ghana, identifying factors such as IT infrastructure, perceived ease of use, expected benefits, competitive pressure, organizational compatibility, educational partners, course content, and e-learning curriculum. The survey-based research involved e-learning stakeholders at the University of Ghana, and the Technology Acceptance Model (TAM), for instance, is one such framework used in studies on the adoption of technology such as e-learning. PEOU to determine an individual's intention to use a system with the intent to use.

According to Tarhini et al. (2017), adopting e-learning systems in the United Kingdom (UK) is influenced by performance expectancy, habit, social influence, hedonic motivation, effort expectancy, self-efficacy, and trust. The Unified Theory of Acceptance and Use of Technology (UTAUT2) incorporates two additional factors, trust, and self-efficacy, to the existing factors of UTAUT2, including performance expectancy, effort expectancy, hedonic motivation, habit, social influence, price value, and facilitating conditions. The researchers collected data from students at two universities in England through a cross-sectional questionnaire survey conducted between January and March 2015. The influencing factors were identified as performance expectancy, social influence, habit, hedonic motivation, self-efficacy, effort expectancy, and trust.

In Cheriyans study (2018), the critical factors for the success of e-learning in India, as identified by students pursuing various higher educational courses, were technological support, e-learning resources, e-learning support and training, characteristics of students, andcharacteristics of instructors. The information was collected through a questionnaire using a convenience sampling technique from undergraduate, postgraduate, and doctoral students at CHRIST (Deemed to be University), Bangalore, India. Factors such as the interaction of the course, accessibility to e-learning resources on and off-campus, adequacy of learning materials, communication with instructors, registration ease, design and layout of information, accessibility, and adequacy of online tests/quizzes, and the ability to return to uncompleted tasks were considered as e-learning resources.

Daniels et al. (2019) identified various factors influencing e-learning, including instructional design, course opening, assessment of learning, interaction, and community, instructional resources for teaching and learning, learner support, technology design, course evaluation, course closing, and instructional design cycle. These factors were considered relevant for teaching and learning in the new age. The researchers proposed Debattistas standards for developing and implementing e-learning environments: instructional design, course opening,assessment of learning, interaction and community, instructional resources, learner support,technology design, course evaluation, course closing, and instructional design cycle.

Bhongade and Sarode (2018) discussed the role of e-learning in higher education in India, including concepts and aspects, trends and issues, scopes, types of e-learning, challenges, industry market, the impact of MOOCs, benefits, advantages, and the future of e-learning.The authors emphasized that poor quality procurement practices act as a barrier to the growth and adoption of e-learning in India while highlighting the positive impact of e-learning on educational development and increasing the percentage of the literate population in India.

Vanitha and Alathur (2021) identified factors influencing the adoption of e-learning, including system quality, information quality, service quality, collaborative quality, computer skill, internet, self-efficacy, learner attitude, learner behavior, learner confidence, and prior knowledge. The researchers collected data through online and offline questionnaires, with 704 responses from graduate and undergraduate students in higher education institutions in India.

Jabeen and Sadique (2020) highlighted the rapid growth of the global e-learning market and its impact on educational institutions and organizations' training methods. They emphasized the importance of e-learning in the United Arab Emirates and its potential to change the learning process. Based on the Technology Acceptance Model (TAM) and incorporating five external variables, the researchers found that subjective norms directly influenced the intention to use e-learning. In contrast, internet experience, system interactivity, self-efficacy, and technical support indirectly influenced the intention through the perception of ease of use and usefulness. The information for this study was collected through questionnaires, with 30 responses from graduate and undergraduate students in higher education institutions in India.

A literature review highlights various factors influencing the adoption and success of e-learning in different contexts. Factors such as performance expectancy, habit, social influence, hedonic motivation, effort expectancy, self-efficacy, trust, technological support, e-learning resources, characteristics of students and instructors, instructional design, interaction and community, learner support, system quality, information quality, service quality,computer skill, internet, learner attitude, learner behavior, learner confidence, prior knowledge, and more have been identified as essential considerations in e-learning adoption.The studies reviewed encompassed regions, including the United Kingdom, India, and the United Arab Emirates, and involved diverse student populations. Data collection methods ranged from questionnaire surveys to online and offline questionnaires with varying sample sizes.

It is evident that an e-learningh play a very crucial role in an educational development and has the potential to transform traditional learning and teaching methods. However, challenges such as poor quality procurement practices, limited applicability of existing models in educational settings, and the need for adequate technical support and resources remain revalent.
Overall, the findings from the literature review provides valuable insight factors influencing e-learning adoption and also emphasize the importance of considering various aspects such as user expectations, support systems, instructional design, learner characteristics, and the quality of resources and services. These insights can guide educational institutions, policymakers, and stakeholders in developing effective e-learning strategies and ensuring the success of e-learning initiatives in diverse educational contexts.

Data Analysis:

To gain insights into e-learning preferences among Chinese undergraduates and better understand the factors influencing e-learning adoption ,in higher educationZhang et al.(2010) employed an innovation adoption perspective. The researchers used the theory of Rogers, which encompasses 5 aspects of innovation adoption,to develop a heirchical structure model for examining the key influence factors of e-learning adoption intention in China using Analytic Hierarchy Process (AHP). The evaluation index layer consisted of 33 influence factors related to the general objective of e-learning adoption. Among these factors, Pricing was found to have the most significant influence, followed by Education quality, while the available advantages perceived had the most negligible influence.

In another study by Punnoose (2012), it was found that inter relation between Perceived enjoyment and agreeableness was positive but not statistically significant. Individual differences in behaviour were moderated through beliefs. They were not affected by the finding by Devaraj et al. (2008) that there might be an affirmative relation between intention and openness to use technology. Among 5 personality traits studied, extraversion, conscientiousness and neuroticism demonstrated significant predictive power.Conscientiousness had a positive and native effect as a personality trait. When considering eLearning intention, conscientiousness and extraversion were the only personality variables influencing the original technology acceptance model(TAM) variables. Perceived Enjoyment did not exhibit a significant relationship with Behavioral Intention to engage in eLearning. The primary determinants of eLearning usage were extrinsic motivational factors such as Perceived Usefulness and Subjective Norms. Compared to females, males exhibited a greater enjoyment of eLearning, lower neuroticism, higher openness, better computer skills, and stronger intentions to use
eLearning in the future.

King and Boyatt (2015) emphasized the importance of organizational culture and infrastructure for supporting the adoption of e-learning in higher education. They recommended that organizations provide staff support,directionand guidance during an implementation of e-learning, along with sufficient time and resources. An introduction of an institutional e-learning strategy for students as well as staff and demonstration of leadership commitment were also suggested. Consistently available and reliable resources should be aligned with the e-learning strategy. Additionally, pedagogical support plays a crucial role in effectively implementing e-learning. Face-to-face support should be complemented by online guidance and facilitated communities of practice that encourage colleagues to share their experiences and utilization of e-learning.
Personal traits, such as optimism, insecurity, and discomfort with technology, were identified as influential factors shaping individual perceptions towards adopting e-learning systems,according to Koloseni and Mandari (n.d.). They argue that considering personal traits can provide a new perspective in the design of e-learning policies. Policy and decision-makers should critically evaluate unique traits while developing policies that effectively cater to the needs of individuals. For each construct influenced by personal traits, a respective policy should consider the specific personal trait that has an influence.The opinions of e-learners from Oman and the United Arab Emirates (UAE) regarding the quality of e-learning programs offered by two different online universities varied across administrative issues, instruction materials, instructor support, Viper sessions, grading, and assessment, as highlighted in a study by Elango et al. (n.d.). The study also

identified differences in opinions among respondents based on their demographic profiles, particularly about crucial factors. Students expressed the usefulness of e-books, e-journals, and platforms like BlackBoard/WebCT/KEWL. Still, they found that graphics and animations included in course materials did not enhance their learning experience. Viper sessions were not considered beneficial, and students suggested that chapter contents should be more informative and exciting.

Elango et al. (n.d.) conducted a study based on the Technology Acceptance Model (TAM) and introduced three external variables to create a comprehensive technology acceptance model. The model demonstrated how perceived usefulness and perceived ease of use could be influenced by personal innovativeness, self-efficacy, and social factors, which in turn affect attitudes, behavioral intentions, and actual usage of e-learning among higher education students.

In a study by Duggal (2022), the acceptance of e-learning in India was influenced by factors such as the effectiveness of instructors or lecturers, students collaboration interests, students competency with computers, accessibility of resources, the effectiveness of course design and content, infrastructure dependability, and provider support received. The study adopted a model based on the Unified Theory of Acceptance and Use of Technology (UTAUT) and encompassed seven factors comprising 44 variables derived from previous research. Notably,students collaboration interests and instructors effectiveness significantly impacted the acceptance of e-learning among Indian students.

Ansong et al. (2017) identified several determinants of e-learning adoption at the University of Ghana, including IT infrastructure, perceived ease of use (PEOU), expected benefits,organizational compatibility, competitive pressure, educational partners, the content of thecourse, and e-learning curriculum.

Tarhini et al. (2017) identified several influencing factors for adopting e-learning systems in the United Kingdom (UK), including performance expectancy, habit, social influence,hedonic motivation, effort expectancy, self-efficacy, and trust.
Cheriyan (2018) highlighted five critical factors for the success of e-learning among students pursuing various higher educational courses, ranging from undergraduate to doctoral programs. These factors included technological support, e-learning resources, e-learning support and training, characteristics of students, and characteristics of instructors.
Daniels et al. (2019) introduced ten specific standards, such as instructional design, course opening, assessment of learning, interaction, and community, instructional resources, learner support, technology design, course evaluation, course closing, and instructional design cycle, which were considered highly relevant by students for the development and implementation of e-learning.

Bhongade and Sarode (2018) emphasized the importance of governments, business companies, and professional associations focusing on the applications and effective implementation of e-learning. They noted that poor-quality procurement practices hinder the growth and adoption of e-learning. They recommended improved evaluation practices to enhance

learners knowledge, performance outcomes, learning outcomes, and business and policy impact, particularly in underdeveloped and developing countries.

Vanitha and Alathur (2021) identified several factors that influence the adoption of e-learning, including system quality, information quality, service quality, collaborative quality, computer skills, internet access, self-efficacy, learner attitude, learner behavior, learner confidence, and prior knowledge.

Jabeen and Sadique (2020) found that subjective norms directly influence the intention to use e-learning. Meanwhile, variables like internet experience, system interactivity, self-efficacy,and technical support indirectly affect the intention through the opinion of ease of use and usefulness. Perceived ease of use and perceived usefulness mediate the relationship between these variables and the intention to use e-learning.

The analysis of various e-learning adoption and preferences studies reveals several key findings. Factors influencing e-learning adoption vary across different contexts and demographics. The quality of e-learning programs, including administrative issues, instruction materials, instructor support, and assessment methods, significantly impacts students perceptions and preferences.

The Technology Acceptance Model (TAM) provides a valuable framework for understanding the acceptance and usage of e-learning among higher education students. External variables such as personal innovativeness, self-efficacy, and social factors play a critical role in shaping perceived usefulness and perceived ease of use, which, in turn, influence attitudes, behavioral intentions, and actual usage of e-learning.

Factors that contribute to the successful adoption of e-learning include technological support, availability of resources, effective design and content of courses, learner characteristics, and instructor qualities. Collaboration interests, instructor effectiveness, and infrastructure dependability are particularly important factors in contexts such as India and the University of Ghana.

Furthermore, the significance of subjective norms, system quality, information quality, service quality, collaborative quality, computer skills, internet access, and learner characteristics, including attitude, behavior, confidence, and prior knowledge, cannot be overlooked in the adoption and acceptance of e-learning.To promote e-learning adoption and effectiveness, organizations and institutions should focus on developing robust IT infrastructure, providing adequate support and training, ensuring quality instructional design, fostering collaboration and interaction, and addressing learners specific needs and preferences. Policymakers should also prioritize evaluating and improving e-learning initiatives to enhance educational outcomes, literacy rates, and economic development, particularly in underdeveloped and developing countries. Overall, the findings underscore the multidimensional nature of e-learning adoption and highlight the importance of considering various technological and human factors to create engaging and effective e-learning environments.

Conclusion:

The study investigated the factors that impact adopting e-learning products in higher education. Specifically, a research aimed to determine the factors influencing students adoption and usage of e-learning. Through a thorough literature review, the current study sheds light on the factors that affect the behavioral intention to use e-learning in higher education.

Many studies in this field have utilized the Technology acceptance model as a framework, which examines the acceptance of various technologies, including e-learning. Initially proposed by Davis in 1989, TAM has been extensively acknowledged as one of the most effective models for understanding technology acceptance. It identifies two primary factors influencing individuals' intention to adopt new technology: perceived ease of use and usefulness. The findings of the study suggest that specific perceived innovative attributes, such as cost, quality, agility, schedule control, certification of degree, personal demands, etc., significantly influence people's adoption of e-learning. Other factors that emerged from the research include system quality, information quality, service quality, collaborative duality, computer skills, internet access and self-efficacy.

It is value noting that most of the literature reviewed in the e-learning field tends to focus primarily on a single stakeholder perspective i.e students. In the future, research should consider the perspectives of all stakeholders involved. Additionally, there should be a greater emphasis on exploring the motives behind new institutions adopting e-learning and how it can be effectively used for student development. The research should also consider internal and external factors that may influence the adoption and implementation of e-learning in higher education in India.

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संस्था नोंदणी क्र-१९९१/जीबीबीएसडी/४२६

त्रिमूर्ती पावन प्रतिष्ठाण शिक्षण संस्थेचे

त्रिमूर्ती कला,वाणिज्य व विज्ञान महाविद्यालय,त्रिमूर्ती नगर,

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३१ वे राष्ट्रीय अधिवेशन

दि :- १९ व २० जानेवारी २०२४

-: प्रमुख संपादक :-

डॉ.अरुणा मोरे

अध्यक्षा

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प्रकाशक

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मुद्रक :- गणेश आर्ट, अहमदनगर

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दि. :- १९/०१/२०२४

- या शोधनिबंध संग्रहात प्रकाशित झालेल्या शोधनिबंधातील मतांशी संपादक व प्रकाशक सहमत असतीलच असे नाही. ती मते त्या-त्या संशोधकाचीच समजावीत.

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१९	उर्मिला क्षिरसागर	महाराष्ट्राचा सांस्कृतिक ठेवा -लावणी	११३-११७
२०	प्रा. सरला ब्रम्हेदव चव्हाण	क्रांतीज्योती सावित्रीबाई फुले यांचे कार्य	११८-१२८
२१	गणेश पुनमचंद बिरुटे	साने गुरुजींवर महात्मा गांधीजींचा पडलेला प्रभाव	१२९-१३२
२२	प्रा. डॉ. शितल अरविंद धरम	अहमदनगर जिल्ह्यातील कम्युनिस्ट कार्यकर्त्यांची संयुक्त महाराष्ट्र चळवळीतील भूमिका	१३३-१३६
२३	डॉ. भूषण गोविंद फडतरे	शोधनिबंध विषय: स्थानिक इतिहासाच्या दृष्टीने हुतात्मा स्मारकांचे महत्त्व	१३७-१४३
२४	प्रा. प्रणय जाधव	भारतीय राज्यघटनेच्या सरनाम्याचे चिकित्सक समालोचन	१४४-१४६
२५	प्रमोद मारुती जाधव	सांगली जिल्हयातील सोने चांदी गलाई व्यवसायिकांचे स्थालांतर	१४७-१५२
२६	प्रतिक बाबासाहेब सुरशे	विसाव्या शतकात महाराष्ट्रातील भिल्ल चळवळीचे योगदान	१५३-१५७
२७	किशोर नागनाथ जोगदं	उपेक्षिताचे नायक : रघुनाथ नामदेव राऊळ उर्फ भाई राऊळ	१५८-१६४
२८	मरकड श्रीराम विलास	शिक्षणमहर्षी मारुतराव घुले यांचे शिक्षणविषयक विचार व कार्य	१६५-१७२
२९	प्रा. अर्चना राजेंद्र गायकवाड	महिला सशक्तीकरणातील डॉ.बाबासाहेब आंबेडकर यांची भूमिका	१७३-१७६
३०	प्रा. डॉ. रघुराज मुगुटराव कुरूमकर	डॉ. बाबासाहेब आंबेडकर यांचे शैक्षणिक विचार	१७७-१८१

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शोधनिबंध विषय: स्थानिक इतिहासाच्या दृष्टीने हुतात्मा स्मारकांचे महत्त्व

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प्रस्तावना :

भारतीय स्वातंत्र्यलढ्याच्या स्मृतीची जपवणूक होण्यासाठी, ज्ञात अज्ञात क्रांतिकारकांचा प्रेरणादायी इतिहास नवीन पिढीसमोर ठेवण्यासाठी आणि स्थानिक इतिहास लेखनासाठी 'हुतात्मा स्मारके' महत्त्वाची आहेत. भारतीय पुरातत्व पुरातत्त्व विभागामार्फत सांस्कृतिक वारसा जतन करण्यासाठी ऐतिहासिक हुतात्मा स्मारके संरक्षित केल्या जातात अशा ठिकाणांना राष्ट्रीय स्मारके असे म्हणतात. या स्मारकांची देखभाल व संरक्षण हे भारत सरकारचे पुरातत्व विभागामार्फत करत आहे. तर प्रादेशिक पातळीवर हुतात्मा स्मारकांची देखभाल व त्यांचे संरक्षण त्या त्या राज्याच्या पुरातत्व विभागामार्फत केले जाते. महाराष्ट्रातील हुतात्मा स्मारके साधारणपणे चार प्रकारची दिसून येतात. १) स्वातंत्र्यपूर्वकाळात हुतात्मा झालेल्यांची स्मारके २) मराठवाडा मुक्ती संग्रामामध्ये बलिदान दिलेल्यांची स्मारके, ३) स्वातंत्र्योत्तर काळात भारतीय सैन्य दलातील सैनिक कार्य करत असताना शहीद झालेल्या सैनिकांची स्मारके. ही सर्व स्मारके स्थानिक इतिहासाच्या दृष्टीने महत्त्वाची आहेत.

स्थानिक इतिहास आणि हुतात्मा स्मारक :

प्रत्येक ठिकाणाला, गावाला राजकीय, सामाजिक, आर्थिक व सांस्कृतिक इतिहास लाभलेला असतो. त्याचे स्वरूप जरीकमी अधिक प्रमाणात असले तरी तेथील इतिहासाचे प्रतिनिधित्व करीत असते. शिलालेख, ताम्रपट, दुर्मिळ वस्तू, मूर्ती, नाणी, शिल्पकृती, मंदिरे, लेण्या, हुतात्मा स्मारके ही वारसास्थळे स्थानिक इतिहासाची साधने आहेत. या साधनांमधून गावातील सांस्कृतिक पैलूंचा उलगडा होत असतो. स्थानिक इतिहासाच्या दृष्टीने हुतात्मा स्मारके ही मुख्यतः ज्या व्यक्तीने देशासाठी बलिदान दिलेले आहे अशा लोकांचे, विशेषतः त्यांच्या गावात हुतात्मा स्मारक उभारलेले आहेत. अशी स्मारके गाव व पंचक्रोशीतील लोकांना नेहमी प्रेरणा देणारे ठरत असतात. त्यामुळे हुतात्मा स्मारक बांधताना गावाच्या प्रवेशद्वाराजवळ, मंदिराजवळ, गावच्या दर्शनी भागात बांधली जातात. हुतात्मा स्मारक बांधण्यासाठी साधारणता ग्रामपंचायत किंवा नगरपालिका, महानगरपालिका यांच्याकडून जागा मिळाली आहे. हुतात्मा

स्मारक बांधल्यानंतर त्याची देखभाल व संरक्षण ग्रामपंचायत, नगरपालिका, महानगरपालिका, सार्वजनिक बांधकाम विभाग, जिल्हा परिषद, सामाजिक संस्था अशा संस्थाद्वारे केली जाते. महाराष्ट्राचे मुख्यमंत्री बॅरिस्टर ए. आर. अंतुले यांच्या १९८० च्या दशकात हुतात्मा स्मृतीस्तंभ व स्मारक उभारणीची संकल्पना पुढे आली. महाराष्ट्रात २०६ हुतात्मा स्मारकांची उभारणी झाली. अशा हुतात्म्यांच्या स्मारकातून वैचारिक परिवर्तनाचा जागर होत आहे. राष्ट्रवादी विचाराच्या दृष्टीने आत्मनिर्भर भारतासाठी देखील हुतात्मा स्मारके महत्त्वाची आहेत. महाराष्ट्रातील जिल्ह्यानुसार हुतात्मा स्मारकांची संक्षिप्त माहिती महाराष्ट्र राज्य गॅझेटियर पुरस्कृत 'स्वातंत्र्यसमरातील महाराष्ट्राचे योगदान' या संदर्भग्रंथात प्रसिद्ध झालेली आहे. या ग्रंथामध्ये २०६ हुतात्मा स्मारकाचे ठिकाण, त्यांची देखभाल व परीक्षण करण्यासाठी निवड करण्यात आलेल्या सेवाभावी, शैक्षणिक संस्थेचे, स्थानिक स्वराज्य संस्थेचे नाव, हुतात्म्याचे नाव, गाव, तालुका, जिल्हा इत्यादींची माहिती दिलेली आहे.[१] असा हा ग्रंथ हुतात्मा स्मारकाच्या संदर्भात स्थानिक इतिहासाच्या दृष्टीने अत्यंत महत्त्वाचा आहे.

हुतात्मा स्मारक ज्या व्यक्तीचे बांधले आहे. त्या व्यक्तीचा पराक्रम समजावून घेतला पाहिजे. कारण हुतात्मा स्मारक हे जरी सध्या दिसत असले तरी त्या स्मारक व्यक्तीचे दुर्लक्षित कार्य समाजापुढे आले पाहिजे. त्या दृष्टीने काही निवडक हुतात्मा स्मारकांचा इतिहास मांडलेला आहे.

हुतात्मा राजगुरू स्मारक :

हुतात्मा शिवराम हरी राजगुरू यांचा जन्म २४ ऑक्टोबर १९०८ रोजी पुणे जिल्ह्यातील खेड येथे झाला. पुणे शहरात नूतन मराठी विद्यालयात शिक्षण घेत असतानाच त्यांच्यावर लोकमान्य टिळकांच्या विचारांचा प्रभाव पडलेला होता. राजगुरू यांच्या क्रांतिकारी जडणघडणीत पुण्याचे श्रीराम बळवंत सावरगावकर व चंद्रशेखर आझाद यांचे उल्लेखनीय योगदान आहे. सावरगावकर, काशिनाथ विठ्ठल सहस्त्रबुद्धे व दत्तात्रय बळवंत करंदीकर या तिघांचा 'हिंदुस्तान सोशालिस्ट रिपब्लिकन आर्मी'शी संबंध होता. त्यांच्याशी पुढे राजगुरू यांचा संबंध आला. राजगुरू यांनी काशी, बनारसला संस्कृतचे अध्ययन केले. बौद्धिक ज्ञानाबरोबरच बलदंड शरीर संपादनेची देखील गरज आहे हे ओळखून त्यांनी अमरावतीच्या श्री हनुमान व्यायामशाळेतून शारीरिक शिक्षण घेतले. त्यानंतर राजगुरू यांचा चंद्रशेखर आजाद व भगतसिंग यांच्याशी परिचय झाला आणि ते 'हिंदुस्थान सोशालिस्ट रिपब्लिकन आर्मी' या क्रांतिकारी संघटनेशी संघटित झाले. शिव वर्मा हे बंदुकीच्या नेमबाजीतील अचूकतेसाठी प्रसिद्ध होते' त्यांच्याकडून राजगुरूंना लाठी काठी, धनुष्यबाण व नेमबाजीचे मार्गदर्शन मिळाले. भगतसिंग, राजगुरू, सुखदेव, जतीनदास व चंद्रशेखर आझाद यांच्यात क्रांती कार्याबद्दल सातत्याने चर्चा होऊ लागल्या. जुलमी ब्रिटिश सत्तेबद्दल त्यांच्या मनात तिरस्काराची भावना निर्माण होत होती.

२९ ऑक्टोबर १९२८ रोजी सायमन कमिशनने लाहोरला भेट दिली. पंजाब केसरी लाला लजपतराय यांच्या नेतृत्वाखाली कमिशन पुढे शांतपणे निदर्शने सुरु होती. लाहोरचा पोलीस अधीक्षक जेम्स स्कॉट व सहायक पोलीस अधीक्षक साँडर्स यांनी मात्र पोलीस बळाचा वापर करीत शांत निदर्शने करणाऱ्या आंदोलकांवर लाठी हल्ला केला. पुढे १८ दिवसातच लाला लजपतराय यांचा मृत्यू झाला. सायंकाळी लाहोरच्या सभेतील जनसमुदायापुढे संदेश बंधू चित्तरंजदास यांच्या पत्नी वासंतीदेवी म्हणाल्या 'लालाजी की चिता की आग ठंडी होने के पहले ही किसी भारतीय नौजवानने इस क्रूरता का बदला लेना चाहिए'[२] याचा परिणाम क्रांतीकारकांवर झाला.

हुतात्मा भगतसिंग, राजगुरू, चंद्रशेखर आझाद आणि जयगोपाळ यांनी लालाजींच्या मृत्यूस जबाबदार असणाऱ्या जेम्स स्कॉट अधिकाऱ्याचा खून करण्याची जबाबदारी घेतली. मालरोड पोलीस स्टेशनच्या फाटकाजवळ जयगोपाळ दबा धरून बसले. काही अंतरावर भगतसिंग व राजगुरू पिस्तुलासह सज्ज होते. पोलीस कार्यालयातून गोरा अधिकारी बाहेर पडला तात्काळ जयगोपाळने भगतसिंग यांना इशारा करताच त्यांच्या जवळ असणाऱ्या राजगुरू यांनी पहिली गोळी साँडर्सवर झाडली.[३] त्यानंतर भगतसिंगानेही आठ गोळ्या झाडल्या. या दोघांचा पाठलाग करणाऱ्या हेड कॉन्स्टेबल छगनसिंगवर चंद्रशेखर आझाद यांनी गोळ्या झाडल्या त्यामध्ये तो ज़खमी झाला.

लाहोरमध्ये धरपकड सत्र सुरू झाल्याने राजगुरू हे गुप्तपणे पुणे शहरात आले. राजगुरू पुण्यामध्ये आल्यानंतरही त्यांच्यातील क्रांतीकार्याचे नवचैतन्य ज्वलंत होते. पुण्याच्या रेस कोर्स मैदानावरील घोड्यांच्या शर्यत स्पर्धेचे बक्षीस वितरणासाठी येणारे मुंबईचे गव्हर्नर फ्रेडरिक साईक्सचा वध करण्याची योजना तयार केली. लाहोरच्या पोलिसांनी माफीचे साक्षीदार झालेल्या जय गोपाळला पुण्यात आणले होते. राजगुरूंना अटक करून फरासखाना पोलीस स्टेशनला नेले. पुढील चौकशीसाठी त्यांना लाहोरला घेऊन गेले. मध्यंतरीच्या काळात भगतसिंग, बुटकेश्वर दत्त, सुखदेव यांनाही अटक झालेली होती. राजगुरूसह या सर्व क्रांतिकारकांवर खटला भरला तोच 'लाहोर केस खटला' होय. या खटल्याचा निकाल लागून २३ मार्च १९३१ रोजी शिवराम हरी राजगुरू यांच्यासह भगतसिंग व सुखदेव यांना लाहोरच्या तुरुंगात फाशी देण्यात आले.[४] यावेळी राजगुरू हे फक्त २२ वर्षांचे होते. ऐनतारुण्यात देशाच्या स्वातंत्र्यासाठी 'इन्कलाब जिंदाबाद' अशा घोषणा देत शिवराम हरी राजगुरू हुतात्मा झाले.

हुतात्मा शिवराम हरी राजगुरू यांचे स्मारक राजगुरुनगर खेड येथे आहे. हे स्मारक व त्यांचा वाडा या दोन्ही ऐतिहासिक वास्तू महाराष्ट्र शासनाने संरक्षित स्मारक म्हणून घोषित केल्या आहेत. पुणे पुरातत्त्व विभागाद्वारे हुतात्मा स्मारक व वाडा या दोन्ही वास्तूंचे जतन व दुरुस्तीचे काम केल्यामुळे आता

या स्मारकाला गतवैभव मिळाले आहे. येथील स्मारकाची देखभाल व स्वच्छता ही राजगुरुनगरनगर परिषदेमार्फत केली जाते. हुतात्मा शिवराम हरि राजगुरु यांची पुण्यतिथी २३ मार्च व जयंती २४ ऑगस्ट या दोन्ही दिवशी हुतात्मा स्मारक व वाडा येथे पुणे अभिलेखागार व राजगुरुनगर परिषदेच्या वतीने कार्यक्रम आयोजित केले जातात. या दोन्ही दिवशी मोठ्या प्रमाणात शासकीय अधिकारी व राजगुरुनगर पंचक्रोशीतील जनसमुदाय हुतात्मा स्मारकास भेट देतात.

चिरनेर हुतात्मा स्मारक :

रायगड जिल्यातील उरण तालुक्यातील चिरनेर येथे हुतात्मा स्मारक आहे. देशाच्या स्वातंत्र्यासाठी लढल्या गेलेल्या चिरनेर जंगल सत्याग्रहाला विशेष महत्व आहे. महात्मा गांधीजींनी पुकारलेल्या सविनय कायदेभंग आंदोलनात मिठाचा सत्याग्रह व जंगल सत्याग्रह हे दोन्ही सत्याग्रह विशेष गाजले आहेत. ब्रिटिश सरकारने आदिवासींचा जंगलावरील हक्क नाकारला. या अन्याया विरोधात देशभर जंगल सत्याग्रह सुरू झाले. देशातील पहिला जंगल सत्याग्रह सांगली जिल्ह्यातील शिराळा तालुक्यातील बिळाशी येथे झाला. यानंतर रायगड जिल्ह्यातील उरण तालुक्यातील चिरनेर येथे जंगल सत्याग्रह झाला. दिनांक २५ सप्टेंबर १९३० रोजी ५ हजार लोकांनी चिरनेरमधील अक्कादेवीच्या डोंगरावर 'महात्मा गांधी की जय' अशा घोषणा देत शांततेच्या मार्गाने गवत कापत जंगल सत्याग्रह सुरू झाला.[६] पोलिसांनी वीस सत्याग्रहींना पकडून बेड्या ठोकल्या. लोकांनी बेड्या काढण्याचा आग्रह केला. पण पोलीस सब इन्स्पेक्टर रामचंद्र पाटील यांनी मात्र त्यास नकार दिला. परंतु मामलेदार केशव जोशी यांनी लोकांच्या बेड्या काढण्यास सांगितले. तेव्हा पोलीस अधिकाऱ्यांनी बेड्या काढल्या. सत्याग्रहासाठी जमलेले सर्व आदिवासी लोकांचा जमाव डोंगरावरून खाली उतरत असतानाच त्यांच्यावर पोलिसांनी बेछूट गोळीबार केला. गोळीबारामध्ये आंदोलकांसह एकूण १३ जण हुतात्मा झाले.
चिरनेर आंदोलनामधील हुतात्म्यांची नावे[७] – १) परशुराम रामा पाटील (पाणदिवे), २) धाकू गवत्या फोफरकर (चिरनेर) ३) रघुनाथ मोरेश्वर न्हावी (कोपोर्ली) ४) रामा बामा कोळी (मोठी जुई) ५) आनंदा माया पाटील (धाकटी जुई), ६) हसुराम बुधाजी घरत (खोपटे) ७) नाग्या महादू कातकरी (चिरनेर) ८) आलू बेमट्या म्हात्रे (दिघोडे) ९) नारायण पांडू कदम (पनवेल) १०) हरी नारायण तवटे, ११. जयराम बाबाजी सावंत १२.काशिनाथ जनार्दन शेवडे १३. केशव महादेव जोशी मामलेदार. या घटनेचे पडसाद संपूर्ण देशभर उमटले.

चिरनेर जंगल सत्याग्रहातील आदिवासी सत्याग्रही हुतात्म्यांच्या स्मृति प्रीत्यर्थ चिरनेरमध्ये स्तंभ उभारला. या स्तंभाला कोणशीला कनैयालाल मुन्शी यांच्या हस्ते २५ सप्टेंबर १९३१ रोजी बसविण्यात आली. ३ जानेवारी १९३२ रोजी चिरनेर स्तंभाचे उद्घाटन झाले. चिरनेरचा स्तंभ हा

या स्मारकाला गतवैभव मिळाले आहे. येथील स्मारकाची देखभाल व स्वच्छता ही राजगुरुनगरनगर परिषदेमार्फत केली जाते. हुतात्मा शिवराम हरि राजगुरु यांची पुण्यतिथी २३ मार्च व जयंती २४ ऑगस्ट या दोन्ही दिवशी हुतात्मा स्मारक व वाडा येथे पुणे अभिलेखागार व राजगुरुनगर परिषदेच्या वतीने कार्यक्रम आयोजित केले जातात. या दोन्ही दिवशी मोठ्या प्रमाणात शासकीय अधिकारी व राजगुरुनगर पंचक्रोशीतील जनसमुदाय हुतात्मा स्मारकास भेट देतात.

चिरनेर हुतात्मा स्मारक :

रायगड जिल्यातील उरण तालुक्यातील चिरनेर येथे हुतात्मा स्मारक आहे. देशाच्या स्वातंत्र्यासाठी लढल्या गेलेल्या चिरनेर जंगल सत्याग्रहाला विशेष महत्व आहे. महात्मा गांधीजींनी पुकारलेल्या सविनय कायदेभंग आंदोलनात मिठाचा सत्याग्रह व जंगल सत्याग्रह हे दोन्ही सत्याग्रह विशेष गाजले आहेत. ब्रिटिश सरकारने आदिवासींचा जंगलावरील हक्क नाकारला. या अन्याया विरोधात देशभर जंगल सत्याग्रह सुरू झाले. देशातील पहिला जंगल सत्याग्रह सांगली जिल्ह्यातील शिराळा तालुक्यातील बिळाशी येथे झाला. यानंतर रायगड जिल्ह्यातील उरण तालुक्यातील चिरनेर येथे जंगल सत्याग्रह झाला. दिनांक २५ सप्टेंबर १९३० रोजी ५ हजार लोकांनी चिरनेरमधील अक्कादेवीच्या डोंगरावर 'महात्मा गांधी की जय' अशा घोषणा देत शांततेच्या मार्गाने गवत कापत जंगल सत्याग्रह सुरू झाला.[६] पोलिसांनी वीस सत्याग्रहींना पकडून बेड्या ठोकल्या. लोकांनी बेड्या काढण्याचा आग्रह केला. पण पोलीस सब इन्स्पेक्टर रामचंद्र पाटील यांनी मात्र त्यास नकार दिला. परंतु मामलेदार केशव जोशी यांनी लोकांच्या बेड्या काढण्यास सांगितले. तेव्हा पोलीस अधिकाऱ्यांनी बेड्या काढल्या. सत्याग्रहासाठी जमलेले सर्व आदिवासी लोकांचा जमाव डोंगरावरून खाली उतरत असतानाच त्यांच्यावर पोलिसांनी बेछूट गोळीबार केला. गोळीबारामध्ये आंदोलकांसह एकूण १३ जण हुतात्मा झाले.
चिरनेर आंदोलनामधील हुतात्म्यांची नावे[७] – १) परशुराम रामा पाटील (पाणदिवे), २) धाकू गवत्या फोफरकर (चिरनेर) ३) रघुनाथ मोरेश्वर न्हावी (कोपोर्ली) ४) रामा बामा कोळी (मोठी जुई) ५) आनंदा माया पाटील (धाकटी जुई), ६) हसुराम बुधाजी घरत (खोपटे) ७) नाग्या महादू कातकरी (चिरनेर) ८) आलू बेमट्या म्हात्रे (दिघोडे) ९) नारायण पांडू कदम (पनवेल) १०) हरी नारायण तवटे, ११. जयराम बाबाजी सावंत १२.काशिनाथ जनार्दन शेवडे १३. केशव महादेव जोशी मामलेदार. या घटनेचे पडसाद संपूर्ण देशभर उमटले.

चिरनेर जंगल सत्याग्रहातील आदिवासी सत्याग्रही हुतात्म्यांच्या स्मृति प्रीत्यर्थ चिरनेरमध्ये स्तंभ उभारला. या स्तंभाला कोणशीला कनैयालाल मुन्शी यांच्या हस्ते २५ सप्टेंबर १९३१ रोजी बसविण्यात आली. ३ जानेवारी १९३२ रोजी चिरनेर स्तंभाचे उद्घाटन झाले. चिरनेरचा स्तंभ हा

बेकायदेशीरपणे बांधला असल्याचे कारण देत रायगडच्या जिल्हाधिकाऱ्यांच्या आदेशान्वये हा स्तंभ जून १९३२ मध्ये पाडण्यात आला. असे असले तरी चिरनेर मधील स्तंभामुळे आदिवासी लोकांना प्रेरणा मिळत ब्रिटिश पोलीस व सरकार बद्दल असणारी तिरस्काराची भावना वाढत होती. अशी भावना कृतीतून व्यक्त होण्यापूर्वीच स्तंभ पाडला असला पाहिजे. सन १९३७ मध्ये प्रांतिक काँग्रेसच्या मंत्रिमंडळाने पुन्हा स्तंभ उभारण्याचा निर्णय घेतला. वर्षभरात पुन्हा चिरनेरमधील स्तंभाचे बांधकाम पूर्ण झाले. मुंबई प्रांताचे मुख्यमंत्री बाळासाहेब खेर यांच्या हस्ते ३ जानेवारी १९३९ रोजी येथील स्तंभाचे अनावरण झाले. अशा ऐतिहासिक स्तंभाच्या चारही दिशेला 'वंदे मातरम्' अशा पाट्या लावलेल्या आहेत.[८] १९८० च्या दशकात चिरनेर येथे हुतात्मा स्मारक उभारण्यात आले. हुतात्मा स्मारकाच्या शेजारी हुतात्मा स्मारक शिल्प उभारण्यात आली आहेत. चिरनेरप्रमाणेच दिगोडे, मोठी जुई, धाकटी जुई, कोप्रोली, पानदिवे आणि खोपटे इत्यादी गावातही हुतात्मा स्मारके उभारण्यात आली आहेत. या सर्व गावांमधील सत्याग्रही चिरनेरच्या जंगल सत्याग्रहात हुतात्मा झालेले आहेत. २५ सप्टेंबर या दिवशी हुतात्मा स्मारकावर शासनाच्यावतीने मानवंदना दिली जाते. याप्रसंगी चिरनेर व परिसरातील आदिवासी बाल-वृद्ध, स्त्री-पुरुष, शेतकरी-कामगार असे सर्वजण मोठ्या संख्येने उपस्थित राहतात.

हुतात्मा मेजर प्रदीप ताथवडे स्मारक

प्रदीप रामचंद्र ताथवडे यांचा जन्म २१ सप्टेंबर १९६३ रोजी झाला. त्याचे मूळ गाव पुणे जिल्ह्यातील शिरूर तालुक्यातील केंदूर आहे. प्रदीप यांना सैनिकी शिक्षणाचा वारसा आई कुसुमताई घनवट यांच्या कुटुंबापासून मिळालेला होता. प्रदीप यांचे आजोबा कोंडाजीराव घनवट यांनी पहिल्या महायुद्धात, मामा लेफ्टनंट मार्तंडराव यांनी दुसऱ्या महायुद्धात तर दुसरे मामा कॅप्टन शिवाजीराव यांनी १९७१ च्या युद्धात अतुलनीय पराक्रम केला. त्यांच्या शौर्याची, पराक्रमाची माहिती प्रदीप यांना बालपणापासूनच मिळत होती. प्रदीप यांनी सातारा येथील सैनिकी स्कूल व पुणे येथील राष्ट्रीय संरक्षण प्रबोधिनी (एनडीए) या संस्थांमधून लष्करी शिक्षण घेतले. लष्करी शिक्षण घेतल्यानंतर प्रदीप ताथवडे हे भारतीय लष्करातील 'लाईट ८ जम्मू काश्मीर इन्फंट्री बटालियन'मध्ये सहभागी झाले.[९] ही बटालियन मुख्यत: पाकिस्तानच्या सैन्याशी कडवी झुंज देण्यासाठी प्रसिद्ध आहे. सियाचिनच्या बर्फाळ भागातील बिला फोंडला खिंड रोखून धरण्यात अग्रेसर होती. येथील जबाबदारी मेजर प्रदीप ताथवडे यांच्यावर होती. या खिंडीपासूनच असणाऱ्या ३ किलोमीटर अंतरावर कैद पोस्ट आहे. या ठिकाणावरून पाकिस्तानी सैन्य भारतीय लष्करावर गोळीबार करत. तेव्हा हे ठिकाण भारतीयांच्या ताब्यात असणे अतिशय महत्त्वाचे आहे हे ओळखून मेजर प्रदीप यांची कैद पोस्टवर निवड झाली. मेजर प्रदीप ताथवडे व पाकिस्तानी सैन्य यांच्यात गोळीबार सुरु झाला. पण भारतीय सैन्यापुढे शत्रूला माघार घ्यावी लागली. कैद पोस्ट भारताच्या

नियंत्रणाखाली आल्याने पाकिस्तानकडून भारतावर होणारा लष्करी मारा कमी झाला. कैद पोस्टवरील पराक्रम पाहून मेजर प्रदीप यांची भीम पोस्टवर देशसेवा केली.

सन १९९९ मध्ये भारत-पाकिस्तान यांच्यात कारगिल युद्ध झाले. या युद्धाच्या प्रसंगी मेजर प्रदीप हे १२० सैन्यानिशी दोडा पोस्टवर होते. कारगिल युद्धाच्या वेळी पाकिस्तानी सैन्याने दोडावर अनेक हल्ले केले. परंतु तेवढ्याच प्रतिकाराने मेजर प्रदीप यांनी देखील ते परतावून लावले व दोडाचा कोणताही भाग पाकिस्तानला घेऊ दिला नाही. कारगिल युद्धात अपयश आल्याने पाकिस्तानी अतिरेकी जम्मू-काश्मीरच्या परिसरात घुसखोरी करू लागले. पूँछजवळील शहापूर गावाजवळील सिलोनिया गावात अतिरेकी आश्रयास येणार ही खबर मेजर प्रदीप यांना मिळाली. तेव्हा मेजर प्रदीप व मेजर हिमांशू सावंत यांनी २० ते ३० सैन्यानिशी २६ नोव्हेंबर १९९९ च्या रात्री सिलोनिया गावाला गुप्त वेडा दिला. अतिरेकी गावात प्रवेश करताच त्यांच्यावर गोळीबार झाला. तेथील गोळीबारात 'हरकत उल मुजाहिदीन' या अतिरेकी संघटनेचा चीफ एरिया लान्स कमांडर मारला गेला.[१०] या घटनेचा बदला घेण्यासाठी अनेक अतिरेक्यांनी हालचाली सुरू केल्या.

शहापूर, सिलोनियाप्रमाणे पिंडी गावातही अतिरेक्यांनी आश्रय घेतला होता. १५ जून २००० रोजी मेजर प्रदीप ताथवडे, मेजर यशपाल राणा आणि मेजर हिमांशू सावंत हे निवडक सैन्यानिशी पिंडीकडे गेले. १६ जूनच्या रात्री मेजर मेजर हिमांशू सावंत यांनी पिंडी गावाला वेडा दिला. पिंडीजवळील दोडागावातही ५ अतिरेक्यांनी आश्रय घेतला होता. दोडाची जबाबदारी स्वतः मेजर प्रदीप ताथवडे यांनी घेतली. दोडा येथील अतिरेक्यांशी लढता लढता मेजर प्रदीप तातवडे १६ जून २००० रोजी धारातीर्थी पडले. पण तेथील पाचही अतिरेकी मारण्यात मेजर प्रदीप ताथवडे यशस्वी झाले होते. मातृभूमीसाठी प्राणाची बाजी लावणारे मेजर प्रदीप ताथवडे हे हुतात्मा झाले. शहीद मेजर प्रदीप ताथवडे यांना कीर्ती चक्र मरणोत्तर मिळाले.

शहीद मेजर प्रदीप ताथवडे यांच्या कार्याचे स्मरण होण्यासाठी त्यांच्या मूळ गावी केंदूर येथे शहीद मेजर प्रदीप ताथवडे हुतात्मा स्मारक बांधण्यात आले. स्मारकासाठी केंदूर ग्रामपंचायतकडून जागा मिळाली असून तेथे मेजर प्रदीप ताथवडे यांचा अर्ध पुतळा उभारला आहे. येथील हुतात्मा स्मारकाची देखभाल केंदूर ग्रामपंचायत व शहीद मेजर प्रदीप ताथवडे प्रतिष्ठान तर्फे केली जाते. शहीद मेजर प्रदीप ताथवडे स्मारकापासून केंदूर परिसरातील अनेक तरुणांना भारतीय सैन्य दलात जाण्याची प्रेरणा मिळत आहेत त्यामुळे केंदूर, पाबळ, धामारी, खैरेनगर या गावातील अनेक तरुण भारतीय सैन्य दलात कार्यरत आहेत. तर कित्येक जण निवृत्त होऊन स्थानिक तरुणांना देशसेवेबद्दलचे मार्गदर्शन करीत आहेत.

मूल्यमापन : भारतीय स्वातंत्र्यलढ्यात व स्वातंत्र्योत्तर काळात शत्रूंची लढा देत असताना बलिदान झालेल्या वीरांचे व त्यांच्या कार्याचे स्मरण होण्यासाठी हुतात्मा स्मारक व स्तंभ उभारलेले आहेत. स्थानिक इतिहासाच्या दृष्टीने हुतात्मा स्मारक व स्तंभ हे अत्यंत महत्त्वाचे आहे. हुतात्मा स्मारक व स्तंभापासून आजच्या तरुणांना राष्ट्रसेवेची प्रेरणा मिळण्यास मदत होते. तसेच हुतात्मा स्मारक व स्तंभ हे राष्ट्रीय एकात्मतेचे देखील प्रतीक आहेत. येथे शासनाच्या वतीने घेतल्या जाणाऱ्या कार्यक्रमाला गावातील बाल-वृद्ध, स्त्रिया-पुरुष मोठ्या संख्येने उपस्थित राहतात.

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-डॉ. पांडुरंग किसन लोहोटे ---------- १९६

४८. ग्रंथप्रेमी सयाजीराव गायकवाड
- डॉ . तृप्ती सुभाष अंब्रे ---------- २००

४९. महाराजा सयाजीराजे गायकवाड यांच्या सामाजिक सुधारणा– ऐतिहासिक विश्लेषण
- डॉ. दीपक सो. वेडे ---------- २०४

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महाराजा सयाजीराव गायकवाड यांचे कृषी, जलसिंचन, सहकार या संदर्भातील विचार व कार्य

प्रा. सुभाष बाजीराव शिंदे
भारतीय जैन संघटनेचे
कला विज्ञान व वाणिज्य महाविद्यालय वाघोली, पुणे ४१२२०२७.
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प्रस्तावना:

महाराष्ट्राच्या जडणघडणीमध्ये महाराजा सयाजीराव गायकवाड यांचे नाव घेतले जाते. आधुनिक महाराष्ट्राच्या जडणघडनीत महाराजा सयाजीराव गायकवाड यांचे कार्य आणि कर्तृत्व अत्यंत प्रभावीपणे लोककल्याणाच्या विकासासाठी दिसून येते. हिंदुस्तानमधील बडोदा संस्थानातील महाराजा सयाजीराव गायकवाड यांचे लोककल्याणकारी प्रयोग तत्कालीन कालखंडात भारताला दिशादर्शक व विकासाकडे घेऊन जाणारे ठरले. साधारणपणे इसवी सन १८७५ ते इसवी सन १९३९ पर्यंत लोककल्याणकारी, प्रजाहितदक्ष, बुद्धीवादी विचारवंत, म्हणून त्यांच्या कार्याचा प्रभाव महाराष्ट्र, गुजरात पर्यायाने

भारतावरती झाला. याच पार्श्वभूमीवर इसवी सन १८८१ ते १९३९ या आपल्या ५८ वर्षाच्या प्रदीर्घ स्वरूपाच्या कारकिर्दीमध्ये सामाजिक, आर्थिक, राजकीय, धार्मिक, कला, साहित्यशास्त्र, संशोधकांना मदत, दुष्काळ निवारणासाठी मदत, शिष्यवृत्ती योजना, स्त्री शिक्षणासाठी राबवलेले प्रयोग, अस्पृश्यांसाठी केलेले कार्य, शेती, कृषी, उद्योग, व्यापार, चलनव्यवस्था, औद्योगिक धोरण या सर्व घटकांवरती प्रभावीपणे बुद्धीवादी दृष्टिकोनातून विकासात्मक कार्य महाराजा सयाजीराव गायकवाड यांनी केले. त्यामुळेच आधुनिक महाराष्ट्राचे शिल्पकार अशी त्यांना दिलेली उपाधी ही अत्यंत सार्थ आणि समर्पक वाटते.

मानवतावादी दृष्टिकोनातून जागतिक धर्मपरिषदमध्ये मांडलेले विचार, सहकार चळवळ, सामाजिक सुधारणा व कायदे पद्धत, मोफत व सक्तीचे प्राथमिक शिक्षण, स्वतंत्र वाचनालयाची निर्मिती, क्रांतीकारकांना उत्स्फूर्त मदत यासारखी विविध कार्य महाराजा सयाजीराव गायकवाड यांनी केल्यामुळे भारताच्या विकासाचे ते पहिले कृतीयुक्त शिल्पकार ठरले. कर्तुत्वान महापुरुषांच्या राष्ट्रउभारणीच्या कार्यात महाराजा सयाजीराव गायकवाड यांचा प्रत्यक्ष सहभाग दिसून येतो.

महाराजा सयाजीराव गायकवाड यांच्या कार्य आणि कर्तुत्वावर प्रकाश टाकण्याच्या हेतूनेच प्रस्तुत शोधनिबंधामध्ये महाराजासयाजीराव गायकवाड यांचे कृषी, जलसिंचन, सहकार या संदर्भातील विचार व कार्य स्पष्ट करण्याचा प्रयत्न केलेला आहे.

संशोधनाचे उद्देश :

१. महाराजा सयाजीराव गायकवाड यांचे सामाजिक कार्य अभ्यासणे.
२. महाराजा सयाजीराव गायकवाड यांचे विविध क्षेत्रातील योगदान स्पष्ट करणे.
३. महाराजा सयाजीराव गायकवाड यांनी कृषीक्षेत्रासंबंधात केलेल्या विकासात्मक प्रयत्नांचा अभ्यास करणे.
४. महाराजा सयाजीराव गायकवाड यांचे शेती विकासातील धोरण स्पष्ट करणे.
५. पारंपारिक शेती व आधुनिकता या संदर्भात महाराजा सयाजीराव गायकवाड यांचे विचार स्पष्ट करणे.
६. औद्योगिक व सहकार क्षेत्रातील महाराजा सयाजीराव गायकवाड यांची भूमिका स्पष्ट करणे.

अशा विविध उद्देशाने महाराजा सयाजीराव गायकवाड यांचे कृषी, जलसिंचन, सहकार या संदर्भातील विचार व कार्य या विषयाला अनुसरून शोधनिबंधाची रचना केलेली आहे.

विषयविवेचन:

महाराष्ट्राच्या इतिहासाच्या संदर्भात साधारणता: एकोणिसाव्या शतकात वैचारिक दृष्टिकोनातून सामाजिक, आर्थिक, राजकीय, धार्मिक अशा विविध क्षेत्रांमध्ये वैचारिक प्रगती घडून आणण्याचे काम तत्कालीन कालखंडात निर्माण झालेल्या शिक्षण पद्धती सामाजिक सुधारकांनी केलेल्या विविध चळवळी यामुळे महाराष्ट्राचा वैचारिक पाया भक्कम झाला. या सर्व विचारधारेमध्ये समाज सुधारकांची योगदान अत्यंत प्रभावीपणे समाजाला दिशादर्शक ठरले.

महाराजा सयाजीराव गायकवाड यांचे प्रत्यक्ष कर्तृत्व, विकासात्मक नेतृत्व आणि बडोदा संस्थांमध्ये राबवलेले विविध

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विकासात्मक प्रयोग भारतीय विकास प्रणालीमध्ये नाविन्यपूर्ण बदल करणारे ठरले असे दिसून येते. त्यामुळेच बुद्धिवंत विचारवंत सर्व समावेशक धोरण राबवणारे महाराष्ट्रातील महान महाराष्ट्राचे शिल्पकार या शब्दात महाराजा सयाजीराव गायकवाड यांचा उल्लेख केला जातो. महाराजा सयाजीराव यांचा जन्म नाशिक जिल्ह्यातील कवळाने येथे ११ मार्च १८६३ रोजी झाला. त्यांच्या आईचे नाव उमाबाई होते. वडिलांचे नाव काशीराव तर त्यांचे मूळ नाव गोपाळराव गायकवाड असे होते.

२०मे १८७५ रोजी महाराजा सयाजीराव गायकवाड दत्तक विधान समारंभ झाला. केशवराव पंडित, व्यंकटराव जोशी, न्यायाधीश मी.बर्डवूड, मिस्टर एफ. ए. एच. एलियट तरुण आयसीएस अधिकारी यांनी महाराजा सयाजीराव यांचे शिक्षक म्हणून काम पाहिले.[१] त्यांच्या जीवन कार्यावर सर्वाधिक प्रभाव एलियट यांचा पडला. महाराजांच्या अंगी उद्योगप्रियता जोडणी, विषय, आत्मसयमन व नियमाधीनता हे प्रभावी स्वरूपाचे गुण दिसून येतात. त्यांनीच सयाजीराव यांच्या सर्वांगीण विकासाचे ध्येय ठेवले होते. प्रशासनातील दूरदृष्टी विकसित करण्यामध्ये एलियट यांचा मोठा सहभाग होता. त्यांनीच स्वाभिमान व राष्ट्रप्रेमाची ज्योत महाराजा सयाजीराव गायकवाड यांच्या मनात निर्माण केली.[२]

दिवाण सर टी. माधवराव यांनी महाराजा सयाजीरावांना राज्यकारभाराचे शिक्षण दिले. २८ डिसेंबर १८८१ रोजी गादीवर आल्याबरोबर सयाजी रावांनी राज्याची आर्थिक स्थिती सुधारण्यासाठी उपाययोजना केल्या. प्रशासकीय जबाबदारीची विभागणी हे तत्त्व राज्यकारभारात लागू करून राज्ययंत्रणेत त्यांनी सुरळीतपणा निर्माण केला.साधारणपणे सल्लागार नियुक्ती, कल्याणकारी योजना (१८८३),. न्यायव्यवस्थेत सुधारणा, ग्रामपंचायतींचे पुनरुज्जीवन (१९०४); सक्तीच्या प्राथमिक शिक्षणाची योजना (१८९३)असे धोरण राबवून अल्पावधीतच ती सर्व राज्यभर लागू केली. संपूर्ण देशामध्ये मोफत आणि सक्तीचे शिक्षण लागू करणारे बडोदा संस्थान हे देशातील पहिले राज्य ठरले (१९०६). गरीब, गरजू विद्यार्थ्यांना शिष्यवृत्त्या देऊन उच्च शिक्षणाची सोय केली. औद्योगिक कलाशिक्षणाकरिता कलाभुवनफही संस्था स्थापन केली. त्यांनी प्राच्य विद्यामंदिरफ या संस्थेच्या वतीने प्राचीन संस्कृत ग्रंथांचे संशोधन व प्रकाशन करण्यास उत्तेजन दिले.[३]

सामाजिक क्षेत्रात सयाजीराव गायकवाडांनी केलेली कामगिरीही त्यांच्या सामाजिक सुधारणेची साक्ष देणारी आहे. पडदापद्धती बंदी, बालविवाह बंदी, कन्याविक्रयबंदी, मिश्रविवाहाचा पुरस्कार, स्त्रियांना वारसा हक्क मिळवून देणे, अस्पृश्यतानिवारण, विधवाविवाह इ. सुधारणा प्रत्यक्ष अंमलात आणल्या. घटस्फोटासंबंधीचा कायदा हा सर्व भारतात पहिल्यांदाच त्यांनी जारी केला. हरिजनांसाठी अठरा शाळा (१८८२). डॉ. बाबासाहेब आंबेडकर यांना शिक्षणासाठी शिष्यवृत्ती दिली आणि त्यांची संस्थानात उच्च पदावर नेमणूकही केली. सुधारणांच्या प्रत्यक्ष पुरस्कारामुळे त्यांना 'राष्ट्रीय सामाजिक परिषदे'च्या अध्यक्षपदाचा मान मिळाला (१९०४)[४] राज्यकारभार हाती घेतल्यानंतर सामाजिक भावनेतूनच शिक्षण विषयक हुजूरहुकूम, अर्थविषयक हुजूरहुकूम, नोकर सेवकविषयक हुजूरहुकूम, न्यायदान व्यवस्थेसंदर्भात हुजूरहुकूम, स्थानिक स्वराज्याची स्थापना हुजूरहुकूम, सामाजिक- सांस्कृतिक क्षेत्रात संबंधात असे विविध हुजूरहुकूम काढून त्यांनी प्रगतशील राज्य यंत्रणेचे निदर्शन केले. त्यामुळेच शेती, शिक्षण, प्रशासन, समाज, न्यायदान, नोकरवर्ग या क्षेत्राच्या दशेसाठी त्यांची हुकूम समकाळातही दिशादर्शक आहेत.[५]

महाराजा सयाजीराव गायकवाड यांनी परदेशातील शेती व भारतीय शेती यांचा तुलनात्मक अभ्यास करून आपल्या शेती सुधारणेविषयी त्यांनी महत्त्वाचे निष्कर्ष नोंदवले. विशेषता: दुष्काळ, नापीकपणा व निसर्गाचा लहरीपणा यामुळे शेतकऱ्यांचे प्रचंड नुकसान होत आहे. शेतकरी कंगाल झाला आहे. सरकारी मदत तुटपुंज स्वरूपात मिळत असल्याने ग्रामीण अर्थव्यवस्था शेतकऱ्यांच्या बरोबर दुबळी बनत चाललेली आहे. असा विचार मांडून शेतीच्या उत्पन्नाबरोबर शेतकरी वर्ग याचाही कशा पद्धतीने विकास होईल ही भूमिका त्यांनी घेतली.[६]

महाराजा सयाजीराव गायकवाड यांनी भाषणाच्या माध्यमातून समाज प्रबोधनाबरोबरच त्यांनी मानवतेच्या कल्याणाच्या हिताच्या दृष्टीने शेतकरी वर्गासाठी व शेतीशी निगडित शेतकरी लोकांसाठी विविध योजना आखल्या. आधुनिक शेती व पारंपारिक शेती यांची तुलना करून कृषी क्षेत्रामध्ये बदल करण्याचा प्रयत्न त्यांनी केला. सुरुवातीला राज्यकारभार हाती घेतल्यानंतर शेतसारा पद्धत त्यांनी पूर्णपणे बदलली. श्रीमंत लोकांना असणारे वसुलीचे अधिकार काढून घेतले. नवीन शेतसारा ठरवण्यासाठी तज्ञ व्यक्तींची नियुक्ती करून शेतसारा ठरविला. शेतसारा ठरवताना सुरुवातीला शेतातील सुरुवातीचे उत्पन्न पहावे, त्याचा अंदाज घ्यावा त्यानंतर जमिनीच्या उत्पादनातून शेतकऱ्यांची मजुरी, येणारा खर्च याचा अंदाज घेऊनच शेतसारा ठरविला. शेतकऱ्यांचे नुकसान होणार नाही याची काळजी त्यांनी घेतली. शेती संदर्भात त्यांनी सलग जमीन होण्यासाठी जमीन एकत्रीकरण्याचा कायदा, जनावरांमुळे शेतीचे नुकसान होणार नाही यासाठी कायदा, जमिनीचे तुकडे न पाडण्याचा कायदा या पद्धतीचे कायदे त्यांनी घडवून आणले.

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शेतकऱ्यांना आर्थिक सहाय्य करण्यासाठी सन १९९० मध्ये स्वतंत्र शेती खाते निर्माण केले. पाणीपुरवठ्याच्या सुविधा उपलब्ध करून देण्यासाठी स्वतंत्र विहिरींची रचना केली. दुष्काळ निवारण, शेतकरी वर्गास सहाय्य करण्यासाठी शेतकरी पतपेढ्यांची निर्मिती केली. शेतकऱ्यांना बी बियाण्यांच्या सुविधा, नवनवीन शेतीमधील प्रयोग, प्रदर्शने, विविध भाषणांच्या माध्यमातून शेतकरी सुधारणेविषयी विचार मांडून शेतकऱ्यांना स्वावलंबी बनवण्याचे महान कार्य त्यांनी केले.

शेती संदर्भात नवीन ज्ञान घेण्यासाठी सन १८९० मध्ये त्यांनी खासेराव जाधव यांना विलायतीस पाठवले. तिथून ज्ञान संपादन करून आल्यानंतर त्यांनी शेती, शेतीपूरक उद्योग, दुष्काळावर मात शेतीसाठी सिंचन अशा विविध विषयावर शेतकऱ्यांची स्थिती सुधारण्यासाठी नमुना सादर केला. त्यातूनच शेतकऱ्यांच्या सामाजिक ,नैतिक, आर्थिक परिस्थितीत सुधारणा घडवून आणणे शक्य आहे हे पटवून सांगितले.

०१ जानेवारी १९३६ च्या भाषणात महाराज म्हणतात, 'कर्ज देणे, तगावी देणे, जमिनीचे बारीक तुकडे होण्याचे थांबवणे, सरकारी पतपेढ्या काढणे' या अशा मार्गाने आम्ही शेतकऱ्याला कर्ज बंधनातून तसेच दुष्काळ आणि पीक नासाडी यांच्यापासून मुक्त करायला सुरुवात केली.[७] शेतीसाठी सिंचन सुविधा याच प्रयत्नातून सन १८८६ ते १९३० या काळात बारा हजारहुन अधिक विहिरी खोदल्या, शेतकऱ्यांना इंजिन, कृषी पंप, ट्रॅक्टर अशी यंत्रे साधने उपलब्ध करून दिली. जल व्यवस्थापनाचे ज्ञान कौशल्य निर्माण व्हावे यासाठी उद्बोधन कार्यक्रम हाती घेतले. शेतकऱ्यांना सहकारी पतपेढीच्या माध्यमातून सहकार्याने कर्ज मिळवून दिली जवळजवळ २३६ पतपेढ्या त्यांच्या कालखंडामध्ये अस्तित्वात होत्या.

०४ मार्च १९३८ मध्ये नवसारी येथील भाषणात महाराजा सयाजीराव गायकवाड विचार मांडताना म्हणतात की, 'भारत देशाची आर्थिक स्थिती सुधारण्यासाठी शेत आणि उद्योगधंदे यांच्यात समतोल साधला गेला पाहिजे'[७] पाणी आडवा पाणी जिरवा ही संकल्पना त्यांनी आपल्या संस्थानांमध्ये सुरुवातीला राबवली.

शेतीला पूरक व्यवसाय म्हणून उद्योगांची निर्मिती करण्याचा प्रयत्न त्यांनी घडवून आणला. राज्यात उद्योगधंदे असल्याशिवाय शेतकऱ्यांची प्रगती होणे कठीण आहे हे त्यांनी जाणले व त्यातूनच प्रथम सन१९८१ मध्ये बडोदा येथे सुत गिरणी, साखर कारखाना निर्माण केला. नैसर्गिक साधनांचा योग्य उपयोग करून उद्योगधंद्याची वाढ कशी करता येईल याचे चित्र त्यांनी आपल्या भाषणातून मांडले. कृषी आणि उद्योग यांच्यातील समतोल कशा पद्धतीने राखला जाईल याची भूमिका त्यांनी हाती घेतली. लघुउद्योग व जड उद्योग यांची साखळी त्यांनी निर्माण केली. त्यातूनच बाजारात मागणी असणाऱ्या विविध वस्तू तयार करणे. लाकडावरील काम. विणकाम. प्रायोगिक पद्धतीचा योग्य वापर, तांत्रिक व व्यावसायिक शिक्षणातून उद्योगधंद्यांचा विकास, लहान उद्योगांना चालना, रोजगाराच्या संधी हे तत्व अवलंबून सहकारी चळवळीचा पाया जर्मनी, हॉलंड, डेनमार्क यांचा आदर्श घेऊन त्यांनी घातला.[८]

जल नियोजनाच्या संदर्भात महाराजा सयाजीराव गायकवाड यांनी मोठी कामगिरी केली. राज्यकारभार हाती आल्यानंतर सुरुवातीला तहानलेला प्रजेला पाणी उपलब्ध करून देण्यासाठी गावोगाव विहिरी खोदण्याचे आदेश त्यांनी दिले. दुष्काळ पडेल त्यावेळी विहिरी आणि तलाव खोदण्याची कामे त्यांनी करून पिण्याच्या आणि शेतीच्या पाण्याचे स्त्रोत वाढवण्याचा प्रयत्न केला. त्यांच्या जल नियोजनाच्या कार्यामुळेच इसवी सन १९३९ साली बडोदा राज्यात शेतीच्या आणि पिण्याच्या पाणीपुरवठ्याच्या जवळ जवळ ७११९५ इतक्या पक्क्या विहिरी बांधण्यात आल्या. तर १०१९५ तलाव निर्माण करण्यात आले. यामध्ये कच्च्या विहिरींची संख्या १७०१८ इतकी होती.[९] यावरून त्यांचे जल नियोजनाच्या संदर्भातील कार्य सहजपणे लक्षात येते. हे महाराजांच्या जलनीतीचे यश मानावे लागेल. त्यांचे हे जल नियोजनाचे तत्व आजच्या काळातही तितकेच प्रभावीपणे दिसून येते. संस्थानात सहकार चळवळीचा प्रसार करणे, सहकारासंदर्भात विषयांच्या अभ्यासाला उत्तेजन देणे, सहकार परिषदा, प्रशिक्षण वर्ग यांचे आयोजन करणे अशी कामे मध्यवर्ती सहकारी प्रशिक्षण या संस्थेला ठरवून दिली. सन १९२६ मध्ये 'श्री सयाजी सहकार सेवा संघ' असे करण्यात आले. पुढे महाराजांच्या आदेशावरूनच तीन जिल्हास्तरीय सहकार प्रशिक्षण वर्गाचे आयोजन केले गेले यातून सहकार चळवळीचे महत्त्व गावोगावच्या लोकांना देण्यात आले.

थोडक्यात खऱ्या अर्थाने महाराष्ट्राच्या जडणघडणीत कृषी, उद्योग, व्यापार, सहकार, सांस्कृतिक, आर्थिक, धार्मिक अशा विविध क्षेत्रामुळेच महाराजा सयाजीराव गायकवाड यांचे कार्य हे मार्मिकपणे समाजासमोर दिसून येते. त्यांच्यामुळेच खऱ्या अर्थाने महाराष्ट्राचा विकास तत्कालीन कालखंडात झाला असे म्हटले तरी वावगे ठरणार नाही. स्वातंत्र्योत्तरकाळात हा विकास अधिकच गतीने वाढत गेला याचे सर्व श्रेय हे महाराजा सयाजीराव गायकवाड यांना दिले जाते.

निष्कर्ष :

१. आधुनिक महाराष्ट्राची जडणघडण घडवून आणण्यामध्ये त्यांचे मोठे योगदान सयाजीराव गायकवाड यांचे आहे.

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२. सयाजीराव गायकवाड यांचे सामाजिक समतावादी विचार समाजविकासासाठी प्रभावी ठरले.

३. सामाजिक, आर्थिक, राजकीय, सहकार, सांस्कृतिक, धार्मिक सर्वच क्षेत्रांमध्ये अत्यंत प्रेरणादायी आणि प्रभावी ठरले.

४. महाराजा सयाजीराव गायकवाड यांचे सामाजिक सुधारणातील योगदान तितकेच प्रभावीपणे होते.

५. जल नियोजनाचे तत्व आजच्या काळातही तितकेच प्रभावीपणे दिसून येते.

६. महाराष्ट्राच्या जडणघडणीत कृषी, उद्योग, व्यापार, सहकार, सांस्कृतिक, आर्थिक, धार्मिक अशा विविध क्षेत्रामुळेच महाराजा सयाजीराव गायकवाड यांचे कार्य हे मार्मिकपणे समाजासमोर दिसून येते.

७. कृषी आणि उद्योग यांच्यातील समतोल कशा पद्धतीने राखला जाईल याची भूमिका त्यांनी हाती घेतली.

८. महाराजा सयाजीराव गायकवाड यांनी परदेशातील शेती व भारतीय शेती यांचा तुलनात्मक अभ्यास करून आपल्या शेती सुधारणेविषयी त्यांनी महत्त्वाचे निष्कर्ष नोंदवले.

संदर्भ :

१. पवार एकनाथ, महाराष्ट्राचे शिल्पकार महाराजा सयाजीराव गायकवाड, महाराष्ट्र राज्य साहित्य आणि संस्कृती मंडळ, मुंबई प्रथम आवृत्ती.२०१८,पृ.क्र.२१-२३.

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Modern Trends in Tourism and Hospitality Sector

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Abstract:

The present research paper intends to focus on "*Modern Trends in Tourism and Hospitality Sector*". It has huge significance in the present time. It is compiled from the thoughts as well as ideas of some of the leading professionals from college circles as well as business. It also studies linked to the tourism as well as hospitality business in the modern globe, where globalization, digitalization, synthetic aptitude, etc. have changed the industry extremely in the last two decades especially during and after the covid-19 epidemic. The research scholar is specialist in the ground and has wide-ranging experience working with tourism and hospitality businesses and academe around the earth. Their understanding of tourism and hospitality ensures that the end result is a book that clearly explains the theoretical and practical concepts which impact the day-to-day activities of the businesses. Simultaneously show the array of implications that may be beneficial for all the stakeholders of the industry viz. society, government, entrepreneurs, etc. this research work has a worldwide move toward, which is essentially important in this epoch of globalization.

The tourism as well as hospitality businesses have become internationalized, where familial companies are penetrating into global markets and vice versa, and the international chain hotels, and travel companies are making a presence in the home market as well. As a result, it is fundamental for academia to add information of the latest dimensions in the field of travel and hospitality business.

Keywords: Hospitality, Tourism, trade and industry growth.

Introduction:

In the present time, certainly, the Hospitality and Tourism Industry, has been an alarming pillar as an unfailing and dependable source of profits and capital for many nations. Many countries have been elevated from poor to appreciable economic statuses as a result of the invaluable contributions their tourism sectors have succeeded in adding to their overall economic growth. Tourism is a major contributor to the Indian economy. The tourism industry in India has a share of 0.52% of world tourism and the receipts as 0.89% of the world receipts. There have been significant improvements in the spheres of increasing air seat capacity, trains and railway connectivity to important tourist destinations, as well as connecting roads. Accommodation facilities have been redefined for the convenience of the visitors. With the industry in perspective, there is quite a vast array of key players such as businesses, modern technology and hotel marketing trends etc., that are set to take root and impact the industry as a whole in 2017 and the years to come.

It aims as well as seeks to recognize and scrutinize the paradigm shifts in the tourism industry over the seeming years and how the trends have behaved in India. It seeks to observe the current trends in the hospitality and tourism

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business, bring to light the challenges faced by the hospitality and tourism industry and finally seriously analyze the future prospects of the hospitality and tourism industry in India.

It also employed secondary data from the Indian Tourism Corporation to ascertain its findings and conclusions. On the other hand, it is revealed that internationally hospitality as well as tourism activities are increasing by leaps and bounds hence a proportionate increase in expenditure both for tourists and service providers.

Aims and objectives :

The present research work deals with following aims and objectives:

- To observe the present trends in the hospitality as well as tourism industry.
- To carry to light the challenges faced by the hospitality as well as tourism business.
- To importantly examine the future prospects of the hospitality and tourism business.

Research Methodology :

The present research work deals with following research methodology:

For the present research work, Data is collected for this research using secondary sources. Methodical studies are conducted on existing literature by reviewing textbooks, related literature, articles, journals and online resources and the seaming trends were identified to predict the future prospects of the industry.

Modern Trends in Tourism and Hospitality Sector :

1. **Foreign Tourist Arrivals:** The Ministry of Tourism supports the initiative regarding the implementation of Tourist Visa on Arrival enabled with Electronic Travel Authorization (ETA) (renamed as e-Tourist Visa) powerfully and committed all support to Ministry of Home Affairs and Ministry of External Affairs and Ministry of Civil Aviation for implementing the programme. The year 2015 witnessed a growth of 4.5 % in Foreign Tourist Arrivals (FTAs) in India; this growth is equivalent to the medium growth rate of 4.5 % witnessed in International Tourist Arrivals, globally. FTAs during 2015 were 80.27 Lakh as compared to the FTAs of 76.79 Lakh during 2014. The Foreign Exchange Earnings (FEEs) from tourism in rupee terms during 2015 were Rs.1, 35,193 crore with a growth of 9.6 %. The Government of India launched the e-Tourist Visa on 27.11.2014. During January- December, 2015 a total of 4, 45,300 tourists arrived on e-Tourist Visa.

   The revision of Visa fee has been done on the principle of reciprocity. Bank charges have also been reduced from US$ 2 to 2.5 % of the e-TV fee. There is no bank charge for zero visa fees.

2. **Developing State-of-the-Art Technology:** it is considered the fuelling power that offers good prospects for efficiency, effectiveness and consolidation for better guests' services. Technology has become a tourism activity in development of strategic resources and is considered as a tool to increase competitiveness. Kapiki, tourism professor at ATEL, expresses that effective use of Information Technology can make significant operational improvements. Advanced software and communication tools allow enlarging operational efficiency, for example orders may be made better, faster and cheaper. Moreover, making decisions have been quicker as well as easier through state-of the-art technology by the use of decision support tools. Thanks to expert systems, sophisticated expertise can be met by any manager. Innovative technology has

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succeeded in changing the tourism business landscape by making information readily available for accessibility wherever and at any time, more tailor-made services are now been provided with marketing opportunities increasing by leaps and bounds.

3. **Niche Tourism:** The Ministry of Tourism has taken the initiative to identify and promote niche products in the country. This is done in order to attract tourists with specific interest, and to ensure repeat visits for the unique products in which India has a comparative advantage. The Ministry of Tourism has constituted Committees for the promotion of Golf Tourism and Medical and Wellness Tourism. The following Niche Products have been identified by the ministry of tourism development and promotion: Cruise, Adventure, Medical, Wellness, Golf, Polo, Meetings Incentives Conferences and Exhibitions (MICE), Eco-tourism, Film Tourism, and Sustainable Tourism. During the year 2015-16 (up to 31st December 2015) the Ministry of Tourism released an amount of Rs. 64.59 lakh to IIS and M for activities related to Adventure Tourism. Also, during the year 2015-16 (till December 2015), the Ministry of Tourism under MDA scheme provided a financial assistance of Rs. 84.84 lakh/- to the Medical Tourism Service Providers.
4. **Globalization:** Nowadays, people more than ever travel freely around the world. The international tourist arrivals from 674 million in 2000, reached the 797 in 2005 (increased by 18.25%) and the 940 million in 2010 (increase 39.46% in relation to 2000 and increase 17.94 in relation to 2005). Respectively, the international tourism receipts (global tourism expenditure) from 475 billion US dollars in 2000, reached the 679 billion in 2005 (increased by 42.94%) and the 918 billion in 2010 (increased by 93.26% in relation to 2000).
5. **Safety as well as Security:** The industry's concern with security has increased greatly due to several terrorist attacks worldwide, as well as because of tourists' kidnappings, robberies and assaults. Security of all types of hospitality and tourism operations is critical and disaster plans should be made for each kind of threat. Individual safety of guests must be the first priority. Increased security measures exist in all the international airports and most airline companies have upgraded their security measures by investing millions of dollars. Moreover, they make plans in order to exceed the requirements of the airline industry through technology advancements.
6. **Diversity:** The tourism as well as hospitality business is among the most diverse of all industries in terms of employee population and groups of guests. Hospitality and tourism present a unique opportunity to understand innovative cultural experiences for both employees and the tourists. It is important for the personnel to understand and appreciate different cultures in order to enhance the nature of their interactions with tourists of different cultures, religions, races, colours, ages, genders and sexual orientations. It is for this reason that businesses plying their trade in this industry must Endeavour to train their personnel to appreciate and accommodate people from diverse backgrounds around the world. As such, diversity not only facilitates easy understanding of different cultural, social and economic perspectives but enhances the delivery of satisfactory services as well, through communication and observation.

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7. **Service:** As global competition and market consumption change the expanding service sector, quality plays an increasingly essential role in both attracting and retaining service customers. Service quality and the degree of satisfaction derived from service quality are becoming the most important differentiating factors in almost every hospitality environment.

Major characteristics of Tourism and Hospitality Sector:

The characteristics of the hospitality industry are:

1. It is a truly exclusive as well as fun workplace and diverse in the scope of responsibilities that one can attain.
2. It is an industry with many career options and a source for a respectful income. Its outstanding dimension is the orientation towards guest satisfaction at ultimate level.
3. It offers intangible and perishable products (if for example 25 rooms are not sold on a specific night, their revenues will be lost forever).
4. The hospitality businesses make continuous efforts for maintaining a positive image along with great guest service. It appears that quality service is the basis to industry success.

Concluding Remark :

As a result, there is a worldwide amplify in tourism as well as hospitality both in tourist arrivals and tourism expenditure. The trends that are typically affecting the industry are: the increased concern with guests' safety and security; the enhanced diversity in the workforce composition; the importance of outstanding services leading to additional opportunities for increased revenue; the new technologies which contribute to improved guest services and enhance competitiveness; the population ageing that impacts directly on tourist demand and the tourism labour market; and the correlation between price and value which is very important for the perceptive guests of today.

In the field of tourism lodgings' development, the trend is an increasing number of hotels worldwide applying policies gracious to the environment. The green lodgings not only do save money for the owners but they save natural resources as well, attracting more and more guests who are environmentally sensitized.

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भूमिका :-

डबली बाबू नामक रेखाचित्र हिंदी के प्रसिद्ध साहित्यिक विनय मोहन शर्मा की एक मार्मिक कृति है। जिसमें डबली बाबू के कर्तव्यनिष्ठ, आत्मनिष्ठ, भोलेपन और मिलनसार प्रवृत्ति का बडा ही मार्मिक सुंदर, अप्रतिम चित्रण किया गया है। रेखाचित्र की चर्चा करने के पहिले लेखक विनय मोहन शर्मा के संक्षिप्त जीवन परिचय का आकलन करना आवश्यक है।

विनय मोहन शर्मा का साहित्यिक परिचय :-

"हिंदी साहित्य के विद्वान और प्रसिद्ध समालोचक विनय मोहन शर्मा का जन्म सन् 1905 में मध्य प्रदेश के कारकबेल नामक कस्बे में हुआ था। उनका वास्तविक नाम शुकदेवप्रसाद तिवारी था। उनकी शिक्षा बनारस हिन्दू यूनिवर्सिटी में हुई। साहित्य में इनकी रुचि छात्र जीवन से ही थी। उनकी कविताओं का संग्रह 'भूले गीत' सन् 1944 में प्रकाशित हुआ। वे निरन्तर साहित्य के विविध पक्षों पर लिखते रहे। वे शासकीय स्नातक कला विज्ञान महाविद्यालय, रामगढ़ तथा महाकोशल कॉलेज, जबलपुर में प्राचार्य पद पर कार्य करने के बाद कुरुक्षेत्र विश्वविद्यालय के हिन्दी विभाग में प्रोफेसर और अध्यक्ष नियुक्त हुए थे। सहृदय समीक्षक शर्मा जी के व्यक्तित्व में एक विवेकशील आलोचक : तथ्यान्वेषी शोधकर्ता और संवेदनशील रचनाकार तीनों का अद्भुत समन्वय है। उनके आलोचनात्मक निबन्ध उनके प्रौढ़ और विवेकपूर्ण निर्णय के साक्षी हैं। वे सच्चे अर्थों में एक सहृदय समीक्षक थे इसीलिए उनकी आलोचना नीरस नहीं होती थी। उनके कुछ निबन्ध आत्मव्यंजक भी हैं, जिसमें उन्होंने मुक्त हृदय से अपनी भावनाओं को भी व्यक्त किया है। उनमें वस्तुओं और दृश्यों को अंकित करने की क्षमता है इसलिए उनके वर्णन सजीव चलचित्र से प्रतीत होते हैं। उनका अध्ययन व्यापक है इसीलिए उन्होंने तुलनात्मक विषयों का अच्छा विवेचन किया है। भाषा शैली: विनय मोहन शर्मा जी की भाषा सशक्त, प्रौढ़ और परिमार्जित है। सामान्यत: वे तत्सम भाषा का ही प्रयोग करते हैं किन्तु विषय के अनुसार उसका रूप परिवर्तन करने में उन्हें संकोच नहीं होता है। भाषा के शुद्ध प्रयोग पर वे बराबर ध्यान देते आए हैं।"[1]

विनय मोहन शर्मा की अनेक पुस्तकें अब तक प्रकाशित हो चुकी हैं, जिनमें से मुख्य निम्न हैं :-

'भूले गीत' (1944) (कविता संग्रह), 'कवि प्रसाद': 'आँसू तथा अन्य कृतियाँ' (1945), 'हिन्दी गीत गोविन्द' (1955 ई.), (अनुवाद)'दृष्टिकोण' (1950 ई.), 'साहित्यावलोकन' (1952 ई.)', हिन्दी को

* प्रोफेसर व अध्यक्ष हिंदी विभाग, भारतीय जैन संघटना का कला, विज्ञान व वाणिज्य महाविद्यालय, वाघोली, पुणे

मराठी संतों की देन' (1957 ई.), 'साहित्य, शोध, समीक्षा' (1958 ई.), 'साहित्य कला' (1980), 'रेखा और रंग' (1955 ई.), 'हिन्दी के व्यावहारिक रूप' (1968 ई.), 'साहित्यांवेषण' (1969 ई.), 'साहित्य-नया और पुराना' (1972 ई.), 'भाषा, साहित्य, समीक्षा' (1972 ई.)।

'हिन्दी को मराठी-संतों का योगदान' उनका शोध-ग्रंथ तथा शेष पुस्तकें निबन्धों के संकलन हैं। इन निबन्धों में कतिपय अनुसन्धानपरक हैं एवं कुछ में स्वतंत्र समीक्षात्मक प्रयास हैं। कुछ निबन्ध या समीक्षाएँ या तो छात्रोपयोगी हैं या फिर परिचयात्मक टिप्पणियाँ मात्र। उनकी पुस्तकों में संस्मरण भी मिले जाते हैं तथा 'कवि प्रसाद: आँसू तथा अन्य कृतियाँ' में उन्होंने आँसू के कुछ दुरूह स्थलों की टीका भी की है। अपने शोध-ग्रंथ एवं कुछ निबन्धों में उन्होंने अंतरप्रांतीय साहित्यों (हिन्दी और मराठी) के तुलनात्मक अध्ययन को उपस्थित करने का महत्त्वपूर्ण कार्य किया है।

साहित्यिक विशेषताएँ :-

विनयमोहन शर्मा की आलोचनाओं का मूल स्वर वस्तुत: 'अकादमिक' है। वे मुख्यत: अध्यापक रहे हैं और अध्यापक का स्वर उनमें सर्वत्र प्रमुख है। भरसक उन्होंने चेष्टा की है कि किसी भी 'वादी' दृष्टि में न बँधकर तटस्थ एवं वैज्ञानिक समीक्षाएँ लिखी जाएँ। अपने दृष्टिकोण को 'साहित्यावलोकन' के 'दृष्टिक्षेप' में उपस्थित करते हुए उन्होंने लिखा है, "एक बात का यत्न मैंने अवश्य किया है कि साहित्य के अवलोकन में अपनी दृष्टि को वादग्रस्त होने से बचाया है। अनुभूति के सहज प्रकाश को साहित्य की कसौटी मान कर उसका रसास्वादन मेरा ध्येय रहा है।" पर इस रसवादी दृष्टिकोण में भी एक बात व्याख्या-सापेक्ष है और वह है 'अनुभूति का प्रकाश'। विनयमोहन ने इसके लिए बहुधा आचार्य रामचन्द्र शुक्ल द्वारा प्रवर्तित शास्त्रीय दृष्टिकोण को अपनाया है पर शुक्लजी के पूर्वाग्रहों से उन्होंने अपने को बचाकर 'संतसाहित्य' या 'छायावाद' को अपनी सहृदयता दी है। आधुनिक काल के दो प्रभावशाली मतवादों 'फ्रायडवाद' और 'मार्क्सवाद' को उन्होंने एकांगी माना है। फ्रायड का तो उन्होंने बहुत विरोध किया है और मनोविश्लेषण-शास्त्र के आधार पर रचित साहित्य को सामाजिक स्वास्थ्य के लिए वे अनुचित मानते हैं। प्रगतिवादी साहित्य के बारे में उनकी धारणा है कि उसमें "प्रेरणा नहीं प्रयास" होता है, इसी से उसके 'स्थायित्व में सन्देह है' उन्हें। उनकी समीक्षा-दृष्टि के मूल में "नैतिक आचार" और "समाज-स्वास्थ्य" की धारणा भी बराबर बनी रहती है। यह अवश्य है कि भौतिक प्रतिमानों को वे शाश्वत नहीं मानते पर उनकी परिवर्तमान सत्ता पर शर्माजी का विश्वास है। आदर्शवाद और यथार्थवाद के समांवय पर भी उन्होंने बल दिया है। शर्माजी की भाषा शैली में भी एक अध्यापक की सरलता एवं स्पष्टता है।[2]

आदर्श रेखाचित्र : डबली बाबू

डबली बाबू के चारित्रिक विशेषताओं का उल्लेख करनेवाला एक परिच्छेद दृष्टव्य है :- "विनयमोहन शर्मा द्वारा रचित 'डबली बाबू' एक मार्मिक रेखाचित्र है। इस रेखाचित्र में उन्होंने डबली बाबू की कर्तव्यनिष्ठा,

आत्मनिष्ठा, भोलेपन और मिलनसार प्रवृत्ति का बड़ा ही सुन्दर चित्रण प्रस्तुत किया है। उनका मानना है की मनुष्य केवल पढ़ने-लिखने तथा ऊँचा पद प्राप्त करने से ही बड़ा नहीं बनता। यदि कोई भी मनुष्य ईमानदार और कर्मनिष्ठ हो और सही ढंग से मानवता का पालन करे, तो साधारण से साधारण मनुष्य भी महान बन सकता है। डबली बाबू ऐसे ही उदार व्यक्ति थे जो अपनी व्यवहार कुशलता, कर्मनिष्ठा से किसी का भी दिल जीत लेते थे। इसीलिए लेखक को नहीं जानते हुए भी डबली बाबू लेखक की सहायता करते हैं और उनके प्रति बड़ी आत्मीयता का भाव रखते हैं। लेखक ने इस रेखाचित्र के माध्यम से यह समझाने का प्रयत्न किया है। यदि सभी मनुष्य मानवता के प्रति उचित व्यवहार तथा सचाई रखते हुए अपने काम के प्रति सजग रहते हैं तो वे भी एक आदर्श जीवन का उदहारण प्रस्तुत कर सकते हैं। यह रेखाचित्र अत्यन्त मार्मिक और हृदयस्पर्शी है।"[3]

डबली बाबू एक आदर्श चरित्र के रूप में हमारे सामने उपस्थित होते हैं। लेखक विनय मोहन शर्मा रेखाचित्र के आरंभ में ही उनकी सादगी, कार्यतत्परता, कार्य संलग्नता, रुची तथा निष्काम कर्मिता इन गुणों की ओर पाठकों का ध्यान आकृष्ट करते हैं। डबली बाबू ट्रस्ट के बगीचे में माली के रूप में कार्य करते हैं, वहाँ आनेवाले प्रत्येक व्यक्ति चाहे वह उनका परिचित हो या अपरिचित उनके आदर सत्कार का पात्र बनता है। आज तो वन-महोत्सव है, परिसर के बच्चों को डबली बाबू ट्रस्ट के बगीचे में आमंत्रित करते हैं, और उन्हें चंपा, गुलाब, चमेली इ. प्रकार के गमले देते हैं, जो उन बच्चों के बगीचे की शोभा बढाने के काम आते हैं।

आज वन महोत्सव के लिए डबली बाबू लेखक के बेटे रश्मिकांत को बुलाने अपने बेटे को भेज देते हैं। लेखक कई दिनों से डबली बाबू से मिलना चाहते ही थें, आज मोका देख अपने बेटे से कहते हैं तुम वन महोत्सव में जाओ लेकिन आते समय डबली बाबू को अपने साथ लेकर घर आना। लेखक कुछ समय तक अपने काम में व्यस्त रहे, उसी समय डबली बाबू बच्चों के साथ लेखक के दरवाजे पहुँच जाते हैं। उसका वर्णन करते हुए लेखक लिखते हैं :-

"कुछ समय बाद देखता हूँ, कनेर, गुलाब, रातरानी, चमेली, चम्पा और न जाने कौन-कौन से अनामा पौधे लिये स्वयं डबली बाबू बच्चों के आगे-आगे सारस-सी डगें धरते हुए बढ़े चले आ रहे हैं। मैंने देखा, उनका कद न ऊँचा, न ठिगना, मजे के मझोल आदमी हैं। न मोटे हैं, न पतले। आँखें भी मझोली ही हैं, कपोलों में धँसी हुई पीली-पीली सी दाँत विरल हैं। उनका कत्थई रंग पान और तम्बाकू के अतिरेक की शहादत दे रहा है। धोती बाबुआना ढंग की पहने हुए हैं, पर मैल खाने से बादामी रंग की हो गई है। पैरों में कोंकणी चप्पल हैं, जो काफी मोटी और मजबूत हैं। और हाँ, काले धारीदार कुरते के ऊपर बटनविहीन खाकी रंग का कोट भी पहने हुए हैं। दाहिने हाथ में एक छड़ी झुलाते हुए वे चले आ रहे हैं। डबली बाबू के कम्पाउन्ड में आने के पहले ही 'रश्मि' दौड़ता हुआ आया और कहने लगा, "यह देखो, डबली बाबू आ गए।" "नमस्कार डबली बाबू! आपने बड़ा कष्ट किया। किसी माली को भेज देते।" मैंने कहा। "नहीं, एक तो आपने बुलाया और दूसरे मैं भी बहुत दिनों से आपसे मिलनेवाला था, आपके कॉलेज के प्रोफेसर... जी से मेरा बड़ा घरोबा था।"[4]

उक्त वर्णन से डबली बाबू के चरित्र की विशेषताएँ सहज ही हमारे ध्यान में आ जाती है। डबली बाबू चाहते तो अपने किसी मालिक को लेखक के घर भेज सकते थे, मगर वे खुद आए। आते ही लेखक के बगीचे में कहाँ कौन-सा पेड़ लगाया जाए इसका जायजा लिया। बिना रुके बगीचे में पहुँचे और अपने हाथ की लाठी से पेड़ लगाने के स्थान निश्चित करके ही वापस चले गए। बिना किसी अतिरिक्त पैसे के डबली बाबू लेखक के बगीचे का खयाल रखते हैं। उसकी देख-भाल खुद करते हैं। ट्रस्ट के बगीचे में एक मामूली नोकर होते हुए भी उनकी यह धारणा कि यदि कोई भी मनुष्य ईमानदारी और कर्मनिष्ठ हो और सही ढंग से मानवता का पालन करें तो साधारण से साधारण मनुष्य भी महान बन सकता है। सचमुच उनकी यह सोच उनको एक महान व्यक्ति बना देती है।

डबली बाबू ने हमेशा अपने काम को श्रेष्ठ माना उसे प्रथम स्थान दिया, अपने काम के आगे वे अपने स्वास्थ तक को भूल जाया करते थे एक प्रसंग दृष्टव्य है-- दस दिन बाद डबली बाबू सबेरे ही आए। चेहरे से बहुत अधिक थकान झलक रही थी। बगीचे के पास बैठते ही घबराए से दिखाई दिए। उनके रोकने पर भी वमन हो ही गया। हम सब उनके निकट दौड़ गए। सिर पर पानी डाला। मुँह धोने के बाद उन्होंने कहा- "पित्त का जोर है, और कुछ नहीं, थोड़ा बुखार भी है और कुछ नहीं थर्मामीटर लगाकर देखा तो पारा 102 डिग्री के ऊपर रहा था।" पर उनसे कहा, "थोड़ी हरारत जरूर है। अब आप घर चले जाइए, आराम कीजिए। "डवली बाबू रिक्शे में चले गए।"[5]

उक्त उदाहरण से डबली बाबू की कर्तव्यनिष्ठा तथा मेहनत ही भगवान है यह धारणा सहज ही ध्यान में आती है। लेखक और उनके बगीचे के बारे में डबली बाबू के मन में कौन सी भावनाएँ थीं इसका उदाहरण प्रस्तुत करनेवाला एक प्रसंग दृष्टव्य है-"सोमवार का सबेरा था। पानी तेजी से बरस रहा था। सिर पर कमली डाले एक आदमी फाटक पर खड़ा आवाज दे रहा था। "क्या है, क्या चाहते हो?" मैंने उससे पूछा।

"मैं माली हूँ। डबली बाबू ने भेजा है?" "और डबली बाबू कहाँ है?"

"वो तो कल मर गए। तुमको नई मालूम?" मेरा सिर चकरा गया। मैंने कहा, "अरे कल तो सबेरे मेरी उनसे सड़क पर मुलाकात हुई थी। दफ्तर गए थे।"

"हाँ, दफ्तर तो गए थे, सब कागज-पत्तर ठीक करने बारह बजे एकाएक उन्होंने चाबी फेंक दी और कहा, 'हमारा काम पूरा हो गया। हम घर जाएँगे और ज्योंही उठकर चलने लगे, उनके पैर लड़खड़ा उठे। उसी समय उन्ने मुझसे कहा- 'देखो सम्पत! प्रोफेसर साब के घर जाकर बगीचे का काम ठीक कर देना, भूलना मत। फिर हम लोग उनको रिक्शे में बिठाकर डाक्टर के पास ले गए। डाक्टर ने नाड़ी देखते ही घर ले जाने को कहा। वहाँ थोड़ी देर में उनकी दम छूट गई।"[6] उक्त प्रसंग से डबली बाबू का अपने काम के प्रति जो दृष्टिकोन था उसके सही दर्शन पाठकों को हो जाते हैं।

निष्कर्ष :-

निष्कर्षत: कहा जा सकता है कि विनय मोहन शर्मा लिखित डबली बाबू एक आदर्श रेखाचित्र है। प्रस्तुत रेखाचित्र में लेखक ने एक सामान्य व्यक्ति के चरित्र में जो सामान्य गुण है उनके प्रति पाठकों का ध्यान आकृष्ट किया है। डबली बाबू एक ट्रस्ट के बगीचे में माली का काम करने वाला सामान्य व्यक्ति है, मगर वन महोत्सव में वे अपने परिसर में जितने बच्चे हैं उन्हें अपने ट्रस्ट के बगीचे में बुला कर बच्चों को कई प्रकार के पौधे दे देते हैं। केवल यही नहीं उन्हें उनके बगीचे में कैसे लगाया जाए, उसकी सुरक्षा का कैसे प्रबंध किया जाए इनकी जानकारी बिना किसी स्वार्थ के करते हैं। डबली बाबू कर्तव्यनिष्ठ, कार्य संलग्न, श्रमशील, धैर्यशील, निष्कामकर्मी, निरपेक्ष भाव से काम करने वाले एक आदर्श चरित्र के रूप में हमारे सामने उपस्थित हो जाते हैं।

संदर्भ :-

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2. विनय मोहन शर्मा का साहित्यिक परिचय विकिपीडिया गुगल से

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COMPLETE SPECIFICATION

(SEE SECTIONS 10 & RULE 13)

1. TITLE OF THE INVENTION

IMPLEMENTATION OF CONTEMPORARY INFORMATION EDUCATION TECHNOLOGY IN PHYSICAL EDUCATION TRAINING AND TEACHING

2. APPLICANTS (S)

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2. PREAMBLE TO THE DESCRIPTION

COMPLETE SPECIFICATION

The following specification particularly describes the invention and the manner in which it is to be performed

Implementation of Contemporary Information Education Technology in Physical Education Training and Teaching

ABSTRACT:

Because of the progression of time, the advancement of science and technique, as well as the rapid development and popularization of computer technology and network technology, contemporary information technology has entered all facets of human life, particularly in the application of education and teaching, which further reflects the teaching. This has led to an increase in the effectiveness of education and teaching. How can modern information technology education be used in physical education teaching? Since the modernization of means, the use of modern information technology for teaching, and the construction of a new teaching model are all favorable to improving the quality of teaching, this begs the question: how can modern information technology education be used? This article will talk about a few of them.

DESCRIPTIONS

The educational approaches and strategies that make use of contemporary information technology are engaging, cutting-edge, and varied. They have triumphed over the conventional approach to education used by teachers in the past through the use of demonstration and explanation. Its application is in keeping with the psychological qualities of children and youngsters, and it has the potential to make the situation as well as the experience better. capturing and holding the attention and interest of students, which can both drive students' enthusiasm for learning and excite students' enthusiasm for learning. Research in educational psychology demonstrates that the most important and active aspect in learning motivation is interest in comprehending, and that pupils are most motivated to study when they are in an intriguing condition. Almost anything that you learn can be rapidly and reliably mastered by you. The utilization of computer-related technology as a teaching aid has the potential to significantly expand both the capacity of the classroom as well as the amount of information that is transmitted within the classroom. In addition to this, it can assist educators in improving the effectiveness of autonomous teaching and enhancing the substance of students' educational experiences. It is possible for teachers to attend class. Show the students a variety of information, pictures, sounds, and words that are associated with the subject matter that they will be learning in this session, and provide them with a fresh kind of stimulation to pique their interest in learning. For instance, when describing the fundamentals of quick running, students should be encouraged to learn by observation. Students

are able to comprehend the correct running posture with the assistance of certain materials and pictures, as well as the physiological principles underlying the movement with the assistance of animation effects contained within the pertinent courseware. Furthermore, students are able to comprehend the optimal movement angle of the shoulder joint, elbow joint, and wrist joint while the swing arm process is in progress. Why is this swing angle considered to be the ideal swing angle, and what part did running technique play in determining this? If the students are able to consciously perceive and understand the movements of the instructor, rather than merely imitating them, then the students' capacity to feel their posture will increase, and their understanding of the full technical movement will improve in quality. In a nutshell, the primary responsibility of teachers of physical education is to facilitate the acquisition of significant athletic skills by pupils in order to strengthen their physical endurance. In addition, educators should make use of physical education in order to assist students in learning the knowledge system associated with physical education. Students are required to create a new movement by listening to and watching others perform the technical movement procedure. In addition, we might consider of it as the most important hint to the student's personal information regarding their school. them' motor abilities can be significantly improved by the application of contemporary information technology, which enables them to rapidly establish accurate visual pictures. According to the research conducted by psychologists, the information that individuals acquire through audiovisual means accounts for 94% of the entire amount of information, and 70% of that knowledge can be recalled after three days, which is significantly better than

other ways of communication. During the learning process, encouraging students to make use of their audio-visual capabilities can significantly boost the students' capacity for independent learning. This approach has the potential to expeditiously foster the children' intellectual growth. The application of contemporary information technology has a sizeable impact on the development of students' powers of observation, and it also plays an important part in the acceleration of the process of acquiring accurate perceptual knowledge. There are a lot of complicated organizational structures for sports technologies that are included in the curriculum for physical education. In addition, in order for pupils to be recognized qualified in physical education, they need to finish the sequence of instructional activities within the allotted amount of time. As an illustration, there is the air movement that occurs during the track and field jumping project, the continuous movement that occurs during the gymnastics support jump, and the rollover that occurs throughout the skill. And there are still some peculiar occurrences. For instance, the kids have a hard time mastering the last order of power for the throwing project. The jump project, the body of the long jump, and other aspects of the project are also challenging. On the one hand, the movement of the teacher's demonstration is restricted by many circumstances, and the degree of randomness is frequently high. These elements include the teacher's age, physical condition, psychological considerations, and other such things. On the other hand, the observation angle and timing provided by the students is of a very vast scale. Students have a hard time accurately observing the activities of the teacher during a demonstration since the activity happens so quickly and the difficulty level is

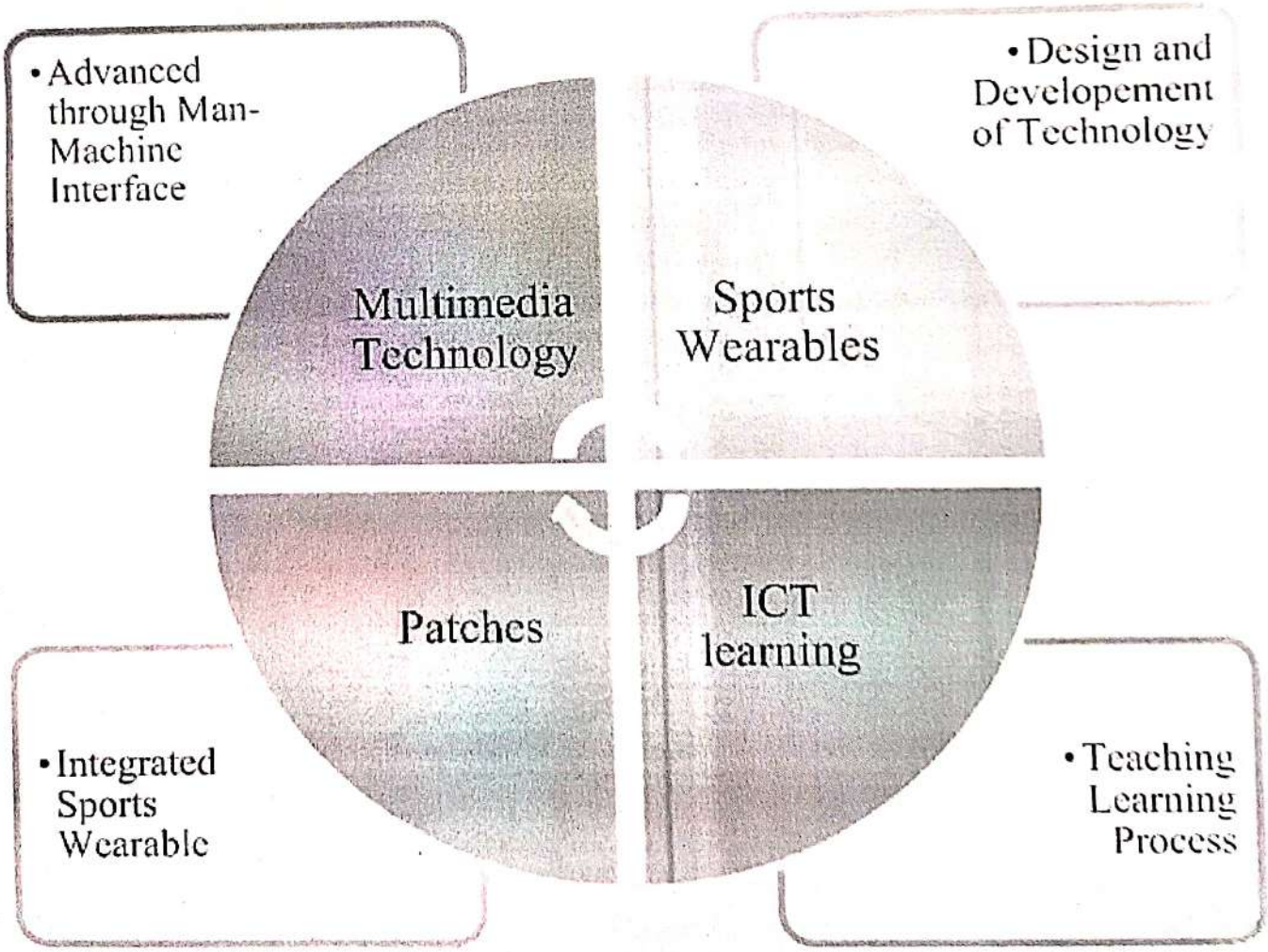
so high overall. The learning of the kids will be affected in some way as a direct result of this unavoidably. When using today's educational technologies, it might be challenging for instructors to illustrate obvious technological connections through developing multimedia curriculum. Teaching strategies such as slow motion, stop mirroring, and replay are used in conjunction with the animations or visuals included in the courseware. These strategies are used to educate students. The instructor can take the time to carefully describe the primary substance of each decomposition action in order to better assist the students in seeing the technical aspects of each immediate activity. Teachers are also able to demonstrate the entirety of the action's procedure to their students over the network. Students have to become proficient in the fundamental aspects of the movement. The crucial and challenging components of the structure of the sports material should be brought to the forefront of the instructional content that teachers deliver. Shorten the length of the teaching process while simultaneously increasing the teaching effectiveness of cognitive learning while it is in the cognitive stage. When we apply contemporary information technology for analysis and comparison, we can use courseware to increase students' overall problem-finding and problem-solving abilities on their own. With today's advanced network technology, we are able to create courseware that covers a variety of sporting tactics and the most typical errors. The effectiveness of pupils' learning can be observed by teachers in the classroom. For instance, you may provide students with multiple sets of simulated shots of leaping jumps (including jumping well, better, generally, poorly, etc.) so that they can engage in collaborative learning. Students would begin by seeing, comparing, and

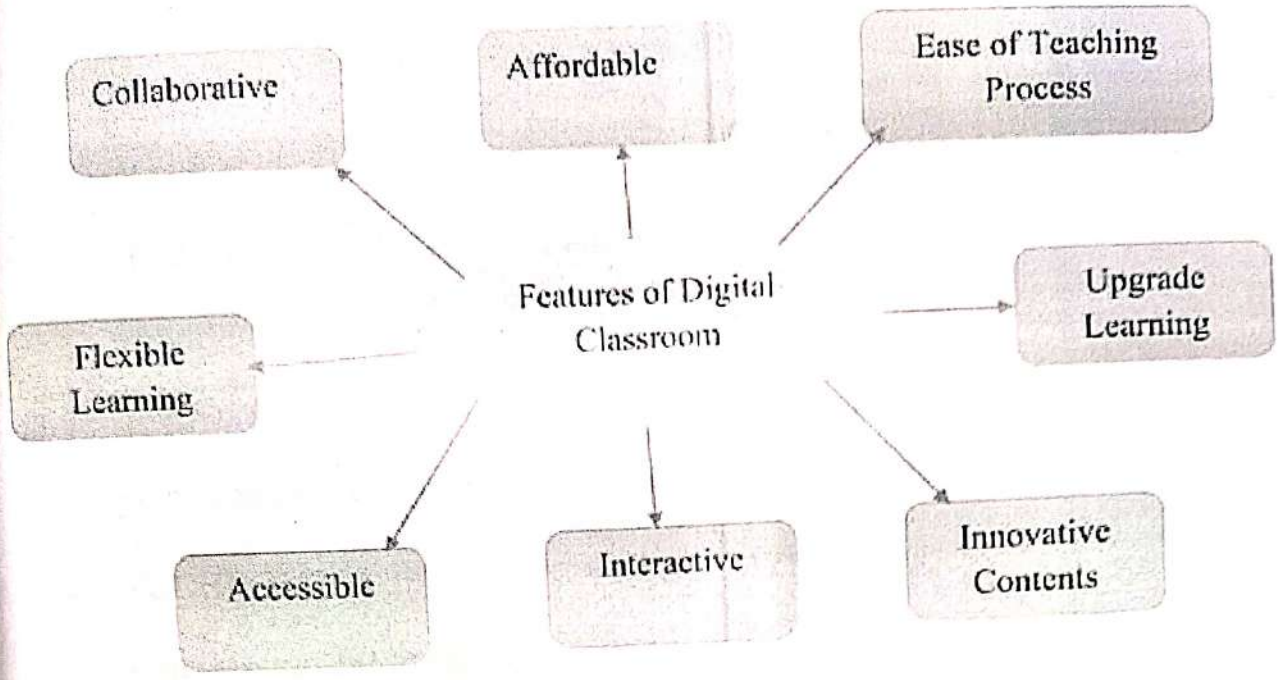
analyzing the videos as a group. The technical fundamentals and safety measures, including run-up, take-off, vacancy, over-the-counter, and landing, were acquired via a series of exchanges and discussions. Following that, the findings were dissected in more intimate settings. The instructor finished by providing a concise summary of the fundamental technical action components of the leap-forward jump. Students will have a better chance of not just acquiring the necessary knowledge but also the skills. They are also capable of mastering the process of self-directed learning. During the process of teaching goat leg, as students begin to learn, the teacher's explanation and demonstration may make pupils unsure about the subject matter that they are studying. When a lesson is broken down into its component parts, it is simple for pupils to misunderstand what is being taught; as a result, they develop a pattern of decomposing and acting while disregarding the qualities of quick coherence [3]. The aforementioned issues can be avoided entirely by employing multimedia instruction software when instructing. The explanations and demonstrations given by the physical education teachers are directly broadcasted to the students so that they can listen to and watch them. Additionally, the crucial points and difficulties are repeated and slowed down, and particular sounds and images are displayed. This highlights the crucial points and difficulties while also making the students intuitive, active, three-dimensional, and comprehensive. Acquiring a command of the moves can help you become a more effective instructor. It is clear that contemporary information technology is utilized in the timely instruction of physical education. This not only makes it possible for students to gain knowledge, but it also strengthens their understanding, memory, and mastery of the

movements that they have been taught. Additionally, it cultivates their active thinking, observational learning ability, and improves the instruction of physical education. Effectiveness. The employment of multimedia for the sake of imparting moral values is not constrained by the constraints of time, space, or scale. The substance of ideological education is made more vivid and colorful and full of attraction, so attaining the purpose of teaching and educating people. It vividly blends physical education with instruction on patriotism and collectivism. For instance, when the class is watching the competition for the group project, the instructor highlights the significance of working together with one another and encourages a spirit of collectiveism that is characterized by unity and cooperation in addition to teaching the students various strategies and methods. Students should be encouraged to attend and watch big international competitions. Such as the Olympic Games, the Asian Games, and so on, when the athletes have won through the tenacious battle and are standing on the top pedestal, the five-star red flag rises. This is done so that students are patriotic and collectivist teaching in a subtle way. The information age has officially arrived in the 21st century. The relentless progression of contemporary technology, which is concentrated on computers and networks, has had an impact on every aspect of modern life. The rate at which education is being modernized is accelerating at an ever-quicker rate. The school and the individual classrooms each have been outfitted with current information technology. In terms of the interaction between contemporary information technology education and more conventional approaches to the teaching of physical education, contemporary information technology education is able to perform an excellent auxiliary

function in physical education. It is not possible to employ contemporary instruction based on information technology as the primary mode of instruction for physical education. It is merely a teaching approach designed to support other teaching methods. The teaching content as well as the teaching methods each play an important and crucial part in the process of teaching in their respective ways. Therefore, teachers of physical education should give full play to the advantages that current information technology teaching offers, incorporate certain new teaching techniques into our physical education classrooms, and use it in a reasonable and correct manner so as to realize the modernization of physical education.

DRAWINGS:

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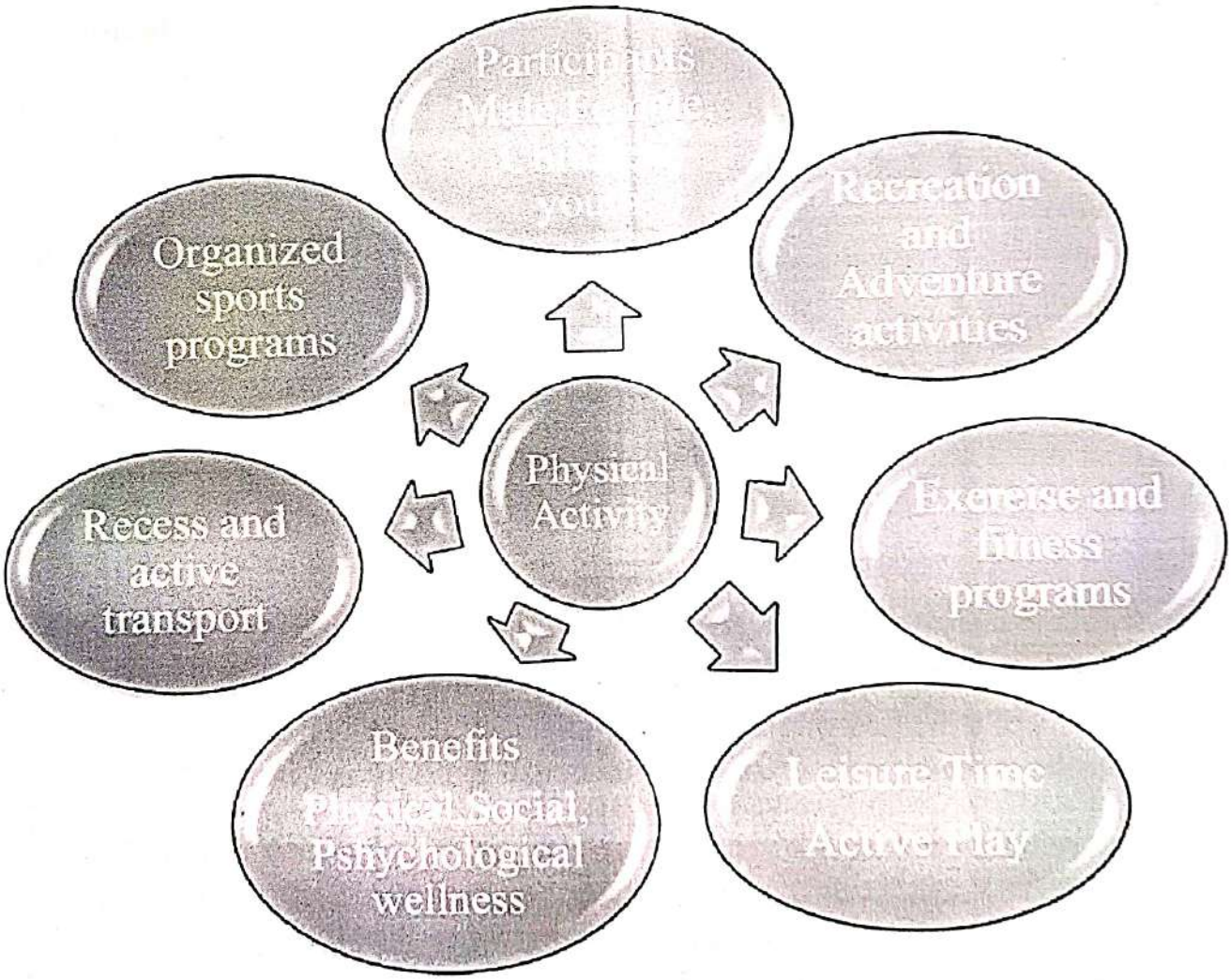
Organized sports programs
Recreation and Adventure activities
Physical Activity
Recess and active transport
Exercise and Fitness programs
Benefits
Psychological wellness

CLAIMS

1. IMPLEMENTATION OF CONTEMPORARY INFORMATION EDUCATION TECHNOLOGY IN PHYSICAL EDUCATION TRAINING AND TEACHING provides ground work for future research.

2. IMPLEMENTATION OF CONTEMPORARY INFORMATION EDUCATION TECHNOLOGY IN PHYSICAL EDUCATION TRAINING AND TEACHING wherein said that In the last 20 years, network technology has changed quickly.

3. IMPLEMENTATION OF CONTEMPORARY INFORMATION EDUCATION TECHNOLOGY IN PHYSICAL EDUCATION TRAINING AND TEACHING wherein said Physical education and training aim to maximize an action in many ways.

4. IMPLEMENTATION OF CONTEMPORARY INFORMATION EDUCATION TECHNOLOGY IN PHYSICAL EDUCATION TRAINING AND TEACHING wherein said Technology integration is crucial to teacher education in all fields worldwide.

5. IMPLEMENTATION OF CONTEMPORARY INFORMATION EDUCATION TECHNOLOGY IN PHYSICAL EDUCATION TRAINING AND TEACHING

wherein said that Traditional teaching strategies have been greatly challenged by new technologies.

6. IMPLEMENTATION OF CONTEMPORARY INFORMATION EDUCATION TECHNOLOGY IN PHYSICAL EDUCATION TRAINING AND TEACHING wherein said that the students using the system have shorter average reaction time and stronger professional, sports training, and tactical awareness of sports training.

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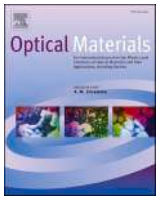

Research Article

Enhancing photodetector performance of MoS_2 thin films by nitrogen ion irradiation

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ABSTRACT

In this work, MoS_2 thin films were grown on a Si substrate using RF sputtering, and subsequently subjected to nitrogen ion irradiation with varying ion fluence. The Raman spectroscopy observed the oxygen doping into MoS_2 lattice and induced shift in E_{2g} and A_{1g} vibration modes, along with a decrease in the interdefect distance (L_D) after ion irradiation. The evolution of oxygen into MoS_2 sample after ion irradiation was confirmed by XPS. The incorporation of oxygen in the MoS_2 is due to the bond breaking of the surface layers of the material due to ion irradiation, which creates dangling bonds. These bonds in the MoS_2 are more reactive with the oxygen and lead to the formation of MoO_x species on the surface of the material. The Field Emission Scanning Electron Microscopy (FESEM) provides the morphological study of post-irradiation samples. As ion fluence increases, the optical bandgap decreases from 1.46 eV to 1.33 eV. Using current-voltage (*I–V*) characteristics, the electrical properties of the irradiated films were characterized, along with photodetector measurements. This combined analysis provided a comprehensive understanding of the film's electrical behaviour, shedding light on their post-irradiation performance. Our results demonstrate that due to oxygen doped into MoS_2/Si thin film significantly affects the barrier height, ideality factor, and carrier concentration in *I–V* characteristics. Taking silicon-based and n-type MoS_2 heterojunction photodetectors, its photoresponsivity can reach ~14.7 mA/W at 7.19×10^{16} ion-cm^{-2} ion fluence. Our findings provide insights into the tunability of the electrical properties of MoS_2/Si thin films through ion irradiation, which has implications for the development of novel electronic and optoelectronic devices based on MoS_2/Si thin film.

1. Introduction

The transition metal dichalcogenide (TMD) materials have gained significant attention in recent years due to their electrical properties showing potential applications in electronic and optoelectronic devices [1–3]. Molybdenum disulphide (MoS_2) is a naturally occurring mineral belonging to the class of TMDs [4]. It has a layered structure and is composed of a sandwich of molybdenum atoms between two layers of sulfur atoms [5]. The intralayer strong covalent bond for each layer and the weak interlayer vans der Waals forces make MoS_2 a highly anisotropic material, with distinct properties in different directions [6,7]. MoS_2 is particularly used as a Photodetector application due to its high mobility, tunable bandgap, and ability to form atomically thin layers.

The photodetectors based on one or two-dimensional nanoscale semiconductors are especially promising due to significant interest in various sensing, imaging, and other optoelectronic applications. There are various nanoscale semiconductor materials have been used in photodetector applications. For example, Im et al. synthesized large-area MoS_2-MoO_x heterojunction thin film structures on SiO_2/Si

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substrates for high response photodetectors. They show the MoS_2-MoO_x heterojunction thin film exhibited significantly higher photoresponsivity (R_{ph}) and specific detectivity (D*) under light illumination over a wide range of wavelengths between 405 nm and 638 nm as compared to MoO_x thin films [8]. Li et al. are demonstrated the photoresponsivity of MoS_2 was improve by using doping method of gold chloride hydrate. The responsivity and specific detectivity were increased to 99.9 A/W and 9.4×10^{12} Jones under low V_{DS} (0.1 V) and V_{GS} (0 V), which are 14.6 times and 4.8 times higher than those of a pristine photodetector, respectively [9]. Wu et al. are showing the enhance the photoresponsivity due to the introduction of electronic states in the band gap of MoS_2 through oxygen substitution by plasma treatment. The photoresponsivity and detectivity are largely boosted to 1.8 A/W and 2.64×10^9 Jones, respectively [10]. However, by altering the MoS_2 properties via the introduction of defects used for a photodetector application [11]. The physical and electrical properties of materials can also be modified using a common ion irradiation technique [11,12]. When a material is bombarded with ions, it undergoes a range of physical and chemical changes, including the creation of defects, damage to the crystal structure, and changes in electronic properties [11–14]. In the case of MoS_2, ion irradiation can lead to changes in its electrical properties, including changes in its conductivity, mobility, and carrier concentration.

One of the research articles by Ma et al. demonstrates the tailoring of optical properties of tungsten disulfide (WS_2) by creating the *S*- vacancies post Ar^+ ion irradiation [15]. *S*-vacancies are seen to increase with Ar^+ ion Fluence, which results in linear increase of WS_2 absorption [15]. In another work, Kim et al. have tuned the Seebeck coefficient and electrical conductivity of Molybdenum diselenide ($MoSe_2$) using helium ion irradiation [16]. A high irradiation Fluence of 1×10^{13} and 1×10^{15} cm^{-2} with energy 1.8 MeV has been used by Mackova et al. to change the surface, enhance structural and electrical properties of MoS_2 [17]. In literature analysis suggests the defects and impurities in any material changes its physical as well as optical properties through ion irradiation. Therefore, ion irradiation can increase the conductivity of TMD materials and their photoresponsivity. Having comprehensive literature survey, it motivated us to carry out the ion beam irradiation on MoS_2 as irradiation can fine tune the properties by creating the defect in TMD materials. Further, ion beam irradiation has an added advantage over chemical methods as it is impurity free.

In the present research article, we have synthesized MoS_2 thin films using RF magnetron sputtering method and investigated the effect of low-energy (30 keV) nitrogen ion irradiation on these films. The changes in structural, optical, and electrical properties confirmed through various characterization techniques like Raman spectroscopy, Field emission scanning electron microscopy, Monte Carlo simulations (SRIM 2008), ultraviolet–visible spectroscopy, X-ray photo spectroscopy and current-voltage (*I–V*) measurements are studied for as-prepared and irradiated MoS_2 samples. The *I–V* results prominently show that due to ion irradiation sulfur vacant site are created and this site further occupied by oxygen present in atmosphere. In the present case doping of oxygen shifts the A_{1g} peak toward a lower wave number with respect to the pristine sample in Raman spectra suggesting a *n*-type doping in the sample. Which further affects the electrical properties and photoresponsivity of MoS_2/Si thin films. The findings of this study are expected to contribute to the advancement of MoS_2-based photodetection devices by providing valuable insights into the role of ion irradiation and oxygen doping in the MoS_2 nanosheets. Overall, the following study highlights the importance of controlling the defect density in these materials for their practical applications in electronic and optoelectronic devices and demonstrate the effects of ion irradiation in increasing the photoresponsivity of MoS_2/Si thin films.

2. Experimental procedure

2.1. Deposition of MoS_2/Si thin films

The MoS_2 thin film was deposited on p- Si substrate by RF sputtering method. A 3-inch MoS_2 target (99.99 %, Vin Korola, USA) was used to deposit MoS_2 films. Initially, the p-type Si substrate is cleaned using standard procedures, including ultrasonic cleaning in solvents and subsequent rinsing with deionized water. To remove any native oxide layer, the substrate may undergo a chemical etching step using a suitable etchant, such as a dilute hydrofluoric acid (HF) solution. The target is loaded into the sputtering chamber, and the chamber was evacuated by employing a rotary and turbomolecular pump. A radio frequency (RF) power supply is used to create a plasma within the sputtering chamber. A suitable inert gas, such as argon (Ar), is introduced into the chamber to create a sputtering atmosphere. Further by applying RF power supply Ar ions accelerates towards the MoS_2 target, causing the ejection of MoS_2 particles from the target surface through physical sputtering. Before the deposition of MoS_2 film, the MoS_2 target was pre-sputtered for 10 min to clean the surface of the target. These ejected MoS_2 particles travel towards the p-type Si substrate and deposit onto its surface. The details of Film Nucleation and Growth:

The MoS_2 particles that reach the Si substrate surface undergo nucleation and subsequent growth. The nucleation process involves the adsorption and diffusion of the MoS_2 particles on the Si surface. Once nucleation sites are formed, the MoS_2 particles continue to deposit and grow on these sites, forming a continuous MoS_2 film. The targeted thickness of MoS_2 was ~200 nm [18,19] and the achieved thickness was ~236 nm. The calibration of thickness was achieved by calculated its deposition rate.

$$Deposition\ rate = \frac{\boldsymbol{Thickness\ of\ film\ (nm)}}{\boldsymbol{time\ of\ deposition\ (min)}}$$

This deposition rate gives us the idea about time of deposition. The deposition rate of 6.6 nm/min of MoS_2 form a 200 nm layer on the Si substrate for the deposition time of 30 min.

The growth process is influenced by various sputtering conditions are listed in Table 1.

The deposited MoS_2 films were then annealed at 400 °C for 60 min. Next, the naturally cooled films were used for characterization. Further, deposited MoS_2 on a p-type silicon thin film is irradiated by Nitrogen ions having the energy 30 keV and the at fluence varying from 1.19×10^{16} ion-cm^{-2} to 7.19×10^{16} ion-cm^{-2}. To make top contacts, a square frame of Aluminium (Al) was coated on the Si layer via an electron-beam evaporator. The current-voltage characteristics of the Al/MoS_2/p-Si thin film was measured under the illumination of a solar simulator with the incident intensity of 100 W/m^2 using a Keithley 2450 source meter.

2.2. Material characterization

The phase of deposited films was confirmed by Raman spectroscopy (Renishaw InVia Raman microscopy). The surface morphology and Film thickness were investigated using Nova NanoSEM 450 FE-SEM. The optical absorbance measurements were performed using UV–Visible–NIR spectrophotometer (JASCO, V-670). The elemental

Table 1
The RF-sputtering system's parameters used for MoS_2 thin film deposition.

Process parameters	Value
Working pressure	5 Pa
Substrate to target distance	7 cm
Deposition time	30 min
Substrate temperature	200 °C
RF Power	120 W

composition of prepared films was examined with energy dispersive spectrometer (Oxford instruments, 51-ADD0058). Thermo Scientific's K-Alpha+, UK equipment, which has a resolution of 0.1 eV, was used for the XPS spectra measurement. The electrical measurement of MoS_2 films were carried out using Keithley 2450 source meter. The Class ABA Solar Simulator ORIEL Sol 2 A 94022 A was used for white light illumination with a power density of 12 mW cm^{-2}.

2.3. Ion irradiation of MoS_2 thin films

The deposited MoS_2/Si thin films were irradiated on low energy ion beam facility (10 keV–100 keV) available at Department of Physics (DoP), Savitribai Phule Pune University (SPPU), Pune, India. The irradiation was carried out with Nitrogen ion beam having 30 keV energy at fluence varying from 1.19×10^{16} ion-cm^{-2} to 7.19×10^{16} ion-cm^{-2}. After irradiation, the square silver (Ag) contact was made on the MoS_2/Si layer via an electron-beam evaporator as top contact for electrical measurements and another set with same irradiation fluence was utilised for other characterisation purpose. The Keithley 2450 source meter with the incident light intensity of 100 W-m^{-2} is used to study the current-voltage (dark/light) characteristics of the MoS_2/Si thin film.

3. Results and discussion

The MoS_2/Si thin films synthesized by RF sputtering method are characterized using several techniques to assess their structural, optical, morphological and electrical properties.

3.1. Raman spectroscopy studies

The structural analysis of synthesized MoS_2/Si thin films is carried out using Raman spectroscopy which is a non-destructive and powerful tool [20]. In this technique, a laser is made incident on the sample and the structural information is obtained by analysing the scattered laser which contains the information of vibrational modes present in the material [21]. The Raman spectra of as-prepared and N^+ ion irradiated MoS_2/Si thin film is shown in Fig. 1 (a). MoS_2 is a two-dimensional material with a layered structure, and its Raman spectrum is dominated by two main peaks viz. E_{2g} and A_{1g} peaks around 381.13 cm^{-1} and 405.88 cm^{-1} respectively. The E_{2g} mode is a characteristic peak of the TMDs family arising from out-of-plane vibration of the S atoms present in the MoS_2 layers, while the in-plane vibrations of Mo atoms result in A_{1g} mode, and is usually used as a reference peaks [22].

As fluence is increased from 1.19×10^{16} ion-cm^{-2} to 7.19×10^{16} ions-cm^{-2}, the Raman peaks are shifted to a lower wave number i.e. red shifted as shown in Fig. 1 (b). The shift of the E_{2g} peak with respective pristine sample is observed to be ~1.71 cm^{-1}, ~3.04 cm^{-1}, ~3.59 cm^{-1} and ~7.35 cm^{-1} for irradiation Fluence of 1.19×10^{16} ion-cm^{-2}, 2.35×10^{16} ions-cm^{-2}, 4.76×10^{16} ion-cm^{-2} and 7.19×10^{16} ion-cm^{-2} respectively. Similarly, for A_{1g} mode a shift of ~0.84 cm^{-1}, ~1.16 cm^{-1}, ~2.71 cm^{-1} and ~3.59 cm^{-1} is observed for 1.19×10^{16} ion-cm^{-2}, 2.35×10^{16} ion-cm^{-2}, 4.76×10^{16} ion-cm^{-2} and 7.19×10^{16} ions-cm^{-2} of ion irradiation respectively.

The shifting of Raman peaks is due to a decrease in the bond strength between the atoms, causing a decrease in the vibrational frequency[17,] [23]. The weakening of van der Waals forces and stretching of bond lengths result in shift of E_{2g} and A_{1g} modes to a lower wavenumber in Raman spectra [23]. The reason for shift in vibrational frequency in the present case can be attributed to ion matter interaction. When energetic N^+ ions collide with the MoS_2/Si film, they transfer momentum to the target atoms, leading to atomic displacements and the creation of vacancies. The energetic ions can displace sulfur atoms from their lattice positions, resulting in the formation of sulfur (S) vacancies. The details of this vacancy formation using SRIM simulation is explained in the next section.

Beside E_{2g} and A_{1g} modes of few layer of MoS_2, a series of new Raman vibration modes appear as fluence increase from 1.19×10^{16} ion-cm^{-2} to 7.19×10^{16} ion-cm^{-2}. The new peaks appear at ~218 cm^{-1}, ~284 cm^{-1}, ~331 cm^{-1}, ~635 cm^{-1}, ~789 cm^{-1}, ~830 cm^{-1}, ~876 cm^{-1} and ~910 cm^{-1} correspond to the vibrational modes of Mo − O bonds [24], confirming the oxygen doping in MoS_2 thin films. The peak 284 cm^{-1}, 218 cm^{-1}, 830 cm^{-1} and 331 cm^{-1} corresponds to the formation of α-MoO_3 in the presence of O_2 [25]. The Raman peaks appearing at ~635 cm^{-1}, ~789 cm^{-1}, ~876 cm^{-1} and ~910 cm^{-1} have not yet been verified, but they may be representing the intermediate oxidation states of MoO_x, where $2 < x < 3$ as reported by L Kumari et al. [26].

The reason for such Mo–O and MoO_x formation can be understood on the following basis. The vacancy sites created by dislocation of sulfur

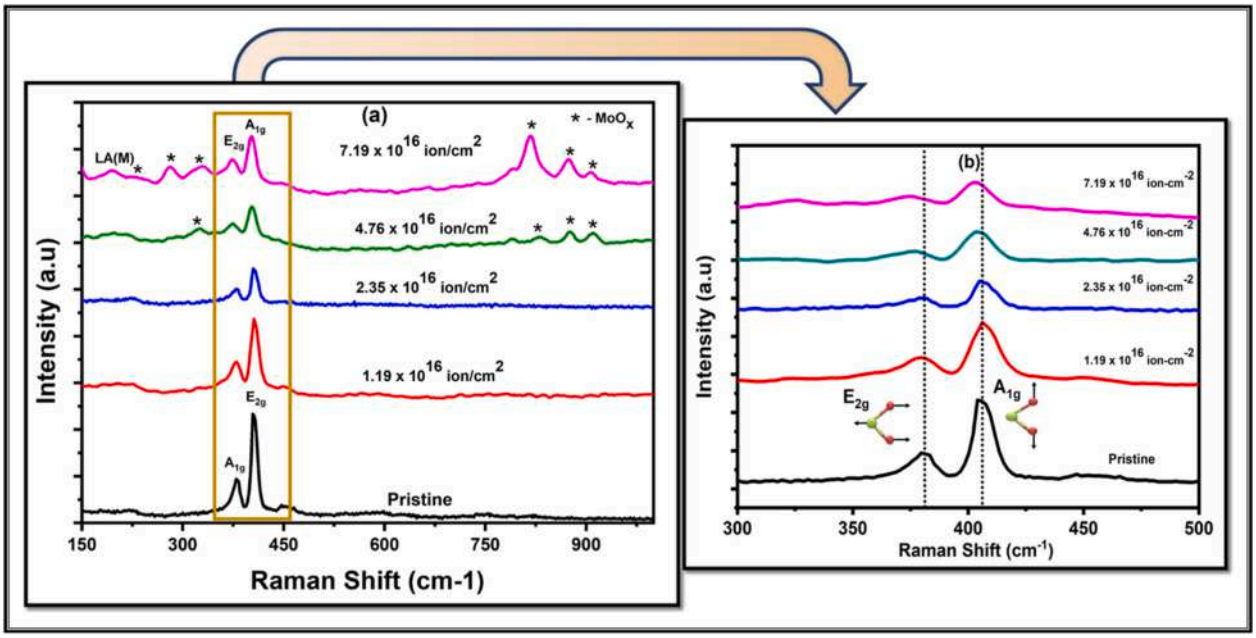

Fig. 1. (a) Raman spectra of pristine and N^+ ion irradiated MoS_2/Si sample of (b) Variation in E_{2g} and A_{1g} mode of pristine with increasing N^+ ion irradiated Fluence in MoS_2/Si sample.

atoms due to energetic N^+ ions gets occupied by oxygen present in the ambient environment, and results in O-doped MoS_2/Si due to irradiation [27]. The penetration depth (ion range) of 30 keV N^+ ion in MoS_2 is ~57 nm (Calculated by SRIM 2008 Software) suggests that sulfur vacancies are created on the MoS_2 surface layers of the sample and further get occupied by oxygen atoms. Thus, assigned Raman peak representing vibrational modes of Mo − O bonds are due to the oxygen doping in MoS_2 lattice, and intensity of these peaks increases with the N^+ ion fluence. Apart from introduction of new modes, the oxygen doping also induce shift of characteristic E_{2g} and A_{1g} vibration modes along with decreasing the interdefect distance (L_D) as evident from Fig. 2.

The interdefect distance (L_D) is calculated using ion fluence (σ) on the surface of irradiated MoS_2/Si thin films as follows [28],

$$\sigma = \frac{it}{Ae} \tag{1}$$

where i and t are the ion current and exposure time to the ion beam of the sample respectively. While A is the area of incident ion beam and e is the elementary charge. These ion fluence correspond to an average inter-defect distance (L_D) calculated as [28],

$$L_D = \frac{1}{\sqrt{\sigma}} \tag{2}$$

By varying t, it is possible to control defect density between 1.19×10^{16} ion-cm^{-2} and 7.19×10^{16} ion-cm^{-2}. The L_D decreases from 9.2 nm to 3.7 nm with fluence increased from 1.19×10^{16} ion-cm^{-2} to 7.19×10^{16} ion-cm^{-2} and it is shown in Fig. 2 (a). Both E_{2g} and A_{1g} modes of MoS_2 are very sensitive to the change in incident ion beam fluence. We observe, maximum E_{2g} and A_{1g} peak shifts of 6.35 cm^{-1} of 3.59 cm^{-1} respectively for 7.19×10^{16} ion-cm^{-2} ion Fluence, as compared to the pristine sample, as depicted in Fig. 2 (b).

A p/n-type doping would cause a blue shift/red shift of the A_{1g} peak for MoS_2/Si due to the change in electron-phonon interactions [29]. Long Qi et al. have experimentally observed n-doping effect originating from oxygen adsorption at the surface defect sites of MoS_2 [30]. They showed oxygen doping resulting in increased current in I–V characteristics. In our case, we also measured the current voltage characteristics, to confirm whether the effect of oxygen doping is helping in increasing the current. Indeed, it was observed a substantial increase in the current, details of which are discussed in later section. The oxygen occupying the sulfur vacancy sites may further enhance the local density of defect-induced energy levels, and reduce the energy required for electron excitation to the conduction band, both these phenomena could lead to enhanced photodetector characteristics of MoS_2/Si thin films [30]. In the present case doping of oxygen shifts the A_{1g} peak toward a lower wave number by ~3.59 cm^{-1} with respect to the pristine sample (Fig. 1 (b)), suggesting a n-type doping in the sample [31,32] is partially confirmed.

3.2. Field emission scanning electron microscopy (FESEM)

Due to defects induced in MoS_2 nanosheets after ion irradiation, the surface morphology varies. It is examined by using Field emission scanning electron microscopy (FESEM) technique at high magnification. In the case of MoS_2/Si synthesized by the RF sputtering method, FESEM can be used to characterize the surface features of as-prepared and ion irradiated MoS_2/Si thin films. Fig. 3 show the FESEM images of pristine (a) Pristine MoS_2/Si sample (b) for N^+ fluence of 1.19×10^{16} ion-cm^{-2} (c) 2.35×10^{16} ion-cm^{-2} (d) 4.76×10^{16} ion-cm^{-2} (e) 7.19×10^{16} ion-cm^{-2} (f) Cross-Section image of MoS_2/Si thin film. Fig. 3 (a) shows the nanosheet of few layer MoS_2 sample. As fluence of N^+ ion is increased up to 7.19×10^{16} ion-cm^{-2}, due to the creation of sulfur vacancies and further introduction of oxygen on the surface of MoS_2 nanosheet agglomeration is seen to increase. The thickness of MoS_2 thin film is ~236 nm measured by using a cross-section image of FESEM as shown in Fig. 3 (d). Since SRIM calculations, it can be concluded that the out of 236 nm MoS_2 film, the nitrogen ion irradiation creates defects up to a depth of 54 nm.

3.3. Ions range and energy losses in materials

The defect/sulfur vacancy creation mechanism in the MoS_2 thin films due to the incident nitrogen (N^+) ion can be understood through monte carlo based simulation Stopping and Range of Ions in Matter (SRIM 2008) package. SRIM 2008 calculates energy losses in materials, defects, sputtering yield etc. [33].

The interaction of ion results in defect formation, surface deformation or creation of latent tracks in the target depending on the nature and energy of the incident ion, and other process parameters [34]. The ions with energy in the keV range suffer predominant energy loss via creation of point defects in the target sample. The interaction of ions with matter is generally explained using either of the two models, namely Coulomb explosion and thermal spike model [34]. Coulomb explosion model explains the relaxation of energy possessed by the ion via radial impulses of atoms in the ion trajectory, and is responsible for outward spread of +ve ions away from the ion path [35]. Hence, radially expandable stress and strain are observed around the ion path. While the thermal spike model suggests the relaxation of incident ion happens by supplying excess energy to the electrons of target atoms within a short time span of 10^{-16} s, leading to a temperature rise locally. This local thermalization is followed by heat transfer from electron to lattice between 10^{-14} s to 10^{-12} s [34,35]. In the present situation, such dense electronic

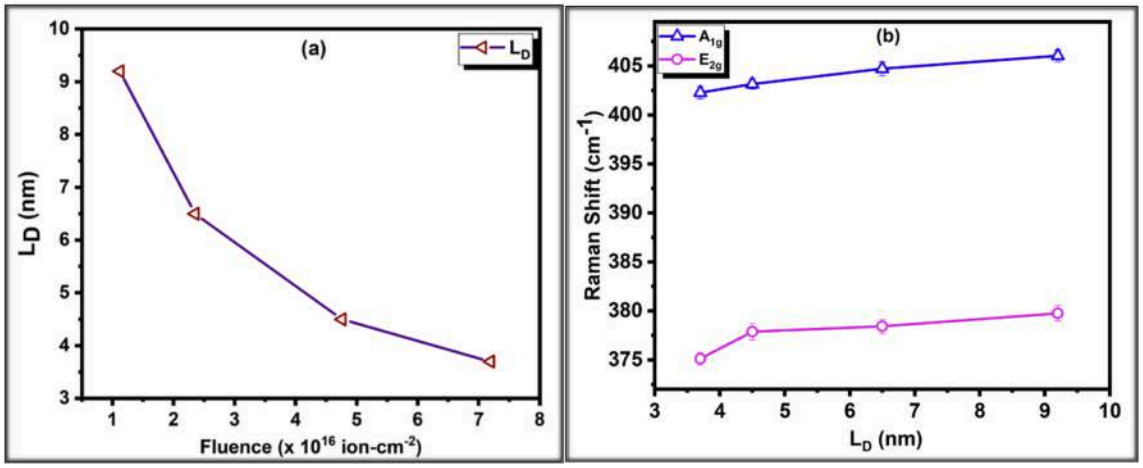

Fig. 2. (a) Variation of inter defect distance (L_D) with respective of Fluence, (b) position of E_{2g} and A_{1g} as a function of L_D.

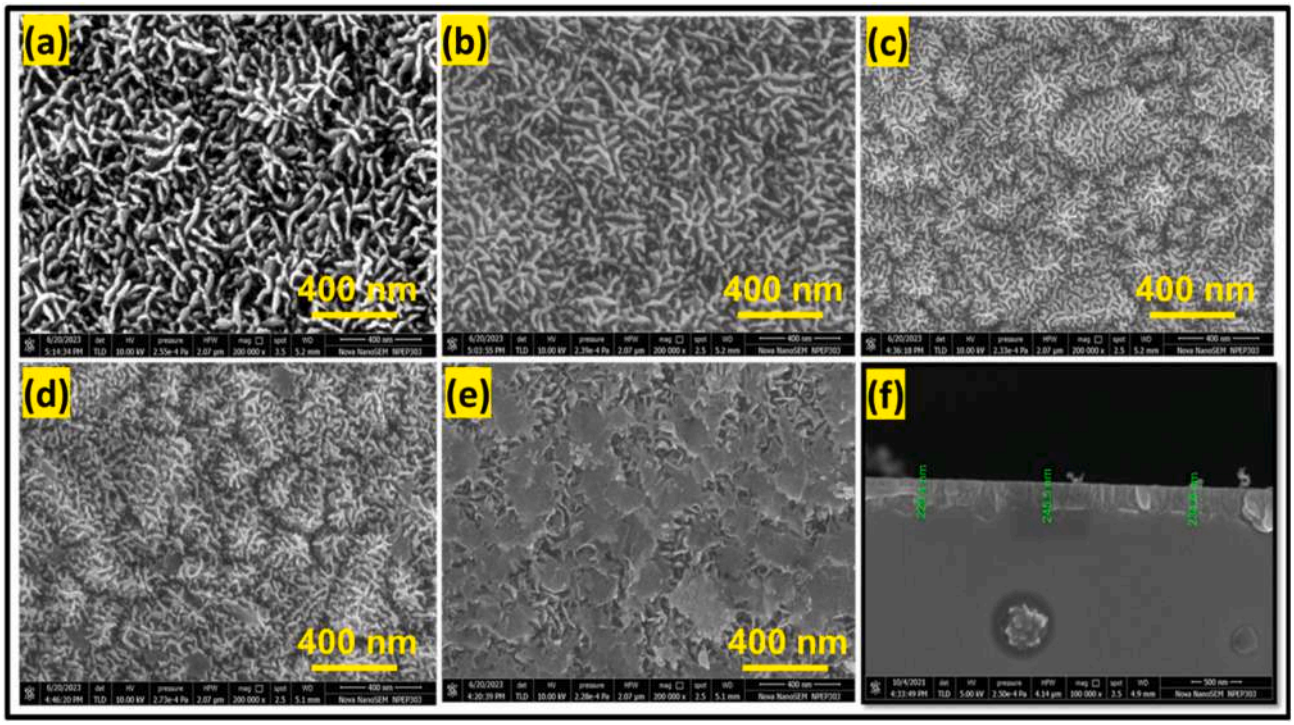

Fig. 3. Field emission scanning electron microscopy (FESEM) of (a) Pristine MoS_2/Si sample (b) for N^+ fluence of 1.19×10^{16} ion-cm^{-2} (c) 2.35×10^{16} ion-cm^{-2} (d) 4.76×10^{16} ion-cm^{-2} (e) 7.19×10^{16} ion-cm^{-2} (f) Cross-Section image of MoS_2/Si thin film.

excitation and efficient electron-phonon coupling may have created defects in the neighbourhood of ion trajectory.

Fig. 4 (a) shows the penetration depth of N^+ ions along the Y-axis refers to how deeply these ions can travel into a MoS_2 material in the Y-direction before their energy is lost. Calculation reveals nitrogen ion range in MoS_2 is ~57 nm. Fig. 5 shows the SRIM 2008 calculation for bombarding 30 keV N^+ (a) recoil energy and (b) collision event as a function of target depth. As shown in Fig. 5 (a) the excess energy of incident nitrogen ions is absorbed by the Mo and S atoms. It is also clear that most of the energy is absorbed by the S atoms, therefore we observe the maximum displacement of sulfur atoms and further creation of sulfur vacancy, as evident from Fig. 5 (b). We can thus infer that, in MoS_2, upon 30 keV nitrogen ion irradiation, mostly sulfur vacancies are created.

3.4. UV–Visible spectroscopy analysis ion fluence

Because of oxygen occupying the sulfur vacancies, the absorption spectra of a pristine and irradiated sample will change, which can be obtained from UV–visible spectroscopy. Fig. 6 (a) shows the variation in absorption spectra with increase in ion irradiation Fluence of MoS_2 thin film. It is seen that N^+ irradiation leads to a blue shift in the absorption spectra.

Fig. 6 (b) (inset) and (c) show the Tauc plot and bandgap energy (E_g) variation respectively of pristine and ion irradiated MoS_2 thin films. At high fluence, the defects induced by N^+ irradiation become more pronounced and have a significant impact on the bandgap of the material it may be due to several mechanisms [36]. One such mechanism is the substitution of oxygen into sulfur vacancy of MoS_2 leads to the decrease in band gap with increasing fluence of ion irradiation [37]. Oxygen atoms have a higher electronegativity compared to sulfur atoms in

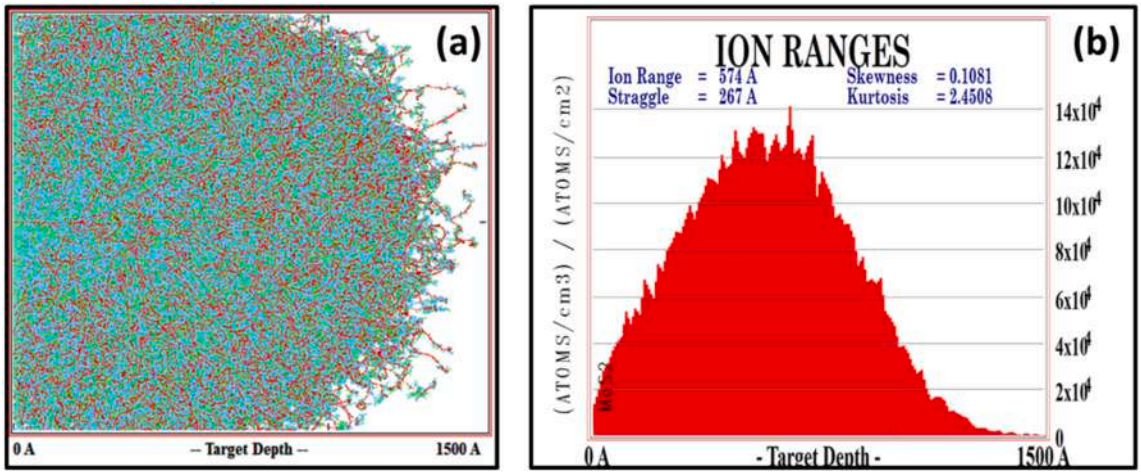

Fig. 4. (a) the penetration depth of N^+ ion along the Y-Axis. (b) Ion range (R) of nitrogen ion.

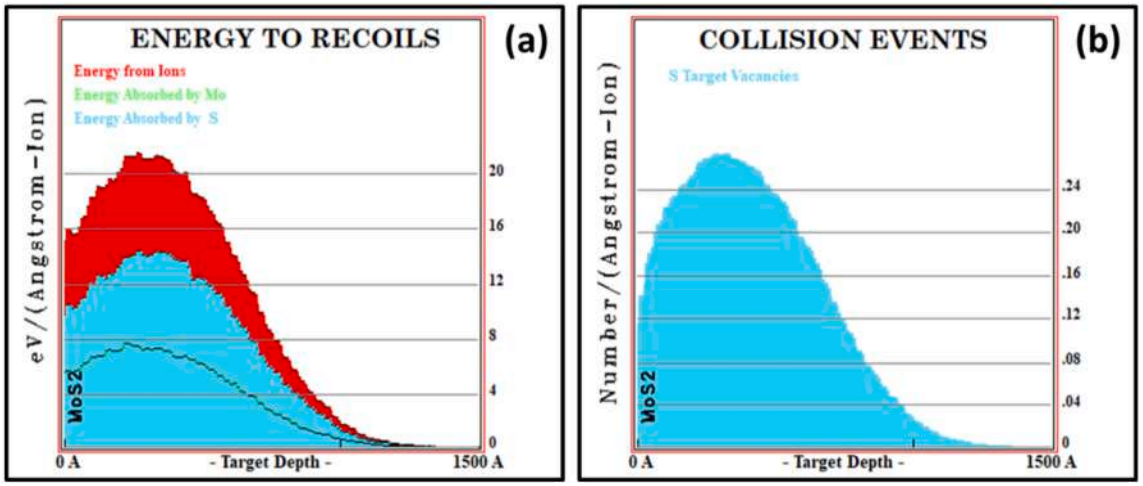

Fig. 5. (a) Amount of energy absorbed by Mo and S atom of nitrogen ion. (b) Sulfur (S) vacancy created by nitrogen ion.

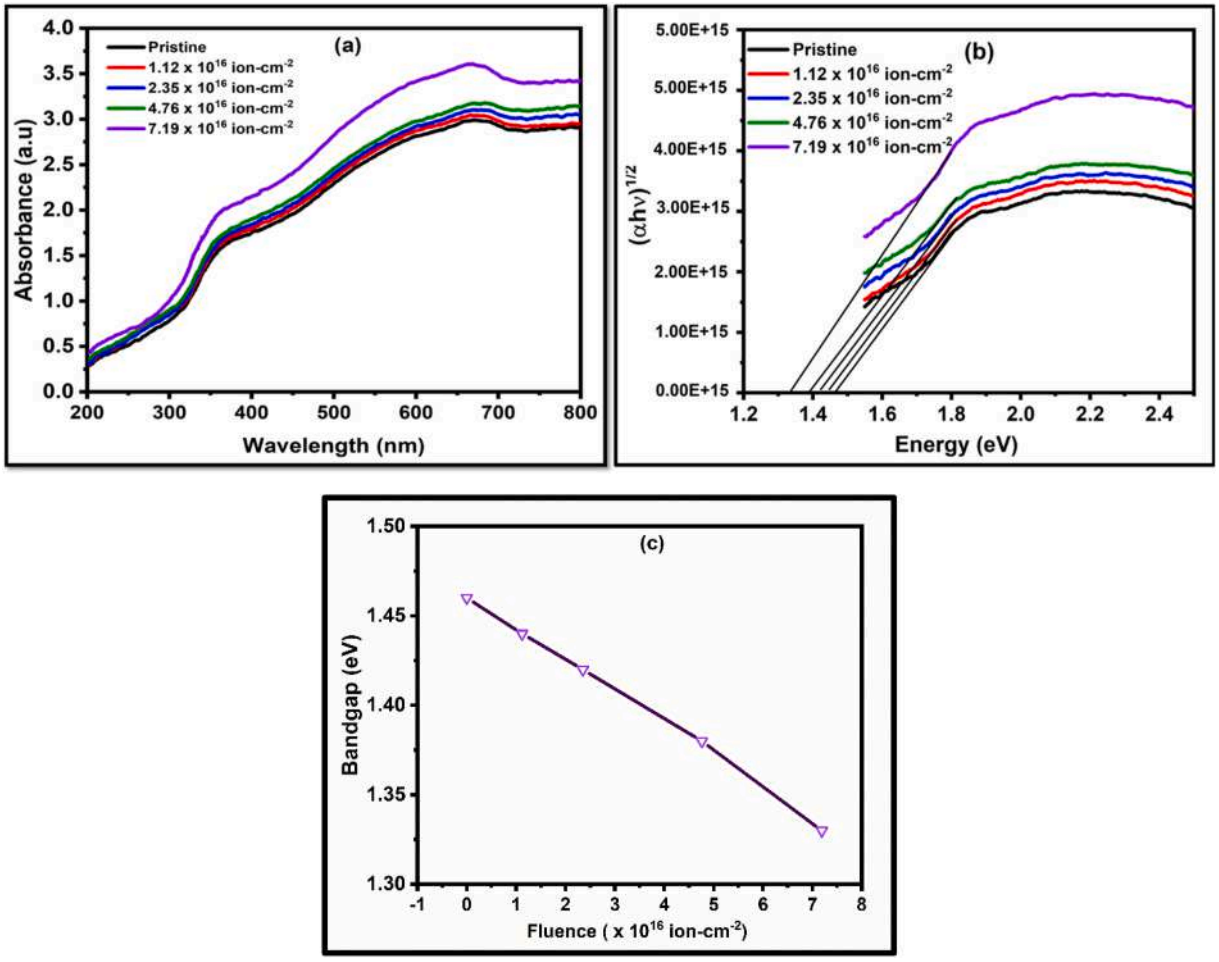

Fig. 6. (a) Absorption spectra, (b) Tauc plot and (c) bandgap energy (E_g) with variation of ion irradiation with respective of pristine MoS_2 sample.

MoS_2. When oxygen is doped into the lattice, the covalent bonding of Mo–S is distinctively weakened and it can withdraw electrons from the neighbouring sulfur atoms, resulting in a charge transfer [37]. This charge transfer can modify the electronic structure of the material, including the position of the valence and conduction bands [37]. The redistribution of electronic states can lead to a reduction in the bandgap energy. Fig. 6 (c) shows the decrease in bandgap from ~1.46 eV for pristine sample to ~1.33 eV for 7.19×10^{16} ion-cm^{-2} fluence.

3.5. X-ray photoelectron spectroscopy (XPS)

The confirmation of oxygen occupied by sulfur is further evaluated using X-ray photoelectron spectroscopy (XPS). The wide survey spectrum recorded for the MoS_2 thin films include peaks corresponding to

O:1s, C:1s, Mo:3 d, O:2s, Mo:3p and S:2p states and are shown in Fig. 7 (a). It can be observed from the XPS spectra that the MoS_2 characteristic peaks, i.e. Mo:3 d and S:2p show shift in the binding energy along with decreases in the intensity of various peaks as irradiation fluence increases. The peak observed at 161.06 eV and 162.13 eV corresponding to S:2$p_{3/2}$ and S:2$p_{1/2}$ states respectively, confirm the sulphide formation in the pristine and ion irradiated samples. These results are analogous with the result obtained Lakshminarayana et al. [38]. The S:2p peak intensity decreases due to the structural damage and defects created as the ion irradiation increases [38]. When energetic ions interact with a material like MoS_2, they transfer their energy to the atoms in the material, which causes atomic displacements, bond breaking, sputtering, and creation of defects. This decreases the number of S atoms in the material and, therefore, the intensity of the S:2p and Mo:3 d peak decreases with increase in the irradiation fluence.

Fig. 7 (a) shows the full survey scan XPS graph for pristine and MoS_2 irradiated samples at different ion fluences. Ion irradiation can cause bond breaking of the surface layers of the material, which creates dangling bonds, and these bonds of MoS_2 are more reactive with oxygen and lead to the formation of MoO_x species on the surface of the MoS_2 material [17]. It is also possible that, after irradiation when the vacuum is break, sample gets exposed to atomic oxygen and reacts with the dangling bonds present at the surface of the MoS_2. These species may have a different chemical environment compared to the Mo atoms in the MoS_2 crystal lattice, leading to a change in the peak intensity. The XPS spectrum also shows the presence of the O:1s peak in the pristine and irradiated samples. The O:1s peak intensity is very low for pristine sample and it increases with increasing fluence, as shows in Fig. 7 (b). Also, the peak position of O:1s is slightly shifts toward the higher binding energy (B. E) of 531.55 eV in case of 7.19×10^{16} ion-cm^{-2} fluence, indicating the formation of MoO_x [39].

Figs. 8 and 9 shows the XPS spectra of S:2p and Mo:3 d deconvoluted peaks respectively for MoS_2 pristine and irradiated samples. The B.E shift in the XPS spectra is related to the core level electrons, and has been considered as an indicator for identifying the type of doping in MoS_2 [9,40,41]. The binding energy shifts of S:2p peaks (S:2$p_{1/2}$ and S:2$p_{3/2}$) and Mo:3 d peaks (Mo:3$d_{3/2}$ and Mo:3$d_{5/2}$) with the irradiation fluence of MoS_2/Si are shown in Figs. 8 (f) and 9 (f) respectively. Compared with the pristine MoS_2/Si, all peak positions of the irradiated MoS_2/Si shift to the high binding energy side. The comparative upshifts of binding energy values of Mo:3 d and S:2p is 0.42 and 0.61 eV, respectively. This result confirms the rising of Fermi level toward the conduction band in irradiated MoS_2/Si.

Overall from Raman analysis, SRIM calculations, SEM and XPS data it confirms predominantly sulfur vacancies are induced due to nitrogen ion irradiation and these defects, especially present on the surface of MoS_2 are occupied by oxygen. The literature reveals that, oxygen occupancies in MoS_2 leads to n-type doping and enhances the conductivity of the MoS_2 [9,30]. To validate and perform the application of irradiated MoS_2/Si thin films, we did dark and light *I–V* measurement.

3.6. Electrical characterization

3.6.1. I–V characteristics in light and dark

The MoS_2/Si thin films irradiated with nitrogen ions at different fluence introduces defects and vacancies in the crystal lattice of the material; these defects act as charge carrier traps and increase the conductivity of the material [42–45]. The number of charge carrier traps increase with the irradiation Fluence causing noticeable increase in the current, as shown in Fig. 10 (a) and (b). The *I–V* characteristics of ideal diode with a barrier height can be calculated as follows [46–48],

$$I = I_o \, exp\left(\frac{qv}{\eta kT}\right)\left[1 - exp\left(\frac{-qv}{kT}\right)\right] \tag{3}$$

$$I_o = AA^*T^2 \, exp\left(\frac{q\varphi_b}{kt}\right) \tag{4}$$

where I_o, q and v are the saturation current, electron charge and applied voltage across the junction respectively. While k, T, A^* and A are the Boltzmann's constant, absolute temperature in Kelvin, Richardson constant and diode area of the contact respectively. The Schottky barrier height at zero bias (φ_b) and ideality factor (η) can be represented as [46].

$$\varphi_b = \frac{kT}{q} ln\left(\frac{AA^* T^2}{I_o}\right) \tag{5}$$

$$\eta = \frac{q}{kT}\left(\frac{dv}{dln(I)}\right) \tag{6}$$

The barrier heights and ideality factors of current measured in dark and light are calculated from equations (5) and (6) respectively, are depicted graphically in Fig. 11 (a) and (b) respectively. In the case of a MoS_2/Si heterojunction, the barrier height is also influenced by the band alignment between the MoS_2 and the Si substrate [49–51]. When ions are irradiated on the MoS_2/Si thin film, it induces defects and impurities that alter the interface properties [50,52].

Qi et al. reported the chemisorption of oxygen on the surface, and that induce *n*-doping effect altering the electronic properties of MoS_2 [30]. They show that sulfur vacancy sites occupied by oxygen on the

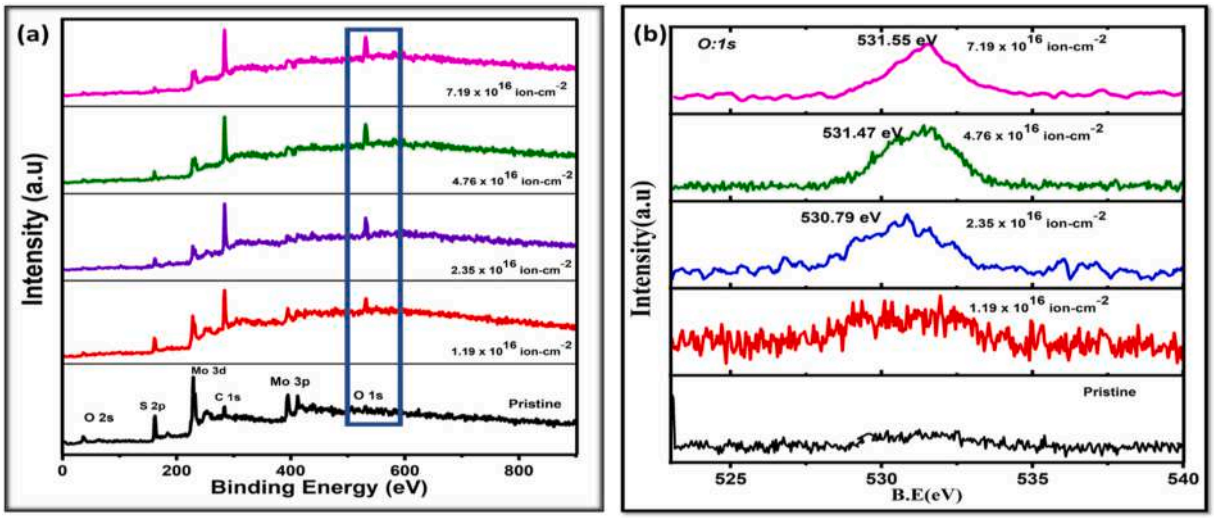

Fig. 7. (a) XPS wide survey spectrum for pristine and irradiated MoS_2 samples. (b) *O:1s* peak with variation of fluence.

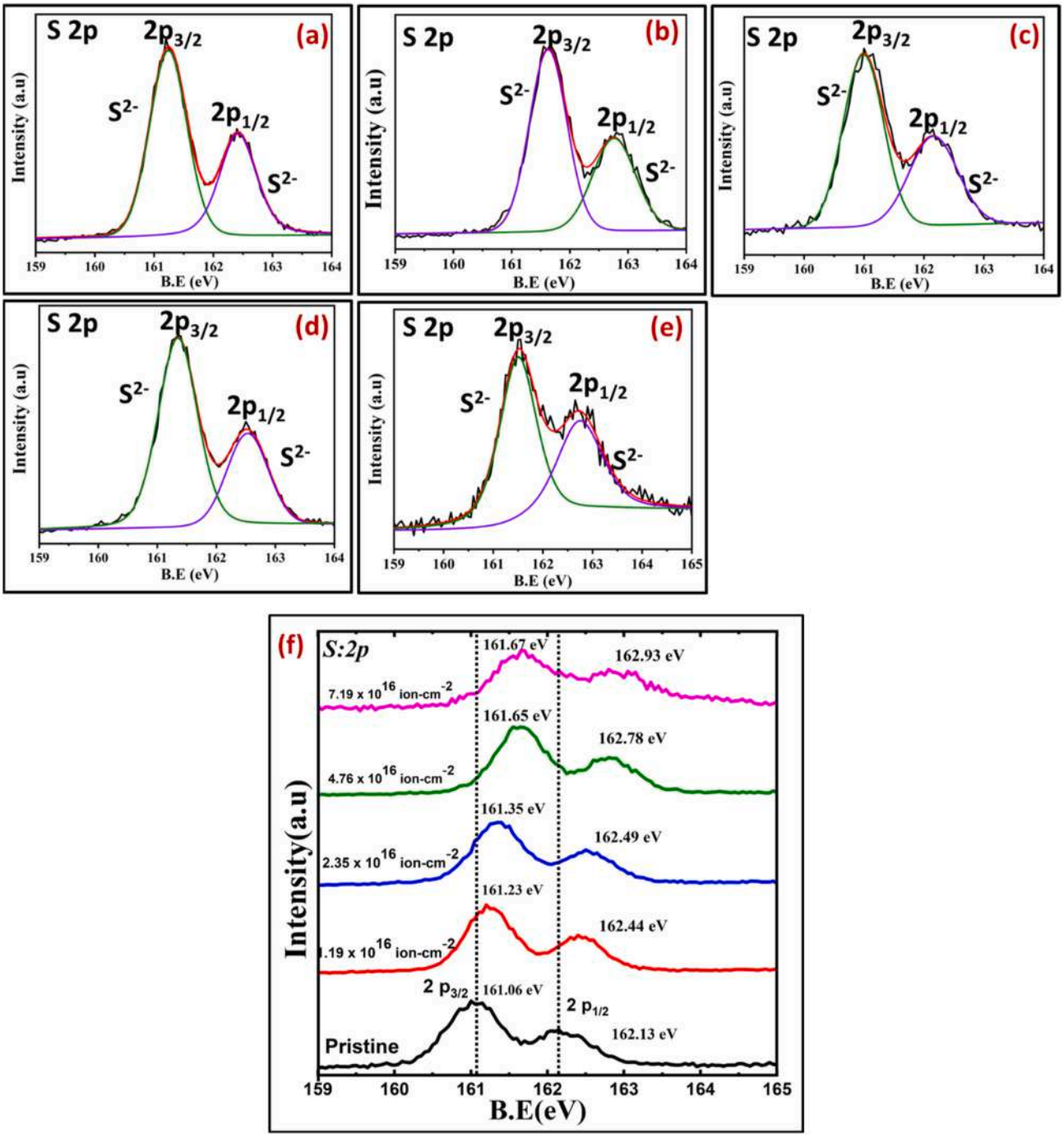

Fig. 8. XPS Spectra of S:*2p* for (a) pristine, (b) 1.19×10^{16} ion-cm^{-2}, (c) 2.35×10^{16} ion-cm^{-2}, (d) 4.76×10^{16} ion-cm^{-2} and (e) 7.19×10^{16} ion-cm^{-2} irradiated MoS_2 samples
(f): Shifting of S:2p peak with variations of fluence.

surface of MoS_2, lowers the conduction band edge with respect to the Fermi level and leaves the valence band edge unaltered [53]. Therefore, it is to be noted that the point defects in MoS_2 induce high density of states near the conduction band edge [54], which can be filled by electrons donated by external impurities. These induced states due to the oxygen at sulfur vacancies reduces the energy required for electron excitation to the conduction band, and result in reduced barrier height for irradiated MoS_2/Si thin film. In our case the value of barrier height is seen to decreases from 0.38 to 0.35 eV in light and for dark is varied from ~0.38 to ~0.37 as the ion fluence increases, the graph is shown Fig. 11 (a).

Unlike barrier height, the ideality factor is a parameter that describes the deviation of *I–V* characteristics of a MoS_2/Si diode from the ideal behaviour [55]. The ideality factor values for pristine and ion irradiated devices for dark and light are determined by using equation (6). As fluence increase from 1.19×10^{16} ion-cm^{-2} to 7.19×10^{16} ion-cm^{-2} the ideality factor decreases from ~2.8 to 2.08 for light and ~1.94 to ~1.14 in dark *I–V* characteristics. When ions are irradiated on the MoS_2/Si thin film, they increase the charge carrier concentration at the interface, reducing the ideality factor [55,56]. These effects can have important implications for the performance of MoS_2/Si-based electronic devices, and they need to be carefully controlled and characterized in order to

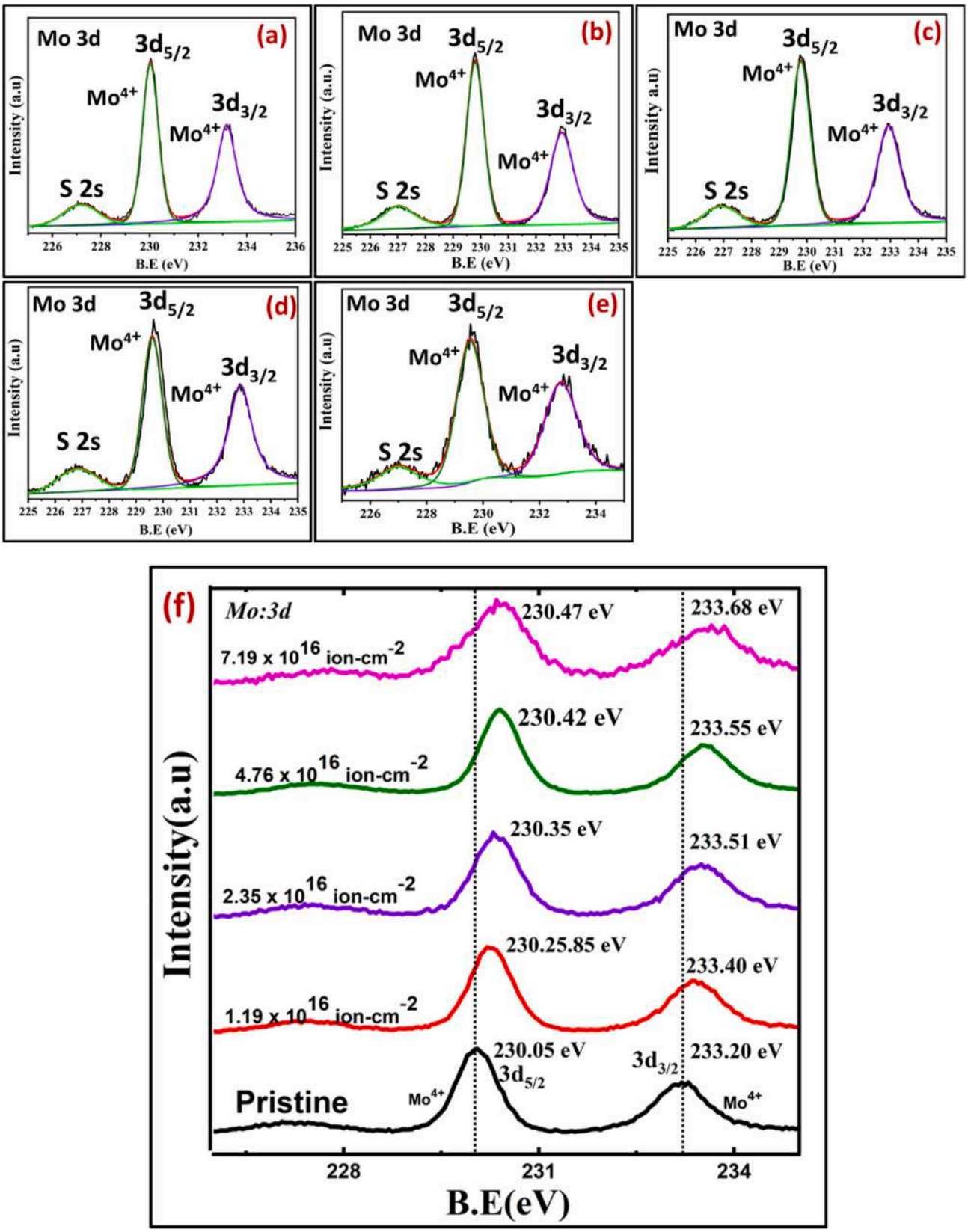

Fig. 9. XPS Spectra of Mo:*3d* for (a) pristine, (b) 1.19×10^{16} ion-cm^{-2}, (c) 2.35×10^{16} ion-cm^{-2}, (d) 4.76×10^{16} ion-cm^{-2} and (e) 7.19×10^{16} ion-cm^{-2} irradiated MoS_2 samples.
(f): Shifting of Mo:3 d peak with variations of fluence.

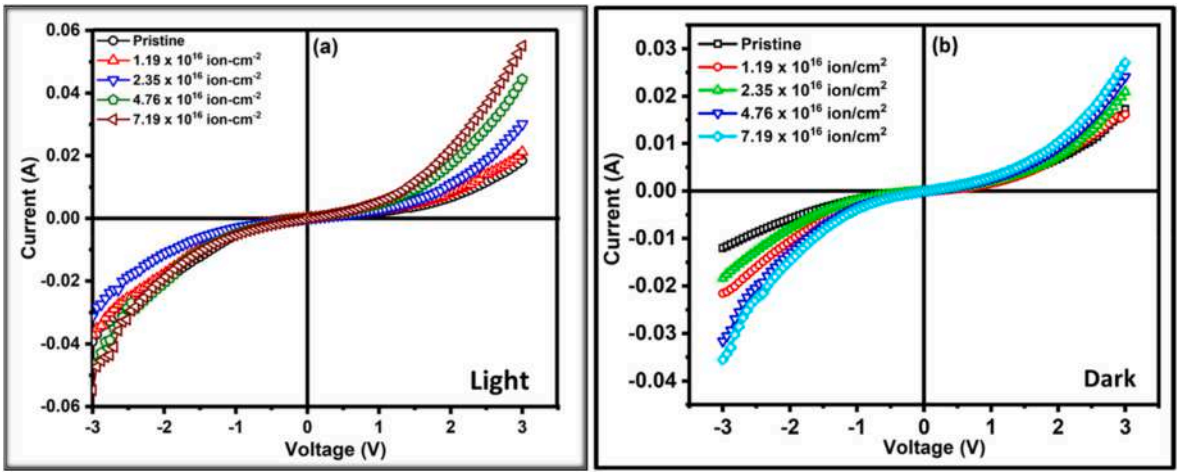

Fig. 10. *I–V* Characteristics of MoS_2/Si in a) Light b) Dark for pristine and irradiated samples.

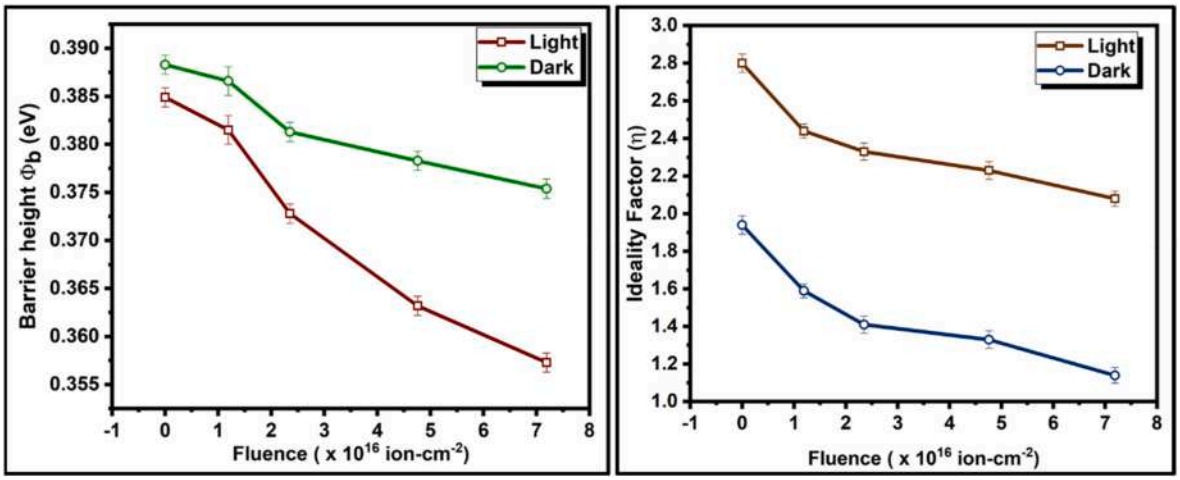

Fig. 11. Variation of (a) barrier height and (b) ideality factor with ion fluence.

optimize device performance. Therefore, as we increase the ion fluence, the barrier height and ideality factor decrease, resulting in increasing current in comparison to the pristine sample.

Fig. 12 shows the series resistance (R_s) variation of pristine and ion-irradiated MoS_2/Si thin films. It shows that the resistance decreases systematically from 400 Ω, 312 Ω, 294 Ω, 265 Ω and 212 Ω for pristine, 1.19×10^{16} ion-cm^{-2}, 2.35×10^{16} ion-cm^{-2}, 4.76×10^{16} ion-cm^{-2} and 7.19×10^{16} ion-cm^{-2} respectively. This indicates that oxygen occupancy at the sulfur vacancies indeed acts as dopant sites. Fig. 13 shows the photo response current with variation of ion fluence, along with rise and decay fitting of pristine and ion irradiated MoS_2/Si samples. Oxygen introduced into sulfur vacancy sites provides additional electrons into the MoS_2 lattice, increasing the concentration of free charge carriers (electrons) in the material. This higher carrier density enhances the conductivity of the material, leading to increased photo response current (see Fig. 14).

The Raman spectroscopy and XPS results show shift of A_{1g} peak to the lower wavenumber, and Mo:3 d and S:2p peaks shift to higher binding energy, respectively indicate the n-type doping of oxygen into MoS_2/Si thin film. When light shines on the ion irradiated MoS_2/Si, photons are absorbed, exciting electrons from the valence band to the conduction band. The doped oxygen atoms can act as electron traps, facilitating the transfer of these excited electrons to the conduction band and enhancing the overall photo response of MoS_2/Si thin film device. Further, by using photo-response current we measured the

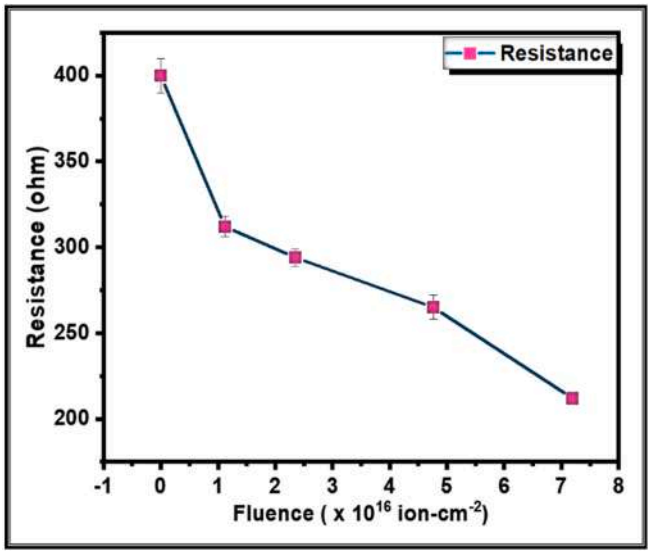

Fig. 12. Series resistance (R_s) variation with ion fluence of irradiated MoS_2/Si thin films.

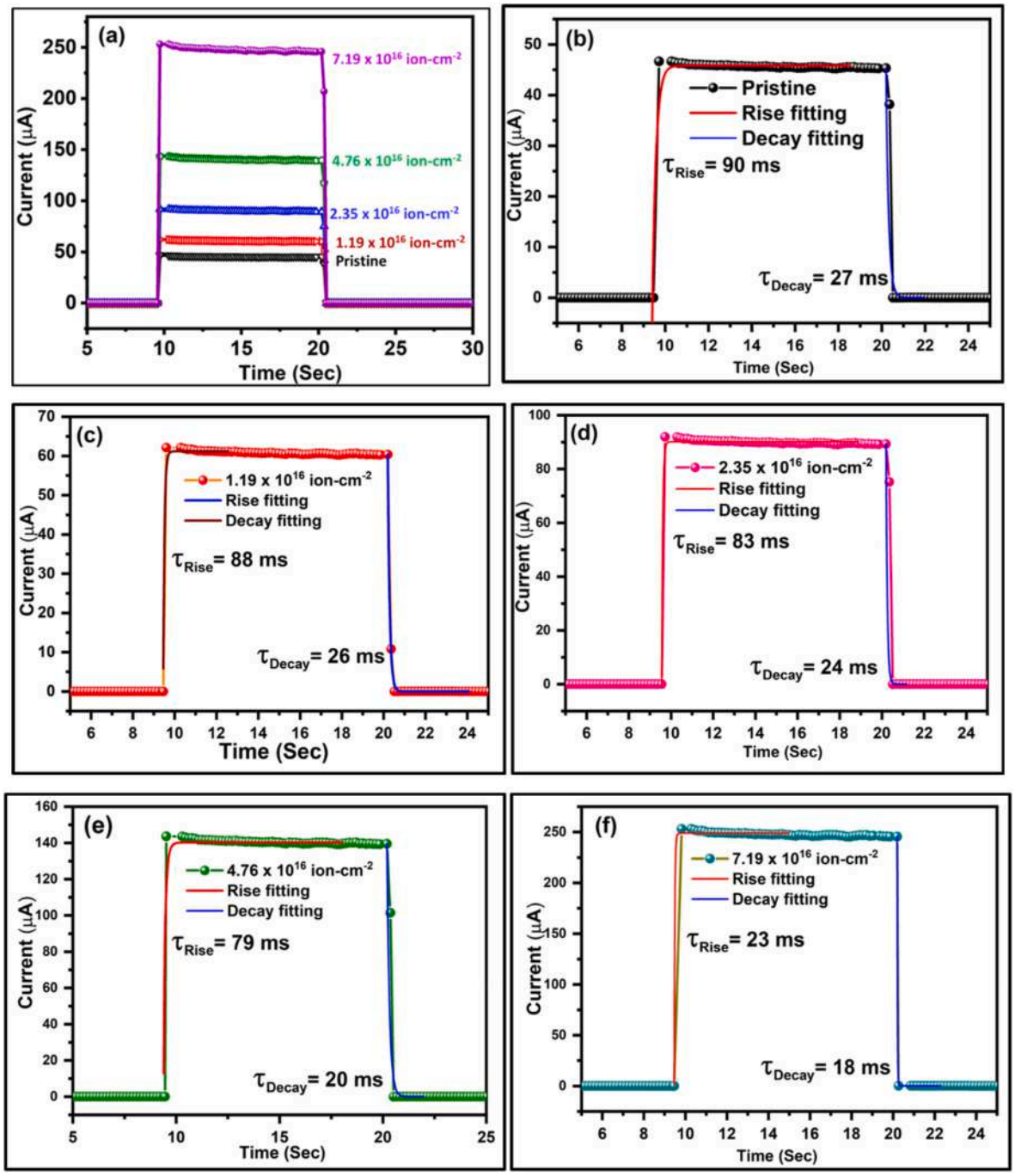

Fig. 13. (a) Photo response current variation with ion fluence; and rise and decay fitting of (b) pristine (c) 1.19 × 10^{16} ion-cm^{-2}, (d) 2.35 × 10^{16} ion-cm^{-2}, (e) 4.76 × 10^{16} ion-cm^{-2}, (f) 7.19 × 10^{16} ion-cm^{-2}.

photoresponsivity, photosensitivity, photodetectivity, rise and decay time for different nitrogen ion fluence in MoS_2/Si. The photoresponsivity is calculated as [57,58],

$$R_\lambda = \frac{\Delta I}{P_\lambda X A} \tag{7}$$

where, $P_\lambda = 12$ mW/cm^2 is the incident light intensity, $\Delta I = I_{photo} - I_{dark}$ is the change in photocurrent, and A is the active area of thin film. The formula for the Photosensitivity (ξ) calculation is expressed as [59,60].

$$\xi = \frac{I_{photo} - I_{dark}}{I_{dark}} \tag{8}$$

The photodetectivity (D^*) of a device is defined as signal to noise ratio and is measured in Jones. Photodetectivity is a figure of merit of the photodetector and calculated using following formula [61],

$$D^* = \frac{R_\lambda}{(2 \times e \times J_{Dark})^{\frac{1}{2}}} \tag{9}$$

where, e is electron charge, J_{Dark} is dark current density.

When light is absorbed by the doped material, electron-hole pairs are generated. The introduced oxygen atoms help to efficiently separate these charge carriers, preventing their recombination. This improved charge separation and increasing the photoresponsivity, photosensitivity and photodetectivity of the material. The values of Photoresponsivity, photosensitivity, photodetectivity, rise and decay time has

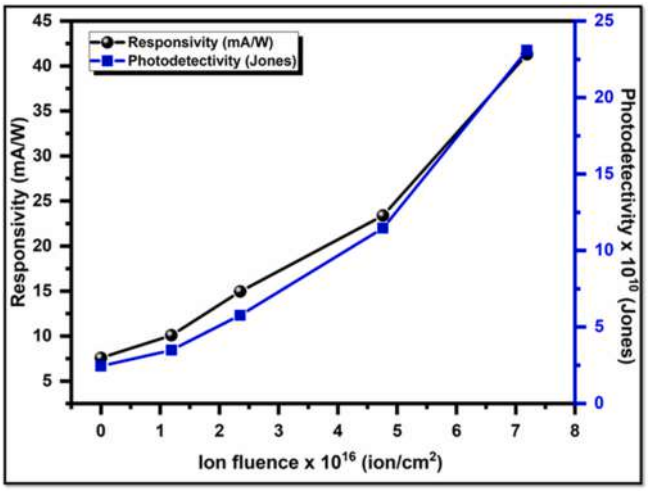

Fig. 14. Photoresponsivity and photodetectivity with variation of ion fluence.

Table 2
Photoresponsivity, photosensitivity, photodetectivity, rise and decay time for MoS_2/Si photodetector irradiated at different nitrogen ion fluence.

Ion Fluence (ion-cm^{-2})	Photo-responsivity R_λ (mA/W)	Photo-sensitivity (ξ)	Photodetectivity (D*) x 10^{10} Jones	Rise time τ_{Rise} (ms)	Decay time τ_{Decay} (ms)
pristine	7.5	151.6	2.4	90	27
1.19×10^{16}	10.0	232.6	3.4	88	26
2.35×10^{16}	14.9	427.3	5.7	83	24
4.76×10^{16}	23.3	1079.3	11.4	79	20
7.19×10^{16}	41.3	2478.9	23.1	23	18

been consolidated in Table 2. As the defect density increases due to ion irradiation, the photo Photoresponsivity, photosensitivity, and photodetectivity increase from 7.5 mA/W to 41.3 mA/W, 151.6 to 2478.9, and 2.4×10^{10} Jones to 23.1×10^{10} Jones, respectively, as compared to a pristine sample. We also calculate the Rise time (τ_{Rise}) and decay time (τ_{Decay}) from Fig. 13. For pristine MoS_2 rise time is 90 ms and as increasing the fluence it decreases up to 23 ms. Similarly, for decay time decreases from 27 ms to 18 ms as compared to pristine sample.

4. Conclusion

The RF sputtering method is an effective way to synthesize MoS_2 thin films on the p-type silicon substrate. These films are subsequently irradiated by nitrogen ions at varying fluence. As the fluence increased from 1.19×10^{16} ion-cm^{-2} to 7.19×10^{16} ion-cm^{-2}, the average inter-defect distance (L_D) decreased from 9.2 nm to 3.7 nm. As fluence increased Raman peaks shifted towards a lower wave number. The shifting of Raman peaks of E_{2g} and A_{1g} represent the decrease in bond strength between the atoms, causing a decrease in the vibrational frequency. Further, the surface composition of pristine and ion-irradiated MoS_2 thin films studied using XPS show shift in the binding energy and decrease in the intensity of S:*2p* and Mo:*3d* peaks, denoting formation of MoO_x after ion irradiation. Furthermore, as increasing nitrogen fluence facilitates formation of sulfur vacancies on the surface of MoS_2 nanosheet and these vacant sites are occupied by oxygen atoms, forming the MoO_x bonds are corroborated in Raman and XPS results. The bandgap decreases from ~1.46 eV to ~1.33 eV with irradiation of samples due to the introduced oxygen at sulfur vacancy sites. The oxygen doped into MoS_2/Si thin film is responsible for the increased current, decrease in barrier height and ideality factor, with the increase in fluence of irradiation. Further, with variation of ion fluence, photoresponsivity, photosensitivity, and photodetectivity increase from 7.5 mA/W to 14.7 mA/W, 151.6 to 2478.9, and 2.4×10^{10} Jones to 23.1×10^{10} Jones, respectively. To summarize, all the obtained results are in corroboration and strongly indicate that the presence of defects significantly impacts the electrical properties of the material. Consequently, depending on the distinct electrical properties brought about by ion irradiation, the MoS_2 thin films have the potential to serve various optoelectronic applications.

Ethical statement

This article does not contain any studies with human participants or animals performed by any authors.

CRediT authorship contribution statement

P.T. Kolhe: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Y.V. Hase:** Resources, Methodology. **P.R. Jadhav:** Resources. **V.S. Ghemud:** Resources. **A.M. Sonawane:** Resources. **S.R. Jadkar:** Resources. **S.N. Dalvi:** Resources. **Shashikant P. Patole:** Resources. **S.D. Dhole:** Resources. **S.S. Dahiwale:** Visualization, Validation, Supervision, Investigation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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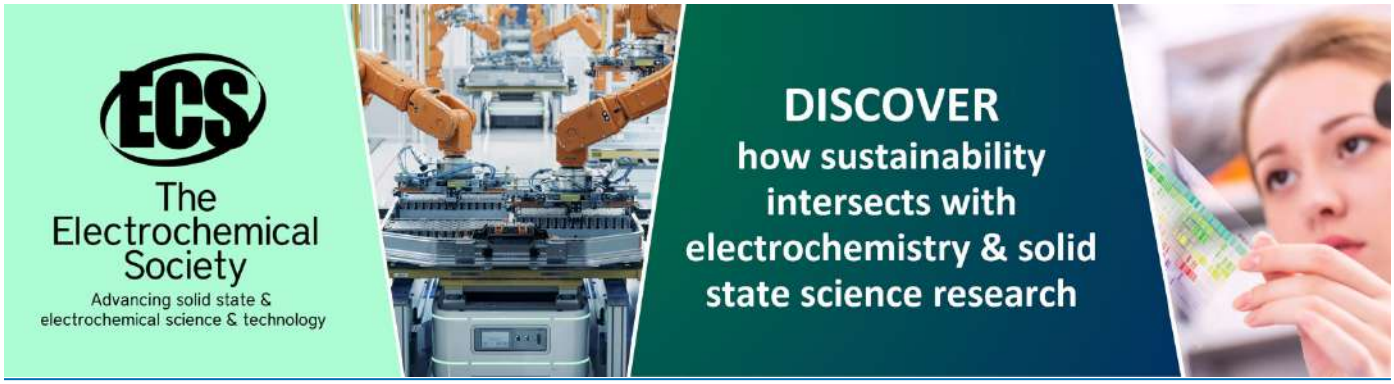

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Modification of WS_2 thin film properties using high dose gamma irradiation

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Abstract

The tunability of the transition metal dichalcogenide properties has gained attention from numerous researchers due to their wide application in various fields including quantum technology. In the present work, WS_2 has been deposited on fluorine doped tin oxide substrate and its properties have been studied systematically. These samples were irradiated using gamma radiation for various doses, and the effect on structural, morphological, optical and electrical properties has been reported. The crystallinity of the material is observed to be decreased, and the results are well supported by x-ray diffraction, Raman spectroscopy techniques. The increase in grain boundaries has been supported by the agglomeration observed in the scanning electron microscopy micrographs. The XPS results of WS_2 after gamma irradiation show evolution of oxygen, carbon, C=O, W–O and SO_4^{-2} peaks, confirming the addition of impurities and formation of point defect. The gamma irradiation creates point defects, and their density increases considerably with increasing gamma dosage. These defects crucially altered the structural, optical and electrical properties of the material. The reduction in the optical band gap with increased gamma irradiation is evident from the absorption spectra and respective Tauc plots. The *I–V* graphs show a 1000-fold increase in the saturation current after 100 kGy gamma irradiation dose. This work has explored the gamma irradiation effect on the WS_2 and suggests substantial modification in the material and enhancement in electrical properties.

Keywords: WS_2 thin film, high dose gamma irradiation, enhanced electronic property, Raman spectra, XPS

Introduction

The transition metal dichalcogenides (TMDCs) have gained interest from researchers due to the size dependent and tunable properties. The most interesting and focused TMDCs are MoS_2 and WS_2. These materials show variation in properties when moving from bulk to nanosheets or a few layered structures. The two-dimensional transition metal dichalcogenides (2D-TMDs) show possible application in the fields where graphene is used, due to the similarity in the properties. There have been many studies reported on TMDCs showing the transformation in indirect band gap nature in bulk form to a direct band gap in mono- or few-layered structure. The changes in optical properties have explored their application in optoelectronics [1]. The TMDCs are layered materials consisting of a transition metal atom like molybdenum, tungsten, or titanium sandwiched between two chalcogen atoms (like sulfur, selenium or tellurium) and have a hexagonal lattice structure [2]. These materials exhibit unique mechanical, optical and electronic properties. The tunable

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band gap and high carrier mobility have opened applications for 2D-TMDCs in optoelectronics, catalysis and photovoltaics [3]. Molybdenum disulfide (MoS_2) shows a direct band gap nature and has shown promising electronic and optical properties, making it the most explored TMDC. It has found its potential in photovoltaic, energy storage, catalysis, field-effect transistors (FETs) and sensors [4–8].

Another TMDC of interest is tungsten disulfide (WS_2), which also has a hexagonal structure with tungsten atoms sandwiched between two sulfur atoms. WS_2 has an indirect band gap when in bulk, and this can be tuned easily by breaking down the material in to a few layers or monolayer [9]. WS_2 changed to a direct band gap with reduction in number of layers, which plays a key role in modification of the property. This property makes it a promising material for the application in FETs, optoelectronics and photovoltaics [10–12]. The WS_2 has been synthesized using vacuum and non-vacuum techniques like hydrothermal or solvothermal synthesis, chemical vapor deposition (CVD) and solid-state reaction [13–16]. The hydrothermal or solvothermal method allows synthesis of WS_2 with specific structural morphology and property by varying the reactant concentration and reaction parameters. The CVD method allows controlled growth of WS_2 films possessing the desirable number of layers with a controlled thickness along with large area synthesis.

The present study related to the interaction of radiation with synthesized materials has shown altered optical and electrical properties and opens up many possible applications. The gamma irradiation of a sample results in creation of point defects which are reflected from the changes recorded in the structural, morphological, optical and electrical properties [17]. The incident gamma radiation ionizes the materials atoms/molecules and create vacancy/interstitial defects. The effect of gamma irradiation depends on the dose of radiation, and atomic masses of the material's constituents. The materials which show a reasonable change in their properties are often chosen for application as radiation detectors, while those with negligible effects are used in space applications [18]. WS_2 consists of a heavy element W but also has a lighter S, which makes it responsive toward gamma irradiation. The literature suggests WS_2 to be a promising candidate for gamma detection, as relevant changes are observed in its properties after irradiation [19].

In one of the studies carried out on single layer WS_2, Aggarwal *et al* have grown monolayer WS_2 using CVD and further irradiated the samples with gamma radiation. The irradiation triggers sulfur vacancy and induces p-type doping as seen from the shifts in Raman and x-ray photoelectron spectroscopy (XPS) peak positions [20]. In another work, Felix *et al* reported gamma irradiated WS_2 samples grown using scalable van der Waals epitaxial method. They share similar observations about gamma irradiation leading to the formation of defects resulting in p-type doping in the samples [21]. In addition to the electrical property alteration, they also demonstrated a change in the nature of the sample from diamagnetic to ferromagnetic behavior post high dose gamma irradiation. In a similar study, Sarmah *et al* have published work showing the change in the magnetic properties of nanoscale WS_2 and suggested the optoelectronic and spintronic applications of the sample [22].

Most of the works available in the literature are related to monolayer or bulk WS_2 and the effect of doping or low energy irradiation. The systematic and comprehensive study of the structural, morphological, optical and electronic properties of WS_2 thin films, as well as the effect of high gamma irradiation, has not been explored explicitly in the literature yet. In this work, the effects of ^{60}Co gamma radiation dose on the properties of few-layered WS_2 are examined and discussed. Raman and XPS results demonstrate that the radiation generates defects, and their density increases with the radiation dose. In general, irradiation increases the conductivity in WS_2 samples and this has been validated through *I–V* measurement.

Experimental details

The SRL grade bulk WS_2 in powder (99% pure) was dissolved in dimethyl formamide (DMF) 99% alfa acer as an exfoliation medium. The exfoliation process was used to improve the surface energy of WS_2 powder sample [23]. A 150 ml Borosil glass bottle sealed with parafilm tape was used to exfoliate WS_2 samples. The sample was sonicated (Microclean 102, Oscar Ultrasonic of 80 W) for 24 h while keeping the bottle sealed. Further, this exfoliated product was centrifuged at 3000 rpm for 15 min and the supernatants were separated. The separated supernatants were then dried using hot air oven for 10 h at 60 °C.

Sample preparation and gamma irradiation

The powder sample obtained after exfoliation of bulk WS_2 was used for thin film deposition using electrophoretic deposition (EPD) technique [24]. Firstly, fluorine doped tin oxide (FTO) coated glass of dimensions 20 mm × 10 mm was cleaned by immersing in a mixture of acetone and ethanol, and ultrasonicated for 10 min. The exfoliated WS_2 powder was then added to a 200 ml glass beaker containing 150 ml isopropyl alcohol (IPA) and stirred for 1 h. Magnesium nitrate was added to this solution and the beaker was fitted with two electrodes (FTO and platinum) for EPD of the WS_2 thin film. FTO substrate and platinum electrode were positioned in parallel to each other with a separation of 5 mm. A constant voltage of 50 V DC applied between the two electrodes for 5 min, resulting in deposition of WS_2 film on FTO substrate. The deposited film was washed thoroughly with distilled water and dried in vacuum oven for 12 h at 80 °C. This sample is referred to as 'as-deposited'. The sample preparation process is visually illustrated in figure 1(a). Some of these films were used for Co-60 gamma irradiation and further characterized using various techniques in order to explore the effect of radiation on the sample.

The WS2 films were sealed in a glass bottle and subjected to irradiation using ^{60}Co gamma source available at Department of Chemistry, Savitribai Phule Pune University.

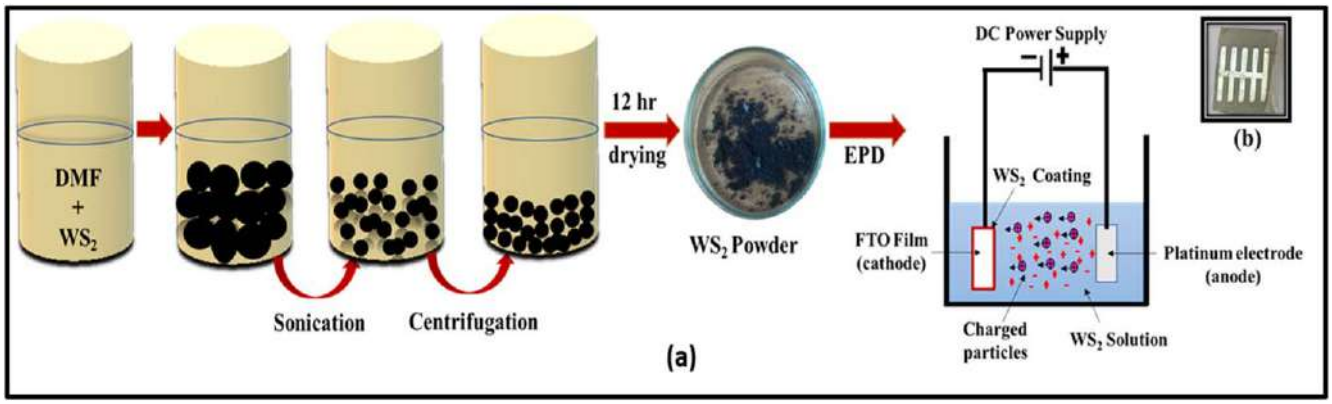

Figure 1. (a) Schematic of steps followed for WS_2 film deposition on FTO substrate and (b) photograph of to a grind contact on WS_2 made for *I–V* measurement.

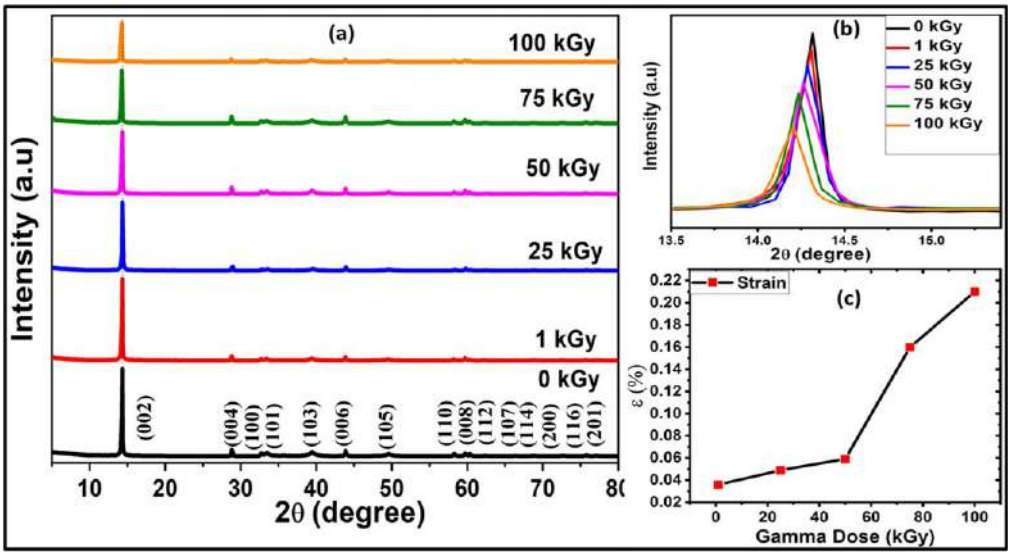

Figure 2. (a) XRD pattern of WS_2 films before and after gamma irradiation at various doses, (b) the shift in dominant (002) plane, and (c) variation of strain with increasing gamma dose.

The films were irradiated at varying doses ranging from 1 to 100 kGy, with a dose rate of 1.2 kGy hr^{-1}. The time duration of irradiation was varied to obtained samples with different doses as 0 kGy (pristine), 1 kGy, 25 kGy, 50 kGy, 75 kGy and 100 kGy. The as deposited and irradiated samples were used for comparative analysis.

Material characterizations

Various characterization techniques were used to systematically study the as-deposited WS_2 and the gamma irradiated films. The structure of the thin films and the effect of irradiation on the peak positions and crystallite size was investigated using x-ray Diffractometer (BRUKER D8 ADVANCE) with Cu Kα (λ = 1.5418 Å) source. Raman spectroscope (RenishawInVia Raman microscope) having excitation wavelength of 532 nm and scanning in the range of 100–800 cm^{-1} was used to confirm and support the XRD structural studies. The elements present in the samples and the change in chemical composition were studied using XPS (Thermo Scientific, K-Alpha+, U.K.). The surface morphology and elemental composition (EDAX) studies were carried out using scanning electron microscopy (JEOL JSM-6360-LA) technique. The optical properties were also studied by obtaining the absorption spectra of WS_2 thin films in the wavelength range of 200–800 nm using UV Visible-NIR spectrophotometer (JASCO, V-670). The current–voltage (*I–V*) characteristic curve for the device was performed using a Xe-based light source solar simulator with simulated 1 Sun AM 1.5 G illumination and Keithley 2450 source meter.

Results and discussion

The XRD pattern of the pristine and gamma irradiated WS_2 films is shown in figure 2(a). The diffraction angle (2θ) associated with each plane depicted over the pristine sample

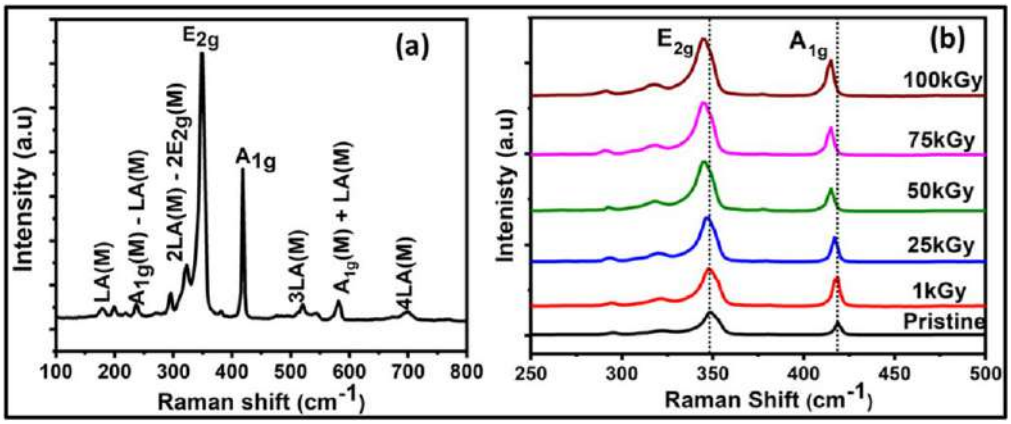

Figure 3. (a) Raman spectra of Pristine WS_2 sample showing characteristic peaks, and (b) the shift of major in-plane and out-of-plane peaks with variation in gamma dosage.

XRD pattern. The diffraction peaks at 14.32°, 28.86°, 32.74°, 33.55°, 39.51°, 43.87°, 49.64°, 58.38°, 59.77°, 60.49°, 62.54°, 66.45°, 68.65°, 69.85° and 75.90° are identified as the respective crystallographic planes for (002), (004), (100), (101), (103), (006), (105), (110), (008), (112), (107), (114), (200), (116) and (201), as evident from JCPDS file no. (08–0237) [25]. The absence of any extra peak in the XRD spectra indicates the formation of pure hexagonal structure bearing P63/mmc space group (group no. 194). Notably, the peak located at 14.32° has the highest intensity making (prominent peak) signifying the most preferred orientation along the (002) plane.

It is observed from figure 2(b) that as the gamma irradiation dose increases, there is significant intensity reduction along with a shift in (002) peak toward the lower 2θ value. The shift in the prominent peak suggests introduction of defect in WS_2 caused by gamma irradiation. More over the reduction in the peak intensity suggests a decrease in the crystallinity of the samples. This reduction in crystallinity is attributed to the displacement of the lattice atoms induced by gamma radiation which leads to the formation of disordered crystals and facilitates the creation of sulfur vacancy defects [26]. Figure 2(c) shows lattice strain as a function of gamma dose. It is clearly seen that up to a gamma dose of 50 kGy there is no significant change in lattice strain however drastic change is observed above 50 kGy.

The average crystallite size calculated from XRD spectra using Scherer's formula and the out-of-plane strains for different samples calculated using Williamson–Hall (W–H) method [27] are summarized in table 1. The crystallite size decreases from 546 to 439 nm for pristine to 100 kGy gamma irradiated samples respectively, and the strain increases indicating either creation of defects or due to possible agglomeration of the particles [28]. Also, results agree with the reduction in peak intensity observed in XRD pattern.

The structural properties of WS_2 are generally discussed using Raman spectroscopy which provides a detailed and precise understating of the formed structure and the defects in the materials. To support the change in structural properties and creation of sulfur vacancies due to gamma irradiation, Raman spectra has been studied. The Raman spectra of pristine WS_2 sample in figure 3(a) show the peaks at ∼ 175.6, 236, 295.34, 348.55, 420, 517, 583.26, and 701 cm^{-1} corresponding to LA(M), $A_{1g}(M) - LA(M)$, $2LA(M) - E_{2g}(M)$, E_{2g}, A_{1g}, 3LA (M), $A_{1g}(M) + LA(M)$ and 4LA(M) modes respectively. These peaks and their positions agree with the earlier reports available in the literature [29]. The E_{2g} mode involves an in-plane vibration of the W atoms with respect to the S atoms, while the A_{1g} mode arises from the vibrations of S atoms in out-of-plane direction [21, 30]. Since the difference between A_{1g} and E_{2g} modes is about 70 cm^{-1}, it indicates that the WS_2 samples are only a few layers.

Table 1. Variation of observed (002) peak position, FWHM, and calculated out-of-plane strain, average crystallite size from XRD spectra with gamma irradiation.

Gamma irradiated sample	Peak position of (002) plane (2θ)	FWHM of (002) plane	Out-of-plane strain (ε%)	Average crystallite size (D) (nm)
Pristine	14.31	0.151	—	547
1 kGy	14.30	0.156	0.036	527
25 kGy	14.28	0.158	0.049	521
50 kGy	14.26	0.160	0.059	516
75 kGy	14.23	0.179	0.16	461
100 kGy	14.18	0.187	0.20	440

Figure 3(b) illustrates the Raman peak shift observed in the spectra of gamma irradiation WS_2 thin films. It shows that with increasing gamma dose from 1 to 100 kGy, both the E_{2g} and A_{1g} modes are shifted to lower wavenumber i.e. red shifted. The A_{1g} mode is attributed to the out-of-plane vibration of sulfur atoms with respect to tungsten atom. Considering WS_2 molecule as a simple harmonic oscillator so that its vibrational frequency is,

$$\omega = \sqrt{\frac{k}{m_e}}. \tag{1}$$

The shift of vibrational frequency (ω) may be observed due to the change in force constant (k) and/or effective mass (m_e), caused by radiation induced sulfur vacancies [20, 31, 32]. The creation of sulfur vacancy (V_S) by gamma irradiation reduces k,

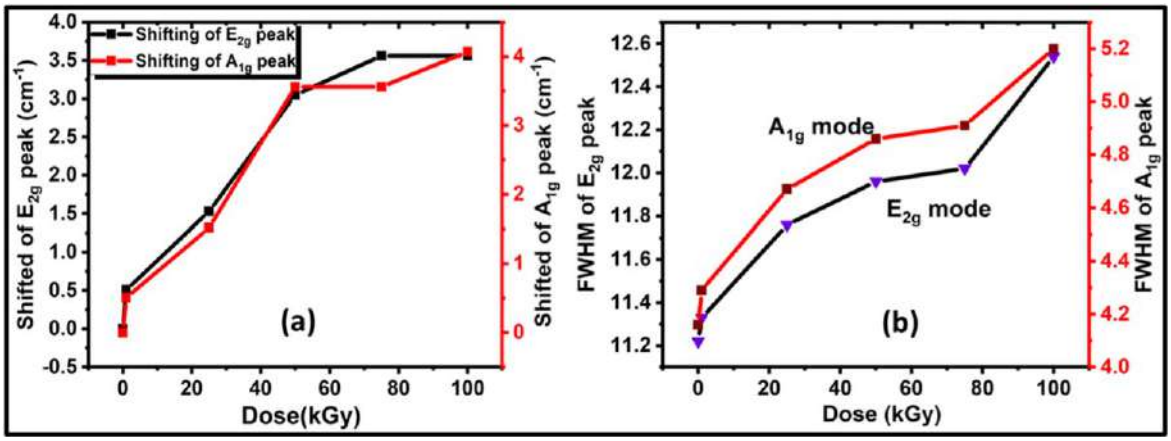

Figure 4. (a) Comparative shifting of E_{2g} and A_{1g} modes, and (b) variation in FWHM with increasing gamma dose from pristine to 100 kGy sample.

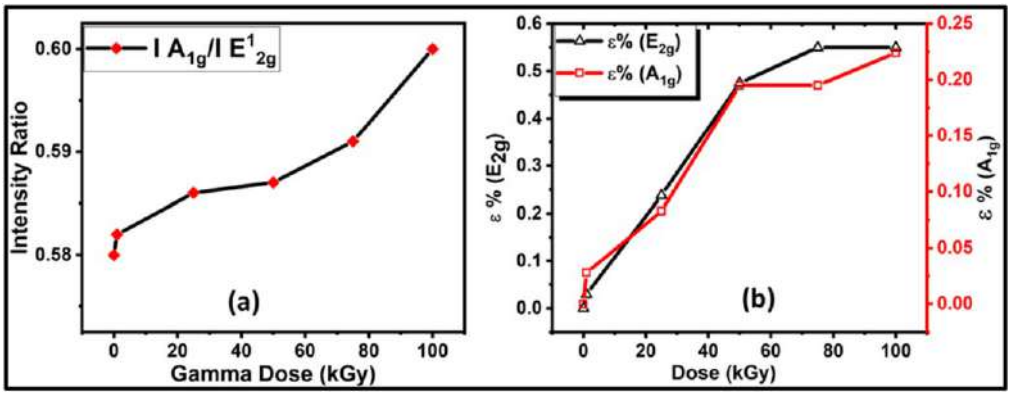

Figure 5. (a) Peak intensity ratio, and (b) in-plane and out-of-plane strain as a function of different gamma dose.

resulting in the red shift of the characteristic peaks. It is claimed that, sulfur vacancies converts WS_2 system to W–S system. In these two atomic systems the effective mass enhances resulting in decreased vibrational frequency, which shifts the Raman peak towards right i.e. blue shift. In our case, we observe red shift which could be due to the following reason: with increase in gamma irradiation the sulfur vacancies are increasing and at the same time these sulfur vacancies are occupied by the oxygen (as the gamma irradiation is carried out in ambient condition). As a result, one of the sulfur in WS_2 having atomic mass number 32 is replaced by oxygen having atomic mass number 16, which results in the reduction of force constant and effective mass, in turn reducing vibrational frequency. The increasing radiation dose continues to removal of more sulfur atoms and simultaneously occupied by oxygen atoms, further enhancing the peak shift [20]. Hence, the sulfur vacancies can be seen to be dominant in our material and are the reason for red shift of Raman peaks.

The noticeable shifting of E_{2g} and A_{1g} mode in response to variation of gamma dose is shown in figure 4(a). Moreover, the intensity of both the A_{1g} and E_{2g} modes is found to increase with the irradiation dose. The increase in radiation dose reduces crystallinity of the samples concurrently increasing full width at half maxima (FWHM) of these peaks, as shown in figure 4(b). It is observed that, with increase in gamma dose the FWHM for E_{2g} mode of vibration increases from 11.22 to 12.54 for 0 kGy–100 kGy respectively. Similarly, for A_{1g} mode, the FWHM increases from 4.16 to 5.2 for 0 kGy to 100 kGy respectively.

The variation of FWHM is mainly due to the presence of tensile strain and is calculated using the equation (2) [31]

$$\varepsilon = \frac{\omega_0 - \omega}{2\gamma\omega_0}. \tag{2}$$

where ω_0 and ω are the frequencies before and after irradiation respectively, and γ is the Gruneisen parameter. The values $\gamma(E_{2g}) = 0.92$ and $\gamma(A_{1g}) = 2.17$ for WS_2 is taken from the literature [33]. This parameter describes the effect on its vibrational properties due to the change in volume of crystal lattice. Figure 5(a) shows the increase in peak intensity ratio $I(A_{1g})/I(E_{2g})$ with the increase in gamma irradiation dose. Also, the maximum tensile strains of 0.55% and 0.22% were deduced for the in-plane (E_{2g}) and out-of-plane (A_{1g}) modes respectively for 100 kGy dose and it is shown in figure 5(b). It is also observed that the value of in-plane strain is higher as compared to the out-of-plane strain. As our WS_2 samples are few layered, the van der Waal interactions are considerable and causing the gradual stiffening of

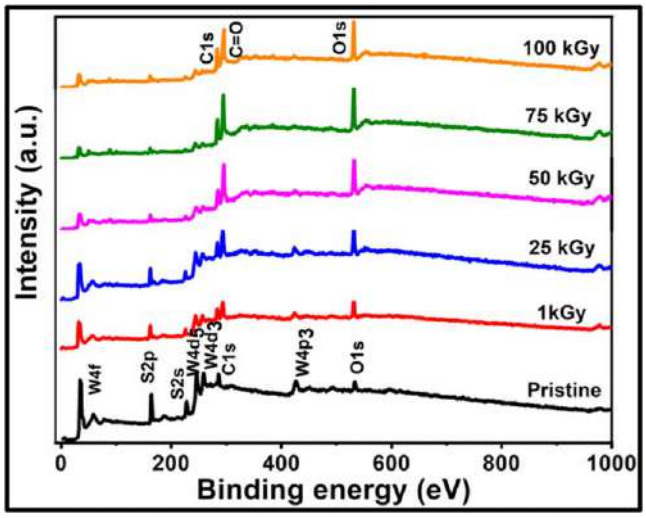

Figure 6. Full survey scan of pristine and gamma irradiated WS_2.

out-of-plane resulting in lesser effect of gamma irradiation than that on the in-plane vibration [20, 31, 32]. Therefore, the structural characterization results obtained from XRD and Raman spectroscopy suggest evolution of sulfur vacancy, oxygen occupancy and reduction in crystallinity of the samples with increasing gamma irradiation. To confirm our speculation that gamma irradiation results in evolution of sulfur vacancy and subsequent occupied by oxygen, XPS analysis was carried out.

The XPS is an effective technique to investigate surface chemical states, elemental composition, electronic and oxidation states of the elements present in the sample. The full survey scan in figure 6 shows the reduction of W and S elements, with a gradual increase in C and O in the gamma irradiated samples. The intensity of peaks corresponding to W and S at 32.13 eV and 34.39 eV, and at 161.62 eV and 162.80 eV, respectively, is observed to decrease by more than 50% in the 100 kGy irradiated sample compared to that of the pristine [20, 34]. While the peaks at 285 eV, 289 eV and 530 eV attributed to C, C=O and O respectively are observed to get intense with increasing gamma irradiation [35].

The region near the characteristic peaks position of S and W in WS_2 has been magnified and represented in figures 7 and 8 respectively. The peaks were fitted for both W and S lines using XPS PEAK 41 software. The $2p_{3/2}$ and $2p_{1/2}$ states of S^{2-} are positioned at 161.62 eV and 162.80 eV respectively (figure 7(a)) [20, 34]. The XPS spectra of the pristine sample shows the $4f_{7/2}$, $4f_{5/2}$ and $5p_{3/2}$ states of W^{4+} corresponds to peaks at 32.13 eV, 34.29 eV and 37.58 eV respectively (figure 8(a)) [20, 34]. After irradiation, the states $4f_{7/2}$, $4f_{5/2}$ and $5p_{3/2}$ seem to be localized at 32.61 eV, 34.67 eV and 37.95 eV, respectively [34]. The energetic photons create sulfur vacancies and the oxygen from atmosphere occupies these sites. In the deconvolution figures 8(c)–(g), the peak emergence at 35.65 eV corresponds to the W^{6+} state, suggesting the W–O bond formation [20, 36]. Further, this peak intensity is increasing with an increase in gamma dose, this confirms our claim that indeed after irradiation sulfur vacancies are increasing and these vacancies are subsequently occupied by oxygen atoms. After irradiation the sulfur state $2p_{3/2}$ corresponding to 162.20 eV and the 162.80 eV peaks have merged, as seen from figures 7(c)–(g). After 1 kGy dosage an additional peak emerges at 168.9 eV and is consistent with S^{2-} peak position which corresponds to the presence of sulfate species SO_4^{-2} [21, 22].

The results show 0.4 eV shift towards higher binding energy for both W and S, shown in figures 7 (a) and 8(a). From figure 8, we observe at a radiation dose of 100 kGy, the $4f_{7/2}$ and $4f_{5/2}$ peak intensities decrease by approximately 70% with respect to their corresponding pristine WS_2 peak intensities. This peak intensity decreases with an increase in gamma radiation dose is due to a several factors. One possibility is the damage caused to the sample surface by the gamma radiation, and leading to the changes in its chemical composition or structure [21]. This may result in a decreased number of available photoelectrons, which results to a decrease in XPS peak intensity. As a result of gamma irradiation effect, numerous S sites became de-atomized, resulting in unsaturated bonds in the lattice. The interaction of gamma radiation with WS_2 causes the breaking of sulfur atoms from the material, which then initiate oxygen present in the air to either react with unsaturated W bond to form W–O or to sulfur to form sulfur dioxide (SO_2). This SO_2 gas can then react with more oxygen in the air to form additional oxygen molecules, resulting in an overall increase in oxygen content and would form a stable SO_4^{-2} in the system [20]. The oxygen has high electron affinity and the surface charge transfer in the film will create O^{-2} leading to stable sulfate formation. Hence, sulfur changes its oxidation state from 2− to 6+, and as this change requires high energy, it occurs at higher gamma irradiation dose.

Overall the XPS analysis suggest the formation of W–O bonds along with SO_4^{2-}. This supports our claim done XRD as well as Raman, where in we said the increase in strain and decrease in crystallinity is due to oxygen occupying the sulfur sites. The XPS results additionally show the strong peak of SO_4^{2-} formation also and we believe this could be the additional reason for the reduction in crystallinity of the WS_2 films with irradiation.

The SEM images in figure 9 show the surface morphology of the WS_2 pristine and gamma irradiated samples. The SEM micrograph of the pristine WS_2 sample in figure 9(a) shows formation of uniformly distributed microstructure with a magnification of 1000 times, and the inset image is of the same sample with 6000 times magnification. The surface morphology and grain size have been significantly altered by the incident gamma radiation, as can be seen from the figures 9(b)–(f). The morphology of the pristine sample looks like uniform separated thin flakes, while with the increasing gamma dose from 1 to 100 kGy, these uniform flakes gets reduced and agglomerate. Figure 9(f) shows that, for maximum γ-irradiation dose of 100 kGy the grain size has increased drastically due to agglomeration and has resulted in smoothening of the surface [37]. The agglomeration might be one of the reasons to reduce the crystallinity as it was observed in XRD. The thickness of the pristine and 100 kGy gamma irradiated sample is found to be 15.76 μm and

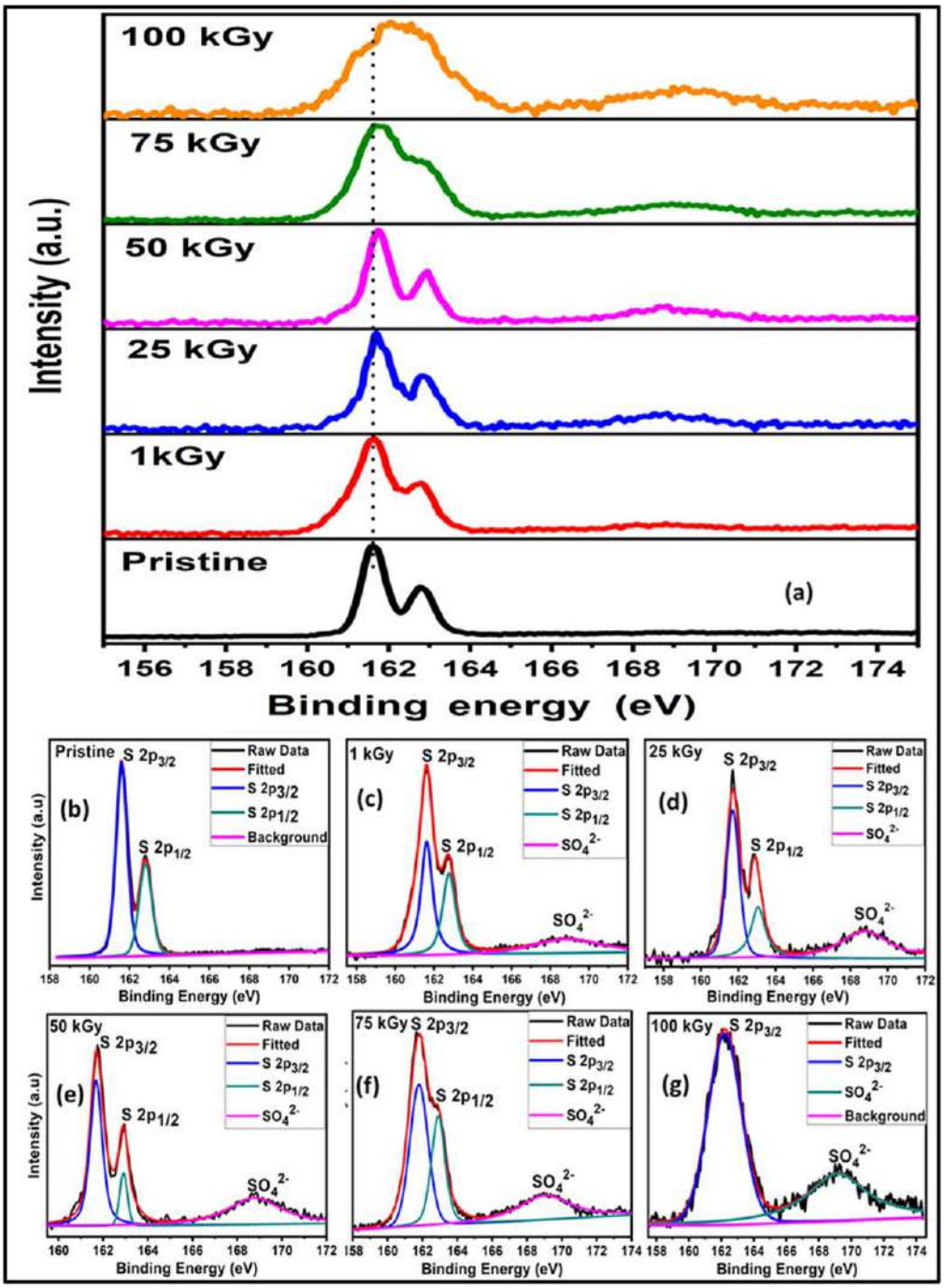

Figure 7. Shift in XPS peaks of S, (a) comparative pristine and gamma irradiated, (b) pristine, (c) 1 kGy (d) 25 kGy, (e) 50 kGy (f) 75 kGy and (g) 100 kGy gamma irradiated and deconvoluted spectra.

15.70 μm respectively using cross-section image of SEM, as shown in figures 9(g) and (h). Therefore, the thickness of the samples seems to be unaltered post irradiation.

The energy-dispersive x-ray spectroscopy (EDS) was also implemented along with SEM using the same instrument for generating the surface elemental composition if the WS_2 samples. Figures 10(a)–(c) consists of elemental composition for pristine, 50 kGy and 100 kGy gamma irradiated samples respectively. These EDS graphs and inset elemental mapping images show the systematic decrease in W and S composition and increase in O with increase in the irradiation dose. The colored micrographs representing the elemental mapping shown in the figure 10 inset show increasing O concentration. In the inset S, W and O are depicted by green, blue and red color, respectively. The decrease in the W and S concentrations has reduced in such a way that the stoichiometry of the material is maintained, which is also seen from other structural characterization techniques. The obtained elemental compositions have been summarized in the table 2, confirming the increase in oxygen percentage with increasing the gamma dose and are in good agreement with the XPS results.

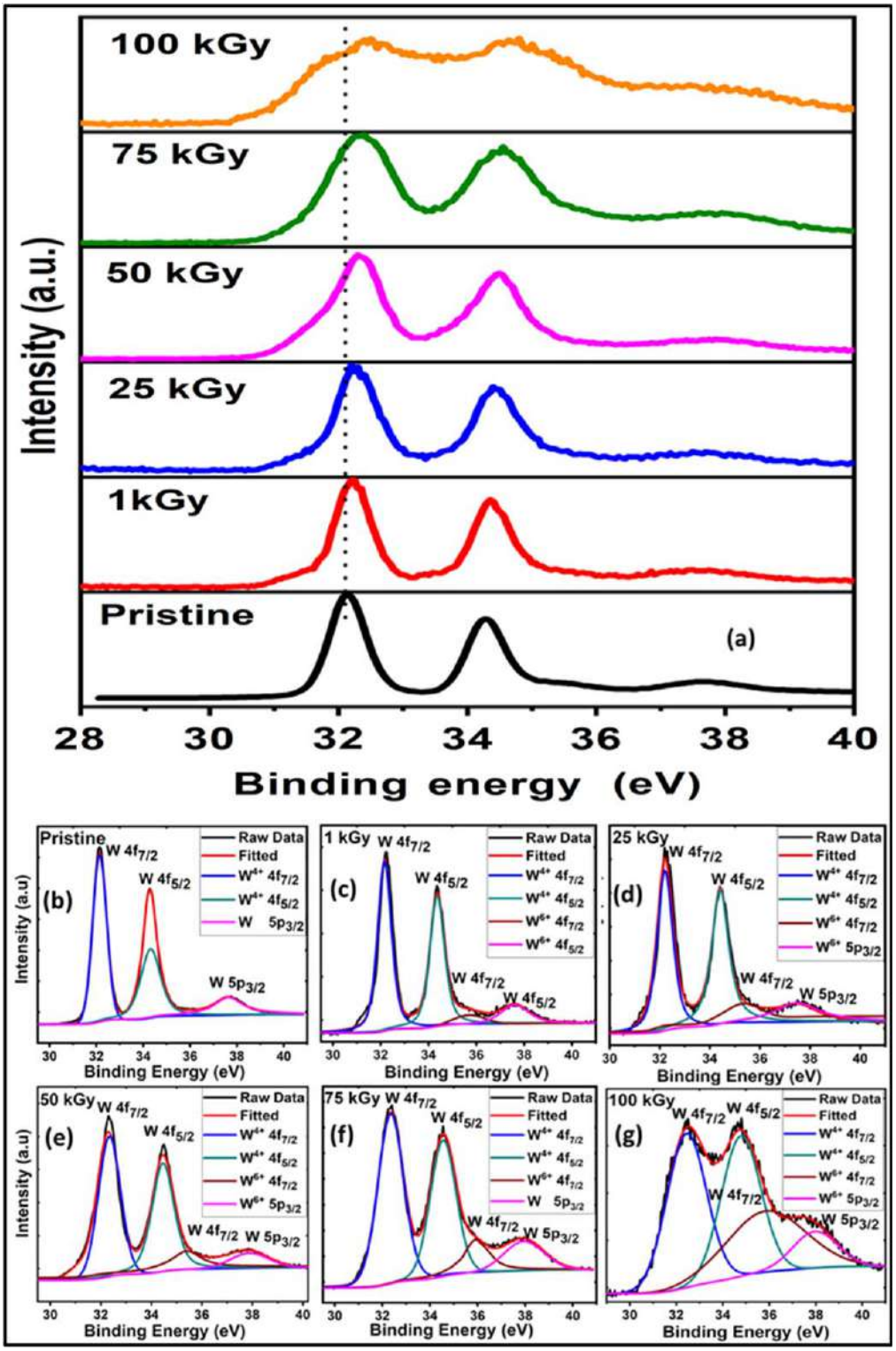

Figure 8. Shift in XPS peaks of W with increased gamma irradiation dosage.

The systematic increase in O concentration in the gamma irradiated samples is seen from the EDS profile. The slight decrease in the sulfur concentration than the ideal stoichiometry of WS_2, with increased gamma dosage suggests the removal of sulfur atoms from irradiated surface [20, 21].

The observed changes in WS_2 due to gamma irradiation inferred reduced crystallinity and strain due to sulfur vacancy and subsequent formation of W–O and SO_4^{2-} along with agglomeration. All these effects may change the optical property. So, in order to see the effect of gamma irradiation on optical properties of WS_2, we have studied absorption spectra. The TMDCs are observed to exhibit indirect band gap semiconducting behavior [38]. Figure 11(a) shows the absorbance spectra of pristine and gamma-irradiated WS_2 thin

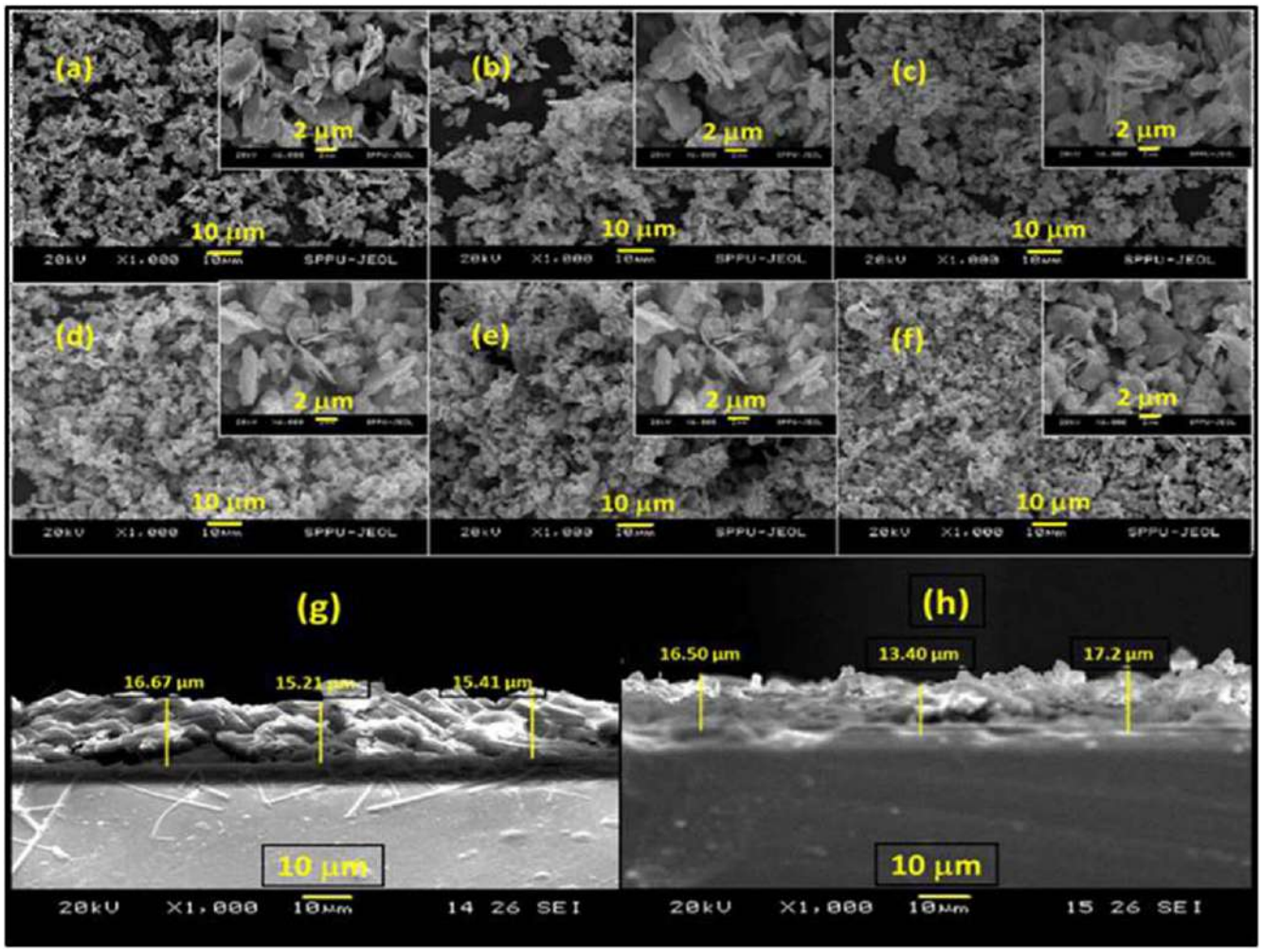

Figure 9. SEM images of (a) pristine, (b) 1 kGy, (c) 25 kGy, (d) 50 kGy, (e) 75 kGy and (f) 100 kGy gamma irradiated samples respectively, with two magnifications, and cross-section images of (g) pristine and (h) 100 kGy gamma irradiated samples respectively.

Table 2. Elemental composition of pristine, 50 kGy and 100 kGy gamma irradiated samples.

Gamma dose	Element	Atomic %
Pristine	W	21.85
	S	43.56
	O	34.59
50 kGy	W	14.06
	S	26.03
	O	59.91
100 kGy	W	7.22
	S	12.95
	O	79.83

films deposited on FTO substrate. The absorption is enhanced post gamma irradiation due to the formation of sulfur vacancies and introduction of oxygen at these sites [38]. The reduction in band gap after gamma irradiation is evident from figure 11(b). The extrapolation of linear part of $h\nu$ versus $(\alpha h\nu)^{\frac{1}{2}}$ gives the energy difference between the valence and conduction band of the material and suggests that the material is exhibiting indirect band gap nature [39–41]. This graph (figure 11(b)) is termed as Tauc plot, and shows systematic decrease in the band from 1.64 to 1.57 eV for pristine and 100 kGy gamma irradiated samples respectively. The gamma irradiation reduces crystallinity and structural homogeneity of the material, leading to introduction of localized energy states between valence and conduction bands and eventually resulting in band gap reduction [42]. Also, the change in band gap may be due to the change in particle size and increased agglomeration with gamma irradiation dose, consistent with the SEM observations.

To further confirm whether the sulfur vacancies are really occupied by oxygen, the electrical studies are performed on pristine and irradiated samples. Few researchers have claimed that oxygen in WS_2 acts as p-type doping and increase the conductivity of WS_2 [43, 44]. Hence, the I versus V characteristics of the samples was carried out to study the electrical properties. The gamma irradiation produces defects in the material which increases the grain size and produces more free electrons [45]. The increased grain size leads to lesser

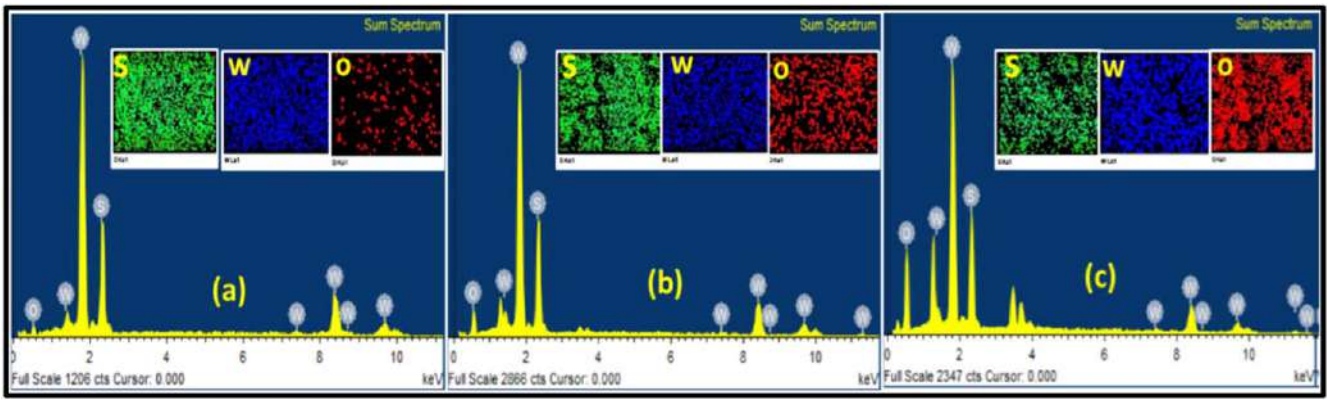

Figure 10. Graphical representation of elemental composition using EDS for (a) pristine, (b) 50 kGy and (c) 100 kGy gamma irradiated samples, along with the color mapping (inset) (green color—S, blue color—W, red color—O).

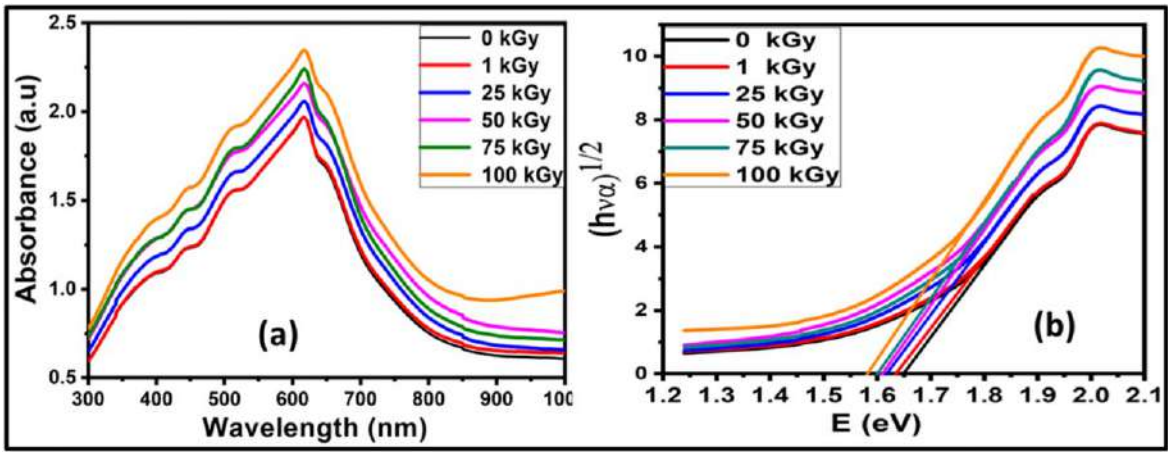

Figure 11. (a) Absorption spectra and (b) Tauc plot variation of WS_2 thin films with increasing gamma irradiation dose.

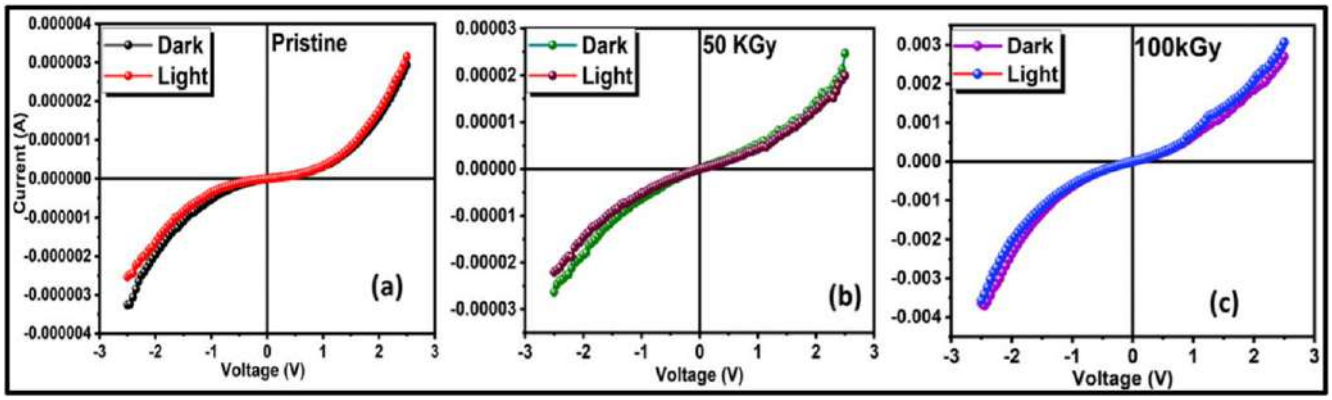

Figure 12. *I–V* characteristics of (a) pristine, (b) 50 kGy irradiated and (c) 100 kGy irradiated sample of WS_2 thin films.

grain boundary scattering of charge carriers, leading to increased current. The figures 12(a)–(c) shows the *I–V* response of the pristine, 50 kGy and 100 kGy irradiated samples respectively. The gamma irradiation induces 10-fold current in the 50 kGy irradiated sample to $\sim$ 25 μA than that of the pristine ($\sim$ 3.1 μA), as evident from figure 12. Further increasing the gamma dose from 50 to 100 kGy current is 100-fold increased to a value of $\sim$ 3.2 mA. Hence, the current has increased to almost 1000 times from pristine to 100 kGy gamma irradiated sample.

The contribution to this massive current gain may also be from the induced defects like sulfur vacancy which may act as electron donor, and creating localized energy states within band gap for enhancing carrier mobility. As the literature suggests, the enhancement in photo-current is observed due to incorporation of oxygen in the vacant sulfur

sites [46, 47]. But, we observe no significant change in the photo response. Hence, we can conclude that the observed increase in the current is due to the increased grain size reducing the recombination at grain boundary, and sulfur vacancy created by gamma irradiation. To summarize, gamma irradiation has created sulfur vacancies and agglomeration of the material resulting in increased grain size and effectively altering the optical and electrical properties. The gamma irradiation carried out in air atmosphere has also led to adsorption of oxygen and sulfate SO_4^{-2}, as observed from XPS peaks. A significant change of 1000 fold in conductivity is observed in 100 kGy irradiated sample as compared to pristine. However, photoconductivity remains almost the same to its counterpart.

Conclusions

The exfoliated WS_2 powder has been deposited on FTO using EPD method and further used for gamma irradiation study. The XRD peaks show formation of pure hexagonal structure of WS_2, and a shift in the peaks with increasing gamma irradiation dose from 1 to 100 kGy resulting in decreased crystallinity and introduction of defects. The decrease in the crystallite size has also been calculated. The red shift of characteristic A_{1g} and E_{2g} modes is evident from the Raman spectra, supporting the reduced crystallinity observed in the XRD results. The pristine WS_2 sample purity is confirmed from the XPS peak position, along with surface oxidation and defect introduction with gamma irradiation. The XPS results have made the picture clearer by confirming the formation of impurities and defects in the irradiated samples, which were not seen in the XRD or Raman results due to dominance of characteristic peaks of WS_2. The SEM micrographs show agglomeration of the material as the gamma radiation dose increases. The EDS results show that stoichiometric percentage of W and S in the samples has been almost maintained even after increased gamma irradiation suggesting that most of the sulfur which has been dislocated from its site is still present in the material. The respective increase in the oxygen is due to the oxidization and sulfate formation, as evident from XPS results. The XPS survey scan of WS_2 has been discussed for the first time along with every minute observation and has been explained to the best of our knowledge. The optical band gap decreases from 1.64 to 1.57 eV for pristine and 100 kGy irradiated samples respectively due to the irradiation effect. All these results are in corroboration and show tunability with controlling gamma dosage of the sample. Finally, the *I–V* characteristic graphs show 10-fold and 100-fold saturation current increase for 50 kGy and 100 kGy irradiated samples respectively, in comparison to the pristine. The sulfur vacancies and increase in the grain size due to the incident gamma radiation leads to massive increase in the current.

This work evidently describes the effect of high dose gamma radiation on the WS_2, and further suggests application in optoelectronics. This work has led the founding stone for researchers in the field to further explore TMD and composites, and tune their properties using irradiation for further application in various fields.

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Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

Credit authorship contribution statement

PR Jadhav: Conceptualization, Methodology, Data curation, Software, Writing—original draft, **PT Kolhe**: Resources, Formal analysis, **VS Ghemud**: Methodology, **PN Shelke**: Resources, **SP Patole**: Resources, **SD Dhole**: Resources, Investigation, **SS Dahiwale**: Formal analysis, Investigation, Resources, Writing—Review and Editing, Supervision.

Data availability

We hereby declare that the data/results are original and have not been communicated for publication elsewhere, have not been published previously, and are not under consideration for publication elsewhere. Therefore, if accepted, the data/results will not be published elsewhere.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in the paper.

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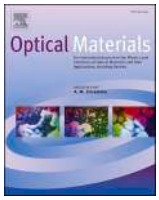

Research Article

Investigations of swift heavy ion induced thermoluminescence effect, trapping parameter analysis, and density functional theory of MgB_4O_7: Eu phosphor

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ABSTRACT

The present work reports swift heavy ion (SHI) induced thermoluminescence (TL) dosimetric properties and density functional theory (DFT) studies of Eu doped MgB_4O_7 phosphor. Comparative investigations of structural, and luminescent properties of MgB_4O_7:Eu phosphor upon irradiation by 100 MeV Ag^{7+} and Ni^{7+} ion beams at the varied fluence range from 1×10^{10} ion/cm^2 to 5×10^{12} ion/cm^2 are presented systematically. Eu doped MgB_4O_7 phosphor is prepared by facile hydrothermal method. X-ray diffraction pattern of the material reveals its orthorhombic structure with crystallite size of ~30 nm. Fourier transform infrared spectroscopy (FTIR) studies demonstrate loss of crystallinity of material after the SHI irradiations. Correlation of stopping powers and projectile range calculations is performed using SRIM software. The investigated photoluminescence properties show emission bands located in the orange-red region with prominent peaks centered at ~593 nm and ~625 nm corresponding to $^5D_0 \rightarrow {}^7F_1$ and $^5D_0 \rightarrow {}^7F_2$ transitions of Eu^{3+}ion. The influence of ion beam fluence on the photoluminescence properties has been explored. Variation in the intensity of the PL peaks without any shift in the peak positions is observed at different ion fluence. The TL glow curve of phosphor exhibits two major dosimetric peaks (a) at 185 °C and 275 °C and (b) at 172 °C and 273 °C upon Ag^{7+} and Ni^{7+} ion beam irradiation respectively. The phosphor shows fairly good linear dose response in the range of 1×10^{10} ion/cm^2 to 5×10^{12} ion/cm^2. Fading measurements reveal 10% and 12% fading for the irradiation of Ag^{7+} and Ni^{7+} ions respectively in two months. Trapping parameter calculations of SHI irradiated phosphors are carried out via various TL glow curve analysis methods such as, peak shape method, whole glow peak method, and glow curve deconvolution method. Efficient thermoluminescence properties of MgB_4O_7:Eu make it a potential phosphor material and promise to provide avenue into swift heavy ion dosimetry applications. DFT computational studies performed to obtain the electronic structure of Eu doped MgB_4O_7 phosphor support the experimental results of crystal structure, symmetry and electronic structure studies.

1. Introduction

Thermoluminescence (TL) is emission of visible light emitted from phosphor materials (either semiconductors or insulators) that were previously "charged" via absorption of ionizing radiation. In TL process, due to high energy radiations electron-hole pairs get separated and the electrons get trapped into trapping centres after the irradiation. The electrons get released from traps due to thermal energy, and recombine

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only after that. Thermoluminescence is the most commonly used technique for the measurement of ionizing radiation in dating of archaeological samples, for defect determination in solids and in environmental, personal, medical, and accidental dosimetry. In radiation dosimetry, various ionizing radiations can be measured such as X-rays, γ-rays, β-rays which contain high energy photons and the swift heavy ions (SHI) consisting of dense ionizing radiation with very highly energetic heavy charged particles [1].

Ion beam therapy using swift heavy ions is gaining huge importance worldwide due to its improved dose distribution properties as compared to the photon beams (i.e. X-ray, γ-rays, β-rays) and hence it allows dose escalation inside the tumour sparing common tissues. In 1946, Robert Wilson proposed for the first time use of heavy ion beams in radiotherapy [2]. Swift heavy ion (SHI) irradiation technique is also immensely useful in the study of material modifications [3], solar energy converters [4], optical [5], electric [6], and structural [7] properties of solid-state materials due to their high energy interaction with the targeted particles. Also, SHI beam irradiation on various materials is vitally used in defect studies and polymers modification [8–10]. Investigation of photoluminescence and thermoluminescence properties of different SHI irradiated phosphors are also explored specifically in therapeutic and dosimetric applications [11–14]. Some of the studies include Ni^{7+}, Ag^{9+} and Au^{8+} ion irradiated Y_2O_3:Tb for space dosimetry [15], Ag^{15+} ion irradiated CaS:Bi^{3+} [16], Ni^{8+} ion irradiated Y_2O_3:Tb^{3+} for ion beam dosimetry [17], etc. In ion beam irradiation process, the effects of ion beam on structural and optical properties of the phosphor material depend on many factors such as fluence of ions, ion beam energy, and the species of ions used for irradiation. High energy beam of energetic ions (greater than several MeV) penetrates through the material and loses its kinetic energy via two independent processes, viz. Nuclear and electronic energy losses. Nuclear energy loss involves elastic collisions with nuclei which dominates around 1 MeV/amu energy and electronic energy loss involves inelastic collisions with atomic electrons having energy ~1 MeV/amu or more [2]. MgB_4O_7 is a very sensitive phosphor material with versatile properties such as chemical and thermal stability (melting point is more than 1000 °C), wide band gap, greater sensitivity as compared to standard TLD-100 [18], and good study are potential to generate huge number of trapping and colour centres [19]. Therefore, MgB_4O_7 phosphor doped with a variety of impurities has been studied for TL dosimetric applications by using gamma and beta irradiations [19–22] such as MgB_4O_7:Ag [23], MgB_4O_7:Dy, Na [24], MgB_4O_7:Tb [25], MgB_4O_7:Gd, Li [26] etc. TL dosimetric properties of swift heavy ion irradiated nano crystalline MgB_4O_7:Dy phosphor material have been studied by Numan Salah et al. [27], in which 3 MeV proton, 50 MeV Li^{3+}, and 120 MeV Ag^{9+} ion beams are used to measure TL dose response. In the present study, we demonstrate the irradiation effect of 100 MeV Ag^{7+} and Ni^{7+} ions on Eu doped MgB_4O_7. MgB_4O_7 phosphor possesses low effective atomic number (Z effective) which is around 8.3 and the band gap of phosphor material is around 5.5 eV. In the present work, we have studied the SHI induced thermoluminescence effect on MgB_4O_7:Eu phosphor using 100 MeV Ag^{7+} and Ni^{7+} ions. The SHI induced modifications in structural, surface, and optical properties of 1 mol % Eu doped MgB_4O_7 phosphor are investigated via XRD, FTIR, PL, and TL respectively after irradiation of Ag^{7+} and Ni^{7+} ions at varying fluence. TL glow curve spectra show two glow curve peaks which linearly increased in the range from 1×10^{10} ion/cm^2 to 5×10^{12} ion/cm^2. Fading measurements of the MgB_4O_7:Eu phosphor are carried out for a period of two months. In order to find out the trapping parameters of the SHI irradiated TL glow curves, peak shape method and whole glow peak method are used and further glow curve deconvolution is performed methodically. The systematic TL studies and trapping parameter analysis of Eu doped MgB_4O_7 phosphor is hardly ever investigated. DFT calculations for pure and Eu-doped MgB_4O_7 crystal are performed with the Vienna ab initio Simulation Package (VASP) based on spin polarized density functional theory.

2. Experimental procedure and characterization techniques

2.1. Synthesis method

MgB_4O_7:Eu phosphor is synthesized via hydrothermal method followed by additional heating treatment for formation of MgB_4O_7 structure. All the chemicals used in the synthesis process are analytical reagents (A. R. Grade) and are used as-received without any further purification. Magnesium Oxide (MgO) and Boric Acid (H_3BO_3) are purchased from Sigma Aldrich. For Eu^{3+} (1 mol %) as a dopant, Europium Oxide (Eu_2O_3) (Sigma Aldrich 99.99 % pure) is used. In a typical procedure, an appropriate amount of MgO, H_3BO_3, and Eu_2O_3 is separately taken into 35 ml double distilled water and is stirred for several hours. Then, all the solutions are mixed and stirred again for an hour. After this process, the above solution is transferred to 100 ml Teflon lined stainless steel autoclave and is heated up to 180 °C for 12 h. It is then allowed to cool naturally up to room temperature. Afterwards, the product obtained from autoclave is filtered and washed several times with double distilled water and is dried at 100 °C for 5 h. The whitish powder thus obtained from this reaction is further annealed at 760 °C for 2 h.

$$MgO + 4H_3BO_3 + Eu_2O_3(1\ \ mol\%) \xrightarrow[180^oC\ \ for\ \ 12\ \ hr]{\text{Hydrothermal}} MgB_4O_7 : Eu$$

After the final synthesis of MgB_4O_7:Eu (1 mol %) phosphor powder, pellets of the as-prepared sample are prepared for SHI irradiation. All the pellets are prepared by using hydraulic press, wherein the diameter and thickness of all the pellets are kept constant - 10 mm diameter and 0.6 mm thickness by taking 50 mg weight. The prepared pellets are annealed at 350 °C for 3 h to eliminate contamination that might have been caused by dies used throughout pellet preparation. This annealing process also removes the unintentional radiation absorbed by the phosphor. These pellets are then used for SHI irradiation.

2.2. Swift heavy ion irradiation

The SHI irradiation process is performed by using 15 UD Pelletron facility available at Inter University Accelerator Centre (IUAC), New Delhi, India. The MgB_4O_7:Eu pellets are irradiated using two swift heavy ions (i) 100 MeV Ag^{7+} ions and (ii) 100 MeV Ni^{7+} ions at fluences in the range of 1×10^{10} to 5×10^{12} ion/cm^2. The pellets are mounted on a rectangular ladder (sample holder). The target ladder shown in Fig. 1, is

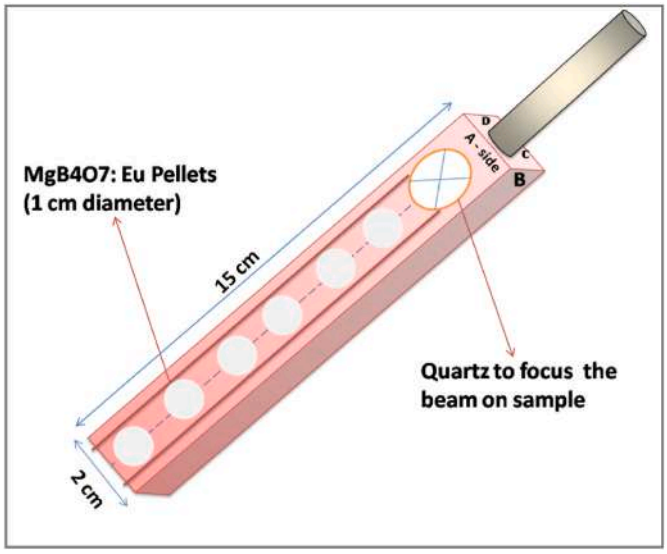

Fig. 1. Schematic diagram of ladder on which pellet samples are pasted for ion beam irradiation.

inserted into the irradiation chamber with a vacuum pressure maintained at 10^{-6} Torr throughout the ion irradiation. The ladder could be moved in up and down directions and it can be also rotated on each of the surfaces A, B, C, and D as per our requirement so as to bring the samples into the path of ion beam. We have pasted the pellets on all four surfaces of the ladder using double sided tape and moved it in-situ during the irradiation process. The beam can scan the samples in horizontal (X-Y-axis) direction in almost 1×1 cm of sample area with the help of electro-magnetic scanner throughout irradiation. Before the irradiation, we can fix the focus of the beam using the quartz as shown in ladder diagram. The number of incident ion per cm^2 are calculated by using the formula:

$$Fluence = \frac{\left(6.25 \times 10^{9}\right) \times Current \times Time\ (T)}{Sample\ area}$$

where.

Fluence is in ion/cm^2, *Sample area* is in cm^2, and *Current* is in pnA.

The Ag^{7+} and Ni^{7+} ion beam parameters are incorporated in Table 1.

We have used Stopping and Range of Ions in Matter (SRIM) software to find out the projectile ranges, nuclear stopping power, and electronic stopping power of the 100 MeV Ag^{7+} and Ni^{7+} ions for MgB_4O_7:Eu phosphor. Variations of the energy losses have been plotted for beam energies from 1 KeV to 1000 GeV of the (a) Ag^{7+} ion and (b) Ni^{7+} ion as shown in Fig. 2. The projectile range (R_p), nuclear stopping power (S_n), and electronic stopping power (S_e) parameters which are found out from the calculations are incorporated in Table 2. Generally, formation of vacancies and defects in the material is caused due to S_n, while the strong ionization of the targeted atoms is caused due to S_e. In the present case, total nuclear energy loss is negligible in the material while electronic energy loss is mostly accountable for the generation of the vacancies and interstitial defects in the material [28].

2.3. Characterization techniques

X-ray diffraction measurements of MgB_4O_7:Eu phosphor are carried out on Bruker AXSD8 Advance X-ray diffractometer. FTIR is recorded using ASCO FT/IR 6100 for functional investigation. Photoluminescence spectra are taken on the HORIBA FL-1057. All TL measurements are done on Nucleonix make TLD reader: Model number 1009I. After effective irradiation of SHI, the TL measurements of all the pellets are done with the irradiated surface of pellets kept on the side of photomultiplier tube in the TL reader. The heating rate of the TL glow curve is kept at 5 °C/s throughout the experiment.

3. Computational Details

The electronic structure calculations for pure and Eu-doped MgB_4O_7 are performed with the Vienna ab initio Simulation Package (VASP) based on spin polarized density functional theory (DFT) [29]. The projector augmented wave (PAW) method is used to describe the interaction between ions and valence electrons [30]. Generalized gradient approximation (GGA) is used with the parametrization of Perdew, Burke and Ernzerhof (PBE) [31] to describe the exchange-correlation energy functional. Plane-wave cut off for the basic functions is set to 500 eV. Atomic relaxations are performed using a conjugate gradient algorithm without imposing any symmetry restrictions. Electronic self-consistency is achieved with an energy convergence of 10^{-7} eV. The forces on individual atoms are reduced to less than 10^{-3} eV/Å. For structural optimization, Brillouin zones of pure MgB_4O_7 and MgB_4O_7:Eu are sampled using 5 × 5 × 5 and 3 × 3 × 3 mesh of *k*-points respectively using tetrahedron scheme. To locate correctly 4*f* electronic states for Eu in MgB_4O_7:Eu, we implement density functional-correlated band theory calculations (DFT + U). In our calculations, we use Dudarev's approach [32] to implement GGA + U, where the on-site Coulomb interaction and exchange are considered through an effective parameter U_{eff} = U − J where U is the Coulomb interaction and J represents Hund's coupling. We have used U = 7.0 eV and J = 0.75 eV for Eu-4*f* states which reproduce correct experimental observations as shown earlier [33], however for completeness we have also compared the results of U = 7.0 eV with those of U = 3.0 eV and without inclusion of U in MgB_4O_7:Eu.

4. Results and discussion

4.1. X -ray diffraction studies

The composition, crystallinity and phase purity of the as-prepared MgB_4O_7:Eu phosphor materials are examined by X-ray diffraction pattern (XRD). The XRD peaks are identified and indexed according to the JCPDS Card No. 31–0787. The XRD spectrum of pristine (un-irradiated) MgB_4O_7:Eu phosphor shown in Fig. 3, matches well with the JCPDS data. The XRD pattern is recorded in the range from 15° to 65°. The '*hkl*' peak positions of 2θ values 19.9°, 22.3°, 26.8°, 28.4°, 30.6°, 33.3°, 35.2°, 36.1°, 40.5°, 42°, 45.6°, 48.2°, 50°, 51°, and 53.1° correspond to (121), (002), (221), (230), (231), (240), (241), (151), (242), (400), (421), (243), (440), (214), and (172) planes respectively. The XRD pattern reveals an orthorhombic structure of Eu doped MgB_4O_7 and the calculated lattice parameters of unit cell from peak position and *hkl* planes are *a* = 8.60 Å, *b* = 13.79 Å, and *c* = 7.97 Å. No extra peak is observed in the XRD patterns due to dopant incorporation, revealing that the Eu dopant has been effectively doped into the host lattice without any phase transformation. The average crystallite size of the phosphor has been calculated using Scherer's equation and it is determined to be around ~30 nm.

Fig. 3 shows a comparison of XRD spectra of un-irradiated samples and 100 MeV Ag^{7+} and Ni^{7+} ion irradiated MgB_4O_7:Eu phosphor samples for the ion fluences from 1×10^{10} ion/cm^2 to 5×10^{12} ion/cm^2. It is observed that no new peaks appeared in the XRD pattern due to the irradiation with varied fluences indicating that the phase of the phosphor material remained unchanged. However, the XRD pattern reveals that with an increase in the ion fluence the XRD peaks shift slightly towards lower angles. The peak shift is up to 1° and 0.5° for Ag^{7+} and Ni^{7+} ion irradiation respectively as shown in Fig. 3 (a and b) at the maximum fluence of beam. This might be ascribed to the production of internal stresses and lattice distortions in the material.

4.2. Fourier transform infrared spectroscopy

Fig. 4 shows FTIR spectra of 100 MeV Ag^{7+} and Ni^{7+} ion irradiated MgB_4O_7:Eu phosphor. Both the spectra show comparative study of different fluences from 1×10^{10} ion/cm^2 to 5×10^{12} ion/cm^2. All spectra are recorded in the wavenumber range from 4000 to 400 cm^{-1} at room temperature. It can be observed from the spectra that the vibrational bands occur at 520 to 526 cm^{-1}, 717 cm^{-1}, 772 cm^{-1}, 965 to 975 cm^{-1}, and 1083 cm^{-1} in all the irradiated and unirradiated samples, enlarged images of which are indicated besides Fig. 4 (a) and (b) by an arrow. The absorption bands appearing in the range 3700 to 3250 cm^{-1} and 1600 to 1650 cm^{-1} can be ascribed to hydroxyl group (-OH) due to the interatomic vibrations. The band at 2344 cm^{-1} in the spectra may be due to the C═O bond [34]. The absorption bands centered at 772 cm^{-1},

Table 1
SHI parameters used throughout the experiment.

Ion	Energy (MeV)	Charge state	Current (pnA)	Temperature (K)	Fluences range (ion/cm^2)
Ag^{7+} and Ni^{7+}	100	7^+	1	300	1×10^{10} to 5×10^{12}

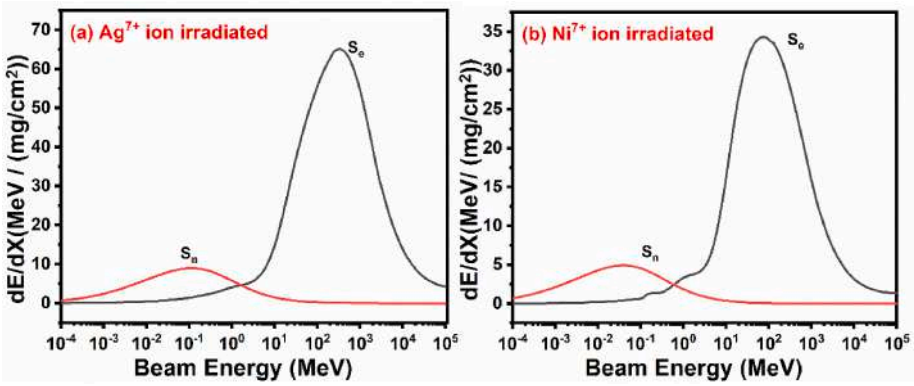

Fig. 2. SRIM graphs of nuclear and electronic energy losses of the (a) Ag^{7+} and (b) Ni^{7+} ion beams on MgB_4O_7 phosphor.

Table 2
Projectile range and stopping power parameters found from the SRIM software.

Ion	Projectile range (R_p)	Nuclear stopping power (S_n)	Electronic stopping power (S_e)
100 MeV Ag^{7+}	325.53 μm	0.254 MeV/(mg/cm^2)	55.51 MeV/(mg/cm^2)
100 MeV Ni^{7+}	433.34 μm	0.0577 MeV/(mg/cm^2)	33.98 MeV/(mg/cm^2)

717 cm^{-1}, 975 cm^{-1} and 717 cm^{-1}, 772 cm^{-1}, 966 cm^{-1} can be attributed to the BO_4 stretching vibrations which vary after irradiation with Ag^{7+} and Ni^{7+} ions respectively [35]. It can be noted that the intensities of these bands have gradually increased with increase in ion beam fluence. Also, the IR bands observed at 526 cm^{-1} and 522 cm^{-1} can be assigned to bending vibration band of B–O that varied upon irradiation with Ag^{7+} and Ni^{7+} ions respectively [36].

4.3. Photoluminescence spectroscopy

Fig. 5 (a) shows the excitation spectra recorded at $\lambda_{em} = 625$ nm of pristine MgB_4O_7: 1 % Eu^{3+} phosphor. The excitation spectrum comprises of excitation band at 280 nm that can be attributed to the $O^{2-} \rightarrow Eu^{3+}$ charge transfer state [37]. Fig. 5 (b and c) show emission spectra of pristine and SHI Ag^{7+} and Ni^{7+} irradiated MgB_4O_7: 1 % Eu^{3+} phosphor samples monitored at $\lambda_{ex} = 280$ nm, at different ion fluences. The emission spectra consist of emission bands ranging from 520 to 720 nm, associated with the transitions from the excited $^5D_{0,1}$ level to ^7F_J (J = 1, 2) levels of Eu^{3+} activators. The two major emission peaks are centered at ~593 nm corresponding to $^5D_0 \rightarrow {}^7F_1$ transition and at ~625 nm corresponding $^5D_0 \rightarrow {}^7F_2$ transition of Eu^{3+} ion, which are well characterized by orange-red and red colours respectively [38,39]. Apart from these prominent peaks, we also observe a weak emission peak centered at ~554 nm that can be assigned to $^5D_1 \rightarrow {}^7F_2$ transitions of Eu^{3+} ions [40]. The emission spectrum shows that the $^5D_0 \rightarrow {}^7F_2$ transition is relatively more intense than the $^5D_0 \rightarrow {}^7F_1$ transition. The $^5D_0 \rightarrow {}^7F_1$ transition is of magnetic dipole (MD) nature and is not sensitive to the crystal field around Eu^{3+} ion in matrix and local site symmetry around Eu^{3+} ion, while $^5D_0 \rightarrow {}^7F_2$ is the electric dipole (ED) transition which is very sensitive to the crystal field [41]. According to Judd-Ofelt theory, the magnetic dipole transition is permitted when the europium ion occupies a site with an inversion centre. The $^5D_0 \rightarrow {}^7F_2$ electric dipole transition is parity forbidden and is allowed when the europium ion occupies a site without an inversion centre [42,43]. The intensity of these transitions is strongly affected by local site symmetry around the Eu^{3+} ions. It is well demonstrated that the relative intensity ratio of $^5D_0 \rightarrow {}^7F_2$ (ED) to $^5D_0 \rightarrow {}^7F_1$ (MD) transitions (asymmetry ratio) conveys the nature of the chemical surroundings of the luminescent centres and the local symmetry of Eu^{3+} ions [44]. In present case, the $^5D_0 \rightarrow {}^7F_2$ electric dipole transition dominates indicating that most of Eu^{3+} ions occupy a non-centrosymmetric site without inversion symmetry and is therefore attributed to the larger degree of disorder and lower local symmetry.

Fig. 5 (b) and (c) depict the effect of different ion fluences on the PL properties of MgB_4O_7: 1 % Eu^{3+} phosphor. It is found that after ion irradiation, the emission peak positions remain unchanged however the intensities vary. The general trend of all the curves indicates that the emission intensity of MgB_4O_7: 1 % Eu^{3+} phosphor is initially enhanced upon SHI irradiation as compared to the pristine phosphor at the ion fluence from 1 x 10^{10} up to 1 x 10^{11} ion/cm^2 and then decreased with further increase in fluence at 1 x 10^{12} and 5 x 10^{12} ion/cm^2. The plot of emission intensity variation as a function of ion beam fluence is shown in Fig. 5 (d). The variation of the PL intensity with ion fluence might be a result of sensitivity of PL intensity to the damage created by swift heavy ions (SHI). The initial increase in PL intensity with increase in SHI fluence might be due to an increase in the concentration of defects or colour/luminescent centres caused by ion irradiations which renders increase in the rate of radiative transitions [45,46]. However, further increase in ion beam fluence may cause annihilation due to concentration quenching caused by interaction between defects themselves. The increase in SHI fluence beyond a certain limit may give rise to the generation of new/increased number of defect centres which leads to enhanced non-radiative recombination and thus luminescence quenching [46,47]. Ion beam irradiation may also lead to loss of crystallinity. These factors result in decreased PL emission intensity upon further rise in ion beam fluence.

The CIE parameters i.e. the chromaticity coordinates for the pristine and SHI irradiated MgB_4O_7: 1 % Eu^{3+} phosphor are determined by using the colour calculator software and are plotted on the CIE-1931 chromaticity diagram. Thus, the colour of MgB_4O_7: 1 % Eu^{3+} phosphor is represented by CIE chromaticity diagram as shown in Fig. 6. The CIE diagram shows that the co-ordinates are located in the red region. The values of CIE parameters for the pristine and different ion irradiated phosphors are summarized in Table 3. No significant variation is observed in the colour coordinate values subsequent to ion irradiation, which suggests that the emission colour of the phosphors is stable against ion irradiation [48]. The red emission for pristine and SHI induced MgB_4O_7: 1 % Eu^{3+} phosphor indicates its practical application in LED's and display devices.

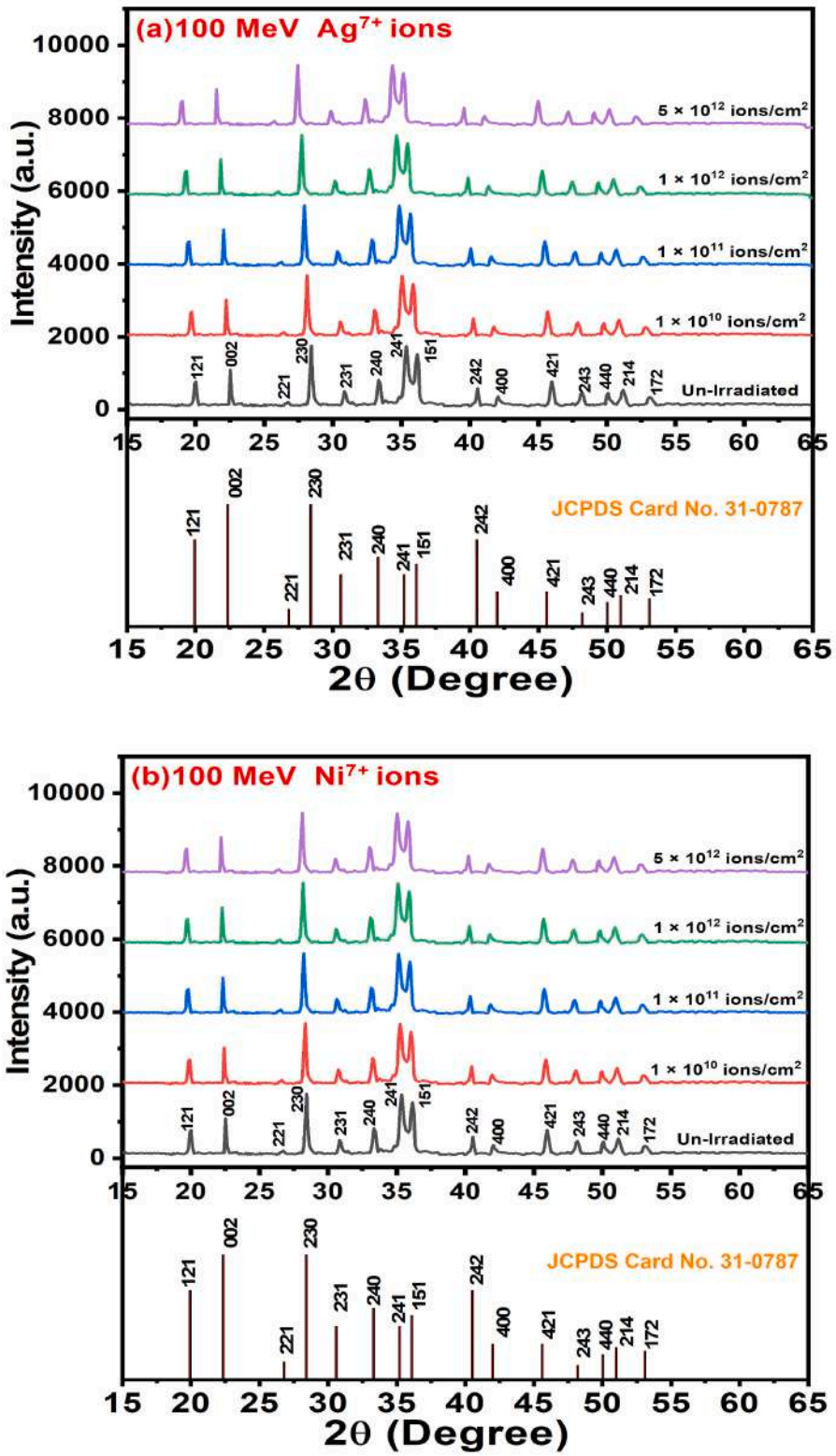

Fig. 3. XRD spectra of (a) Ag^{7+} and (b) Ni^{7+} ion irradiated MgB_4O_7:Eu phosphor in the range of fluences 1×10^{10} ion/cm^2 to 5×10^{12} ion/cm.^{2}.

4.4. Thermoluminescence dosimetric properties of MgB_4O_7: Eu phosphor

4.4.1. Thermoluminescence glow curve

In TL process, the defects which are already formed in the phosphor material due to doping of Eu^{3+}, are filled up by the electrons in the colour centres after the SHI irradiation. Due to the high energy irradiation, the electron-hole pair concentrations increase that lead to lattice distortion. After providing thermal heating to the phosphor material, maximum number of electron traps become unstable and undergo recombination thereby emitting the stored energy in the form of TL emission. Fig. 7 (a) and (b) show a characteristic TL glow curve of MgB_4O_7:Eu (1%) phosphor which has been irradiated with 100 MeV

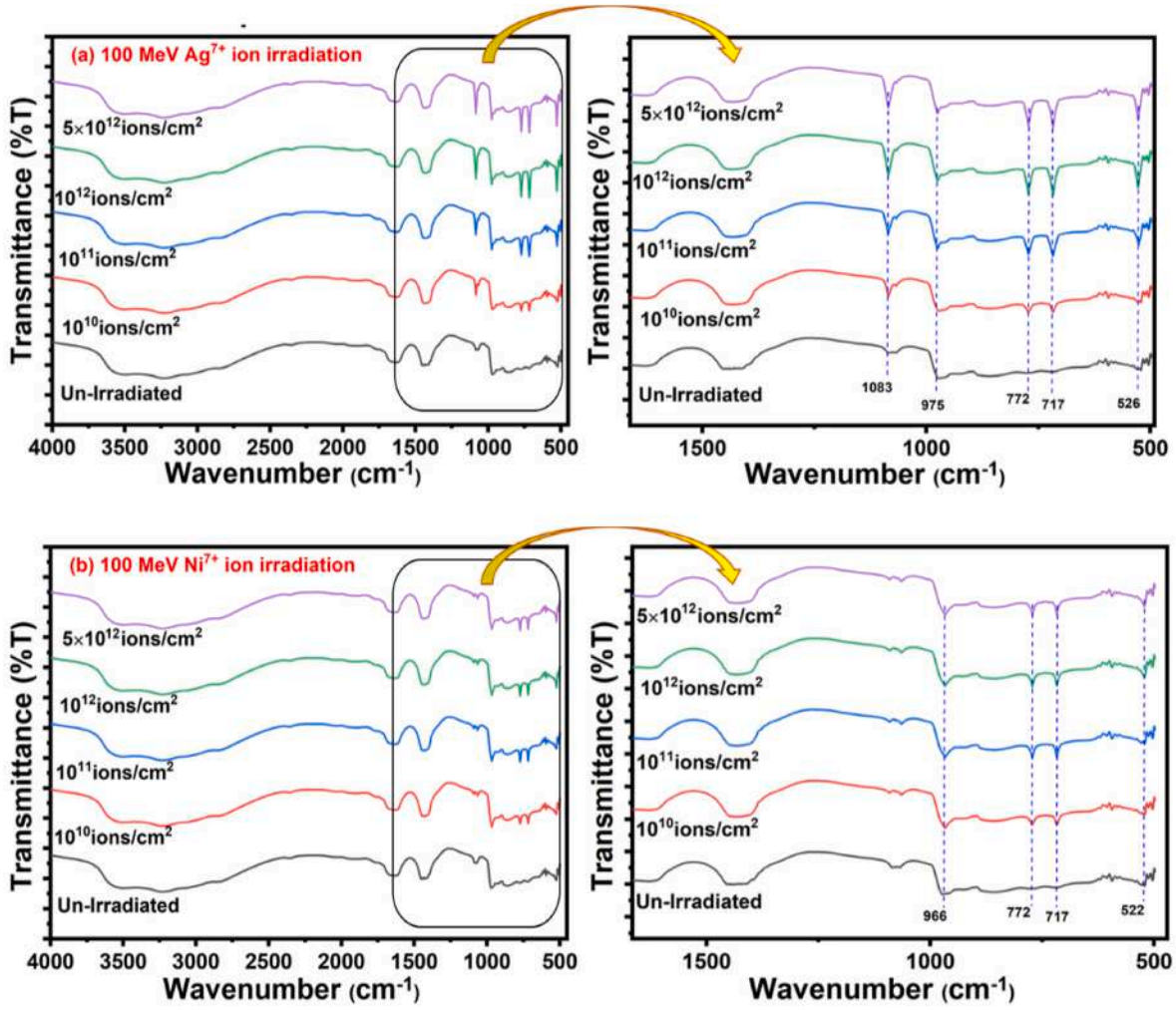

Fig. 4. FTIR spectra of (a) Ag^{7+} and (b) Ni^{7+} ion irradiated MgB_4O_7:Eu phosphor in the range of fluences 1×10^{10} ion/cm^2 to 5×10^{12} ion/cm^2.

Ag^{7+} and Ni^{7+} ion beam at various fluences in the range from 1×10^{10} ion/cm^2 to 5×10^{12} ion/cm^2. Two major glow curve peaks are observed (a) at 185 °C and 275 °C and (b) at 172 °C and 273 °C, upon irradiation by Ag^{7+} and Ni^{7+} ion beams respectively, which clearly point out the formation of two main trapping levels in the phosphor material. The TL intensity of the glow curve increases as the dose of ion beam increases without modification in the shape and position of the glow curve.

The TL glow curve response of MgB_4O_7:Eu phosphor which is irradiated at 100 MeV Ag^{7+} and Ni^{7+} ions has been plotted in Fig. 8. The figure shows that the TL intensity increases linearly from 1×10^{10} to 1×10^{12} ion/cm^2 but increases sub-linearly beyond 1×10^{12} ion/cm^2 up to 5×10^{12} ion/cm^2 in both the ion irradiation. This behaviour can be understood knowing that the TL signals are proportional to the number of ion beam fluences or ion beam tracks according to the Horowitz's TIM model [16,49,50]. During the low dose of ion beam fluence, recombination of many luminescent centres occurs completely inside the tracks. Also, the removal of electrons from the tracks is prevented by the non-radiative competitive centres in the intermediate region. During the high fluences of dose the luminescent intensity gets enhanced as the distance between the neighbouring traps reduces and the electrons removed from the tracks can spread into the neighbouring tracks.

4.4.2. Fading

Fading is one of the important factors in dosimetry, wherein the stored dose within the phosphor gradually decreases in certain time interval, and that has to be measured in the fading process. In the present study, fading measurements have been carried out over a period of two months for the samples of MgB_4O_7:Eu phosphor with span of 5 days after the irradiation. The irradiated samples are stored in dark at room temperature in light sealed packets. For the fading study we have used samples irradiated at 100 MeV Ag^{7+} and Ni^{7+} ions with fluences 5×10^{12} ion/cm^2 at which the most intense glow peak is observed. Fig. 9 (a) and (b) show the fading curves of the Ag^{7+} and Ni^{7+} beam irradiated MgB_4O_7:Eu phosphor respectively. Over an interval of two months post ion irradiation by Ag^{7+} and Ni^{7+} ions, 10 % and 12 % fading respectively is observed.

4.5. Trapping parameters analysis

4.5.1. Peak shape method: Chen's formulae

The shape and geometrical properties of the TL glow curve play a very crucial role in the calculation of activation energy (E) of trapping levels within phosphor material [51–54]. By measuring some of the points on TL glow curve, we get the exact dimensions of the glow curve as shown in Fig. 10. Chen's empirical formulae are applied to the glow curves resulting from irradiation with 100 MeV Ag^{7+} and Ni^{7+} with fluence of 5×10^{12} ion/cm^2.

$$E_{\alpha=} C_{\alpha}\left(\frac{kT_m^2}{\alpha}\right) - b_{\alpha}(2kT_m) \quad (1)$$

where $\alpha = \tau$, δ, and ω,

with $\tau = T_m - T_1$, $\delta = T_2 - T_m$, $\omega = T_2 - T_1$

$c_\tau = 1.51 + 3.0\ (\mu_g - 0.42)$, $b_\tau = 1.58 + 4.2\ (\mu_g - 0.42)$

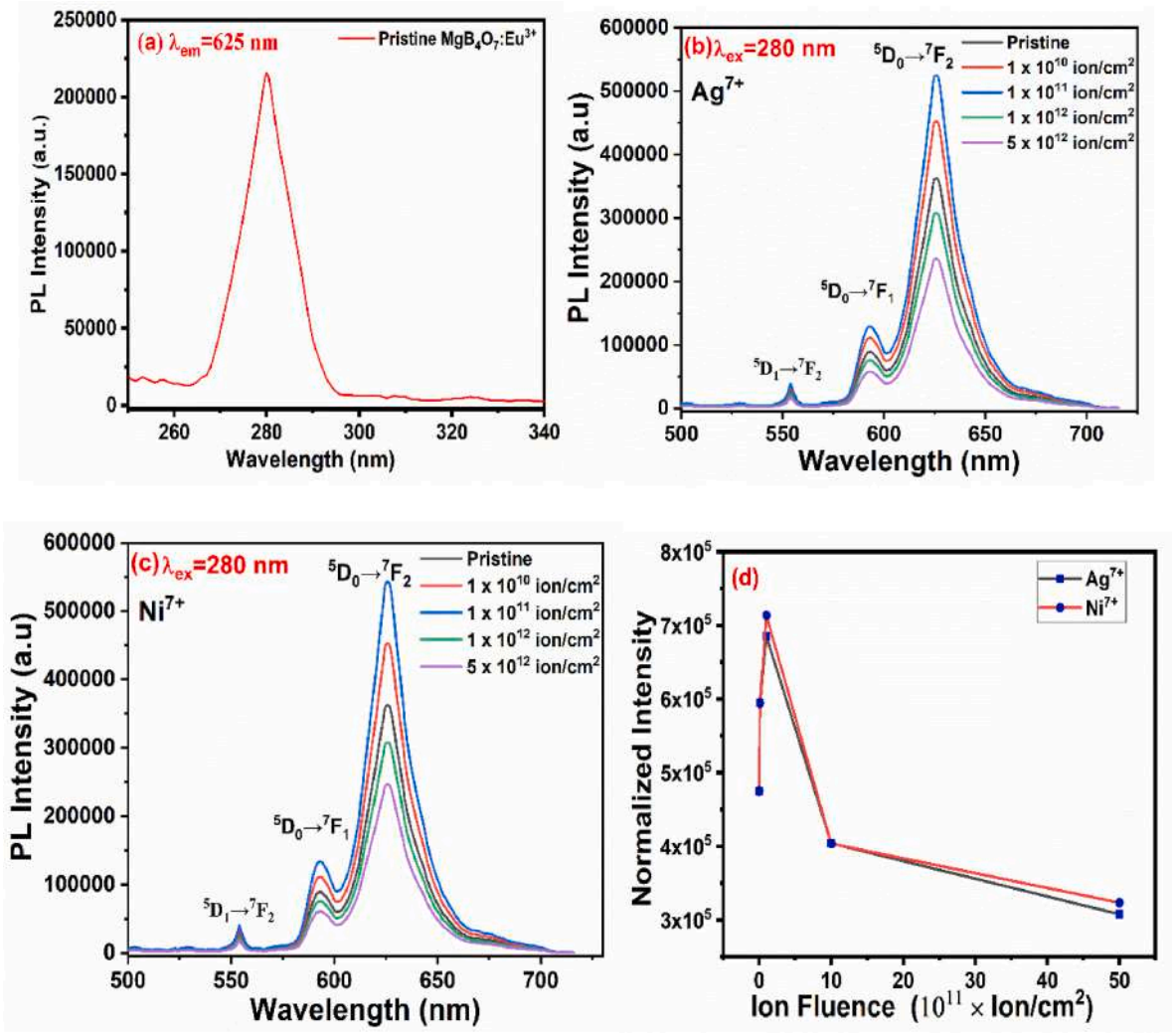

Fig. 5. (A) Excitation spectrum of pristine MgB_4O_7:Eu phosphor with inset showing the various transitions, (b) and (c) emission spectra of pristine and SHI Ag^{7+} and Ni^{7+} ion irradiated MgB_4O_7: 1 % Eu^{3+} phosphor for different fluences and (d) the plot of emission intensity variation as a function of ion beam fluence for Ag^{7+} and Ni^{7+} ions.

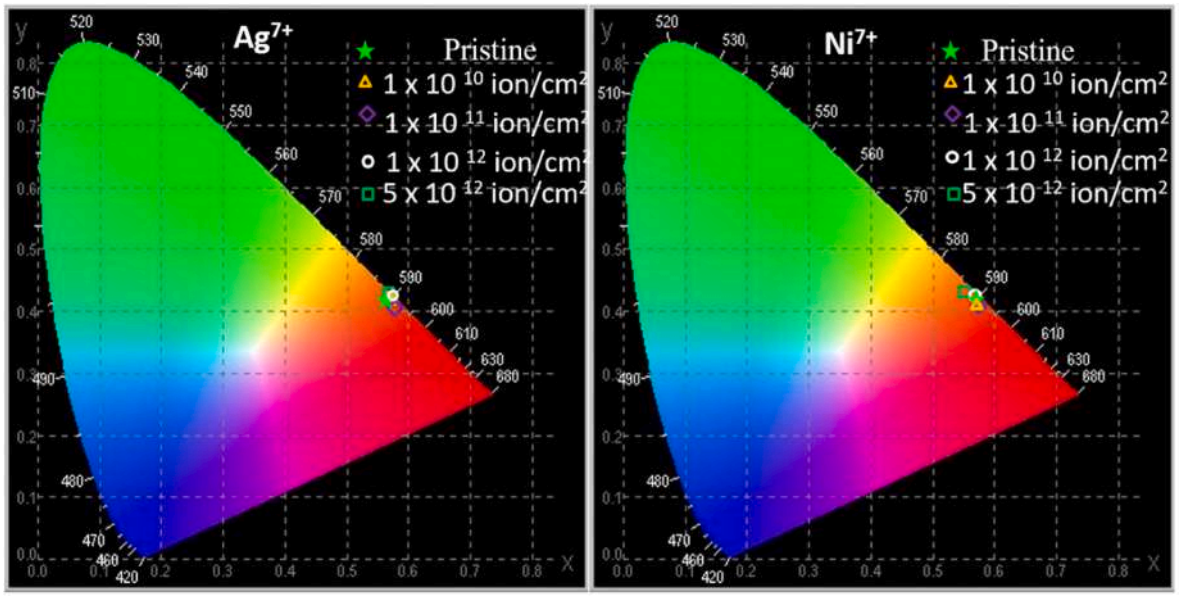

Fig. 6. CIE chromaticity diagram of 100 MeV Ag^{7+} and Ni^{7+} ion irradiated MgB_4O_7:Eu (1%) phosphor.

Table 3
Colour co-ordinates and values of CIE parameters of 100 MeV Ag^{7+} and Ni^{7+} ion irradiated MgB_4O_7:Eu (1%) phosphor.

	Ag^{7+}		Ni^{7+}	
MgB_4O_7: 1 % Eu^{3+} phosphor	x co-ordinates	y co-ordinates	x co-ordinates	y co-ordinates
Pristine	0.5651	0.4152	0.5677	0.4271
1 x 10^{10} ion/cm^2	0.5755	0.4195	0.5677	0.4171
1 x 10^{11} ion/cm^2	0.5761	0.4015	0.5767	0.4065
1 x 10^{12} ion/cm^2	0.5755	0.4149	0.5708	0.4272
5 x 10^{12} ion/cm^2	0.5750	0.4315	0.5673	0.4402

$c_\delta = 0.976 + 7.3\ (\mu_g - 0.42)$, $b_\delta = 0$

$c_\omega = 2.52 + 10.2\ (\mu_g - 0.42)$, $b_\omega = 1$

The order of kinetics is calculated via form factor μ_g,

$$\mu_g = \frac{\delta}{\omega} \tag{2}$$

where μ_g is a symmetry factor, and for general order kinetics it lies between 0.42 and 0.52. All the calculations of activation energy and order of kinetics are made via general order kinetics [52,55] and are mentioned in Table 4.

4.5.2. Whole glow peak method

Whole glow peak method is used to evaluate the energy parameters of isolated TL glow peaks. Two TL glow peaks are observed upon irradiation with 100 MeV Ag^{7+} and Ni^{7+} ions at fluence 5 × 10^{12} ion/cm^2. The area 'n' under each glow peak and its order of kinetics (b) is associated with each other as per equation (3)

$$ln\left(\frac{TL_{exp}}{n^b}\right) = ln\left(\frac{s^1}{\beta}\right) - \left(\frac{E}{kT}\right) \tag{3}$$

where s^1 ($cm^{3(b-1)}\ s^{-1}$) is effective frequency factor.

Fig. 11 depicts various plots of (TL_{exp}/n^b) against $1/(kT)$ corresponding to $b = 1$, 1.2, 1.5, 1.8, and 2. Fig. 11 (a) Peak 1 and (b) peak 2 correspond to 100 MeV Ag^{7+} irradiated TL glow peaks, and Fig. 11 (c) Peak 1 and (d) peak 2 correspond to 100 MeV Ni^{7+} irradiated TL glow peaks at fluence of 5 × 10^{12} ion/cm^2. The regression square fitting for the best values of 'b' can be selected through the plot [51,52]. Also, the best slope and intercept values are used for the determination of activation energy (E) and frequency factor (b) respectively,

$$s = \beta e^{(intercept)} \tag{4}$$

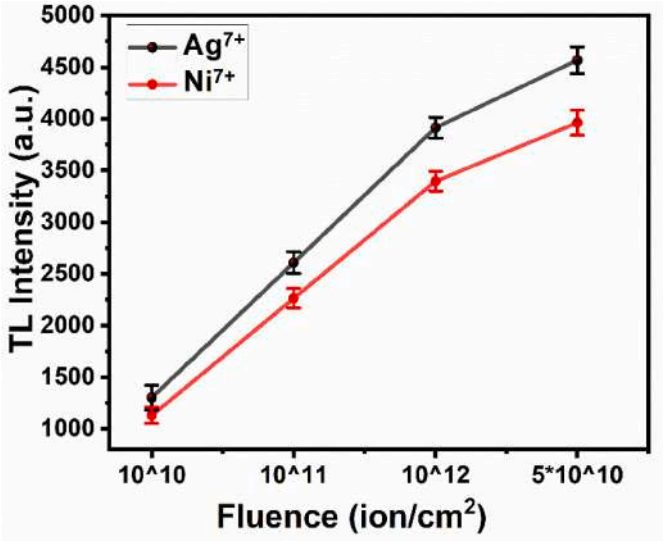

Fig. 8. Linear TL dose response of MgB_4O_7: Eu phosphor from 1 × 10^{10} ion/cm^2 to 5 × 10^{12} ion/cm^2 of 100 MeV Ag^{7+} and Ni^{7+} ion.

where.

's' is frequency factor, and 'β' is heating rate (i.e. 5 °C s^{-1}).

All information gathered from the whole peak method is incorporated in Table 4.

4.5.3. Glow curve deconvolution

Glow curve deconvolution (GCD) is a method to characterize whole TL glow curve into individual glow peaks by accurate fitting and to evaluate their kinetic parameters. The kinetic parameters are associated

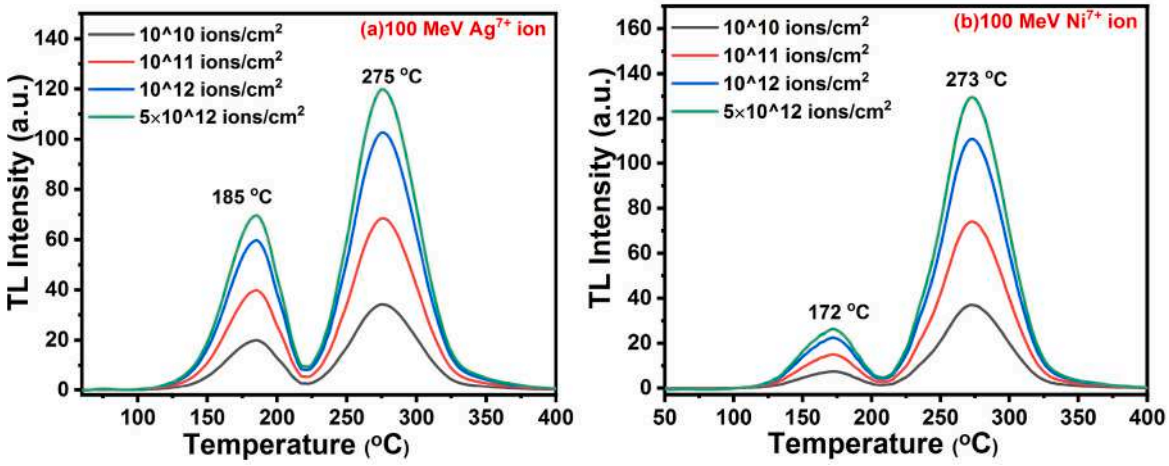

Fig. 7. TL Glow curves of MgB_4O_7:Eu phosphor exposed to 100 MeV (a) Ag^{7+} ion and (b) Ni^{7+} ion from 1 × 10^{10} ion/cm^2 to 5 × 10^{12} ion/cm^2.

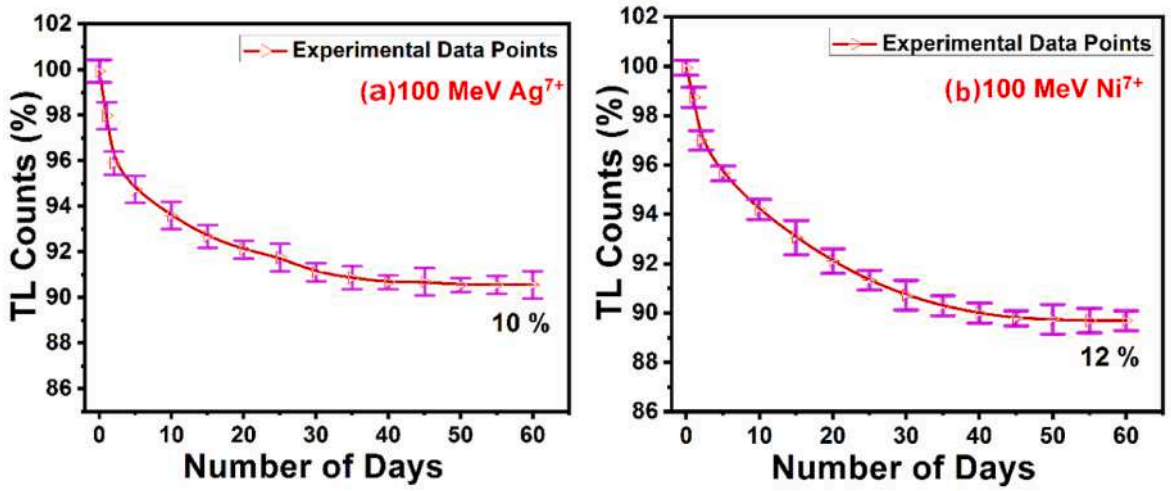

Fig. 9. Fading curves of the MgB_4O_7: Eu phosphor irradiated with 100 MeV (a) Ag^{7+} and (b) Ni^{7+} ion at fluence 5×10^{12} ion/cm^2 over a period of two months.

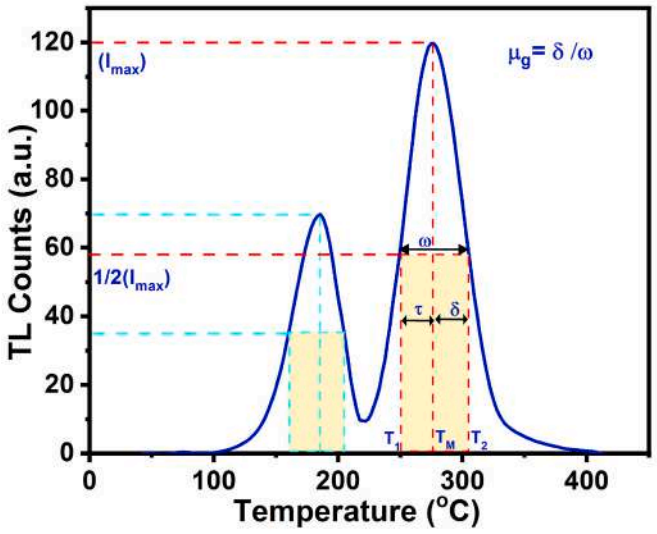

Fig. 10. The TL glow curve showing the parameters of peak shape method.

with the electron traps [56]. After the irradiation with 100 MeV Ag^{7+} and Ni^{7+} ion on MgB_4O_7: Eu phosphor, two main TL glow peaks are observed which are deconvoluted by Kitis equation of general order kinetics (5) as follows,

where I(T) represents TL intensity at temperature T(K),

T_m is the temperature corresponding to maximum peak intensity (I_m),

k is Boltzmann's constant (8.6×10^{-5} eV/K),

and E is activation energy (eV).

The general order of kinetics expression not only satisfies the first order (b = 1) and second order (b = 2) kinetics but, it also fulfils the conditions of all other probable values of order of kinetics which come in between 1 and 2 [57,58]. Activation energy (E) is the energy required to recombine the electrons from trapping centres. Frequency factor (s^{-1}) is nothing but the vibration frequency of the particles which depends on the temperature.

The equation of general order kinetics to find frequency factor [59] is as follows:

$$S = \frac{\beta E}{kT_m^2\left(1 + (b-1)\frac{2kT_m}{E}\right)} \exp\left(-\frac{E}{kT_m}\right) \quad (6)$$

where β is heating rate i.e. 5 °C/s.

Fig. 12 (a) and (b) represent a glow curve deconvolution of MgB_4O_7: Eu phosphor irradiated by 100 MeV Ag^{7+} and Ni^{7+} ions respectively at the fluence of 5×10^{12} ion/cm^2. All the measured kinetic parameters such as activation energy, frequency factor, and order of kinetics are mentioned in Table 5. The figure of merit (FOM) reveals the best fitting between experimental and theoretical values and it is determined to be only 2 % and 2.5 % for both glow curve fittings. Fig. 12 (a) represents

$$I(T) = I_m b^{\left(\frac{b}{b-1}\right)} \exp\left[\left(\frac{E}{kT}\right)\left(\frac{T-T_m}{T_m}\right)\right]\left\{(b-1)\frac{T^2}{T_m^2}\left(1-\frac{2kT}{E}\right)\exp\left[\left(\frac{E}{kT}\right)\left(\frac{T-T_m}{T_m}\right)\right] + 1 + (b-1)\frac{2kT_m}{E}\right\}^{-\frac{b}{b-1}} \quad (5)$$

Table 4
Glow curve trapping parameters of MgB_4O_7: Eu phosphor using whole peak method.

		Peak shape method			Whole glow peak method	
Ion	*Peak*	*Order of Kinetics (b)*	*Frequency Factor (s^{-1})*	*Trap Depth Energy (eV)*	*Order of Kinetics (b)*	*Trap Depth Energy (eV)*
Ag^{7+}	Peak 1	1.5	7.70×10^{10}	1.13 ± 0.005	1.2	1.058 ± 0.004
	Peak 2	1.8	1.58×10^{12}	1.65 ± 0.007	1.8	1.654 ± 0.007
Ni^{7+}	Peak 1	1.5	1.11×10^{12}	1.19 ± 0.02	1.5	1.190 ± 0.02
	Peak 2	1.8	1.84×10^{11}	1.55 ± 0.01	1.8	1.550 ± 0.01

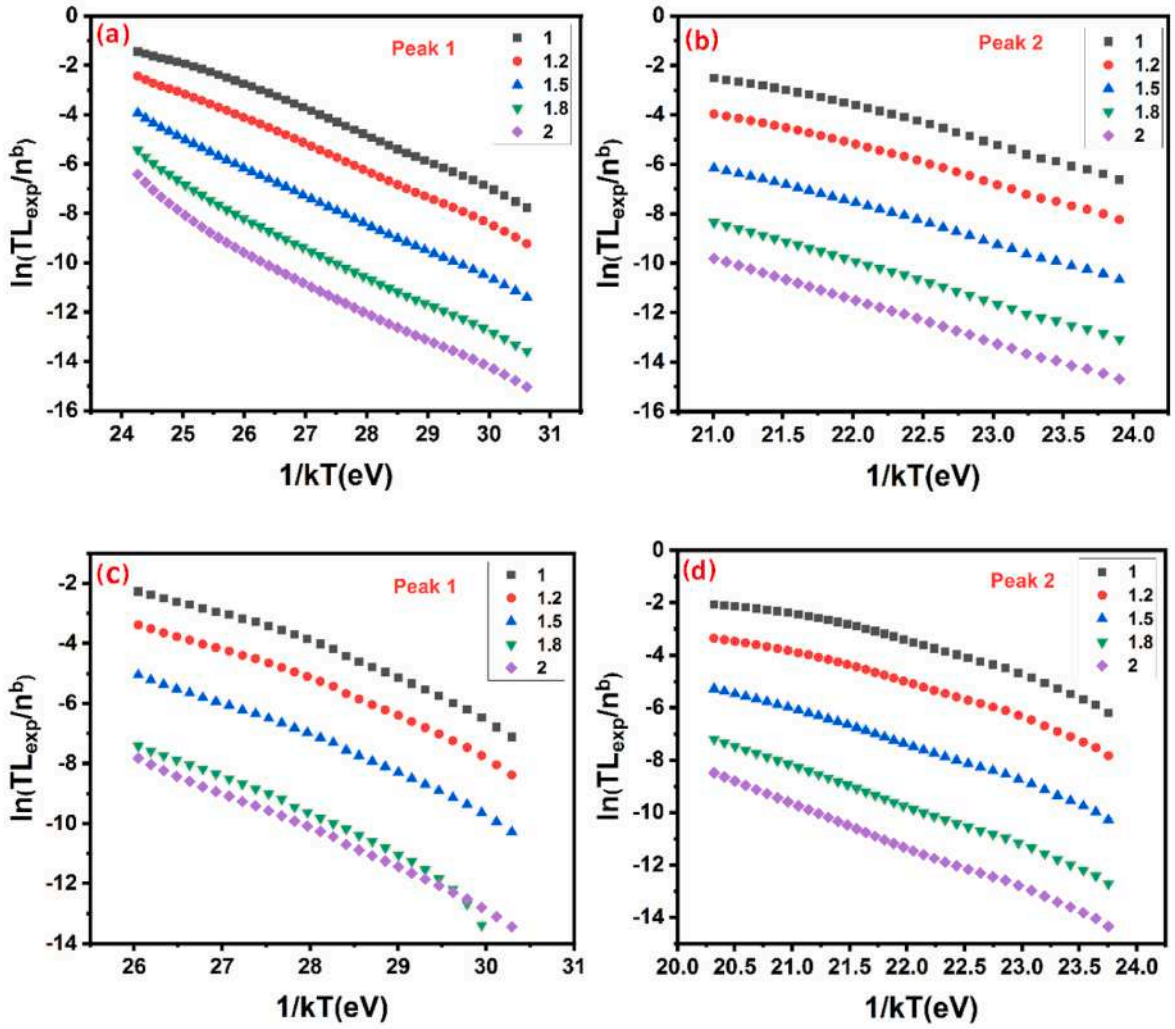

Fig. 11. Plot of $\ln(T_m^2/\beta)$ *vs* $1/kT_m$ to evaluate the energy parameters of TL glow curve of 100 MeV Ag^{7+} (a) peak 1 and (b) peak 2 and 100 MeV Ni^{7+} (c) peak 1 and (d) peak 2 of MgB_4O_7: Eu phosphor at fluence of 5×10^{12} ion/cm^2.

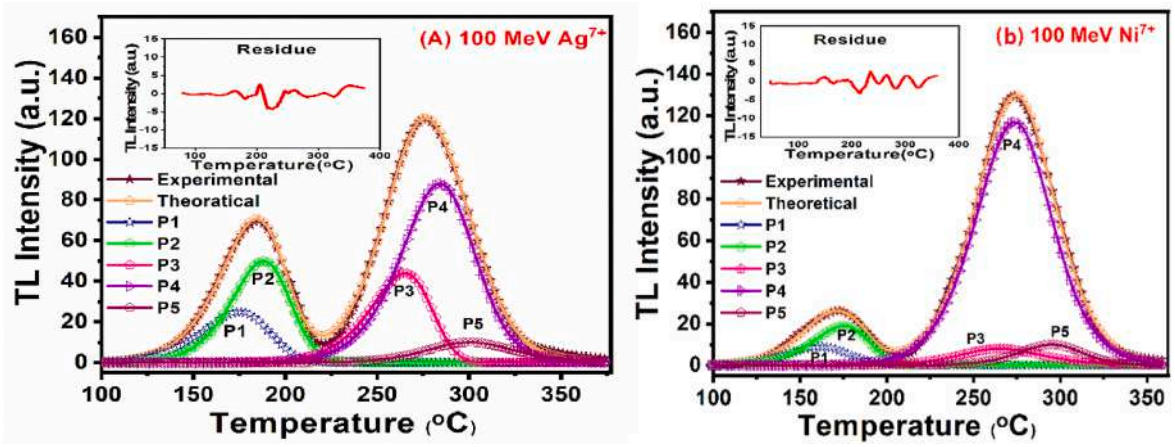

Fig. 12. The GCD curve of MgB_4O_7: Eu phosphor irradiated at 100 MeV (a) Ag^{7+} ions and (b) Ni^{7+} ions with fluence of 5×10^{12} ion/cm^2.

100 MeV Ag^{7+} irradiated glow curve possessing 5 trapping levels with activation energies of around 1 eV, 1.27 eV, 1.55 eV, 1.59 eV and 1.66 eV. Fig. 12 (b) represents 100 MeV Ni^{7+} irradiated glow curve having 5 trapping levels with activation energies around 1.04 eV, 1.14 eV, 1.4 eV, 1.49 eV, and 1.85 eV.

4.6. Crystal structure and electronic properties from density functional theory

The optimized crystal structure of pure MgB_4O_7 containing 96 atoms (8 Mg, 32 B and 56 O) is shown in Fig. 13 (a). The structure optimizes in

Table 5
Glow curve trapping parameters of MgB_4O_7: Eu phosphor using Kitis equation.

Sample Name	Ion beam (100 MeV)	Peak	Temperature (T_m)	Order of Kinetics (b)	Trap Depth (eV)	Frequency Factor (s^{-1})	FOM (%)
MgB_4O_7:Eu	**Ag** $^{7+}$	P1	175	1.15	1 ± 0.05	2.76×10^{12}	**2.1 %**
		P2	188	1.25	1.27 ± 0.01	1.42×10^{15}	
		P3	265	1.08	1.55 ± 0.01	5.54×10^{15}	
		P4	284	1.46	1.59 ± 0.02	3.90×10^{15}	
		P5	303	1.99	1.66 ± 0.03	6.30×10^{15}	
	Ni $^{7+}$	P1	161	1.35	1.04 ± 0.02	2.05×10^{13}	**2.5 %**
		P2	175	1.16	1.14 ± 0.01	1.18×10^{14}	
		P3	265	1.9	1.4 ± 0.02	1.96×10^{14}	
		P4	273.5	1.65	1.49 ± 0.01	8.54×10^{14}	
		P5	295	1.51	1.85 ± 0.02	4.61×10^{16}	

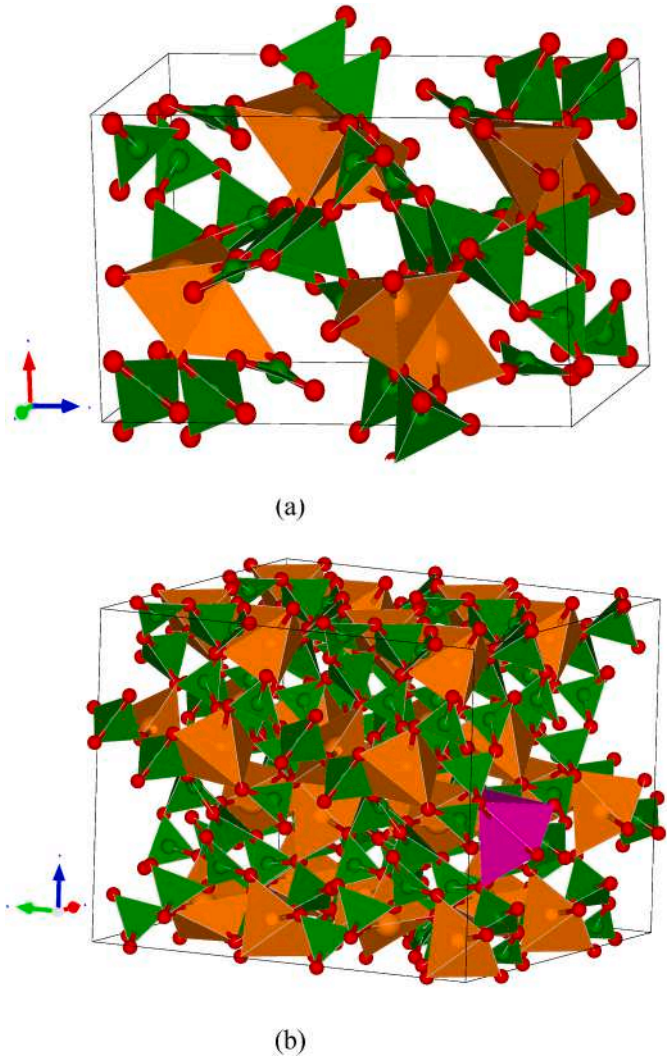

Fig. 13. (color online) The optimized crystal structure of (a) pure MgB_4O_7 and (b) Eu doped at Mg site in MgB_4O_7 2 × 2 × 1 supercell. The corners of all polyhedra are oxygen atoms and are shown by red spheres. The atoms in green polyhedra are B sites, whereas the orange polyhedra enclose Mg atoms. In MgB_4O_7:Eu, the purple polyhedron encloses Eu atom.

orthorhombic phase with space group no. 61 (*Pbca*). The optimized lattice parameters are $a = 8.12$ Å, $b = 13.89$ Å and $c = 8.73$ Å.

In order to investigate the effect of doping with low concentration of Eu in MgB_4O_7, we have employed 2 × 2 × 1 supercell of MgB_4O_7 and have checked possible doping of Eu atom separately at Mg and B sites. The doping of Eu atom at Mg site in the 2 × 2 × 1 supercell is shown in Fig. 13 (b). The supercell contains 31 Mg atoms, 128 B atoms, 224 O atoms and 1 Eu atom, giving 3.125 % of Eu doping at Mg site in the system, whereas doping Eu at B site.

(not shown) leads to 32 Mg atoms, 127 B atoms, 224 O atoms and 1 Eu atom leading to 0.78 % of Eu doping at B site. We have fully relaxed both the structures (Eu at Mg site and B site) using DFT calculations without considering Hubbard U parameter. Our results yield lattice parameters $a = 8.13$ Å, $b = 13.92$ Å and $c = 8.74$ Å for Eu doped at Mg site. The lattice parameters of MgB_4O_7 are enhanced slightly after Eu doping at Mg site, indicating slight expansion in the lattice due to larger ionic radius of Eu atom, which is consistent with the previous calculations of Eu doping in other crystals [60]. Interestingly, after doping Eu at B site, the lattice parameters tend to shrink ($a = 8.11$ Å, $b = 13.87$ Å, $c = 8.72$ Å) than that of MgB_4O_7:Eu with Eu doped at Mg site as well as pure MgB_4O_7. In both the doped structures, the Eu atom occupies a site with no inversion symmetry. Our computationally optimized structures, their lattice parameters and symmetry generally match with our experimental results.

The relative stability of the two structures (a) Eu doped at B site in MgB_4O_7 and (b) Eu doped at Mg site in MgB_4O_7 is determined by computing cohesive energies and formation energies for both the cases. The cohesive energy per atom for Eu substituted at B/Mg site in the supercell $Mg_{32}B_{128}O_{224}$ is calculated as

$$E_{coh}^{B} = \frac{E_{Total} - \left(32\,E_{Mg} + 127\,E_{B} + 224\,E_{O} + E_{Eu}\right)}{384} \text{ and}$$

$$E_{coh}^{Mg} = \frac{E_{Total} - \left(31\,E_{Mg} + 128\,E_{B} + 224\,E_{O} + E_{Eu}\right)}{384}$$

where E_{Total} is the total energy of the substituted system and E_X is the energy of atom X. The formation energy for Eu substituted at B/Mg site in $Mg_{32}B_{128}O_{224}$ is calculated as

$$E_{form}^{B} = E_{\{Mg_{32}B_{127}O_{224}Eu\}} - \left(E_{\{Mg_{32}B_{128}O_{224}\}} - E_B + E_{Eu}\right)$$

and

$$E_{form}^{Mg} = E_{\{Mg_{31}B_{128}O_{224}Eu\}} - \left(E_{\{Mg_{32}B_{128}O_{224}\}} - E_{Mg} + E_{Eu}\right)$$

Our cohesive energy calculations for (a) Eu doped at B site in MgB_4O_7 and (b) Eu doped at Mg site in MgB_4O_7 give $E_{coh}^{B} = -6.80$ eV/atom and $E_{coh}^{Mg} = -6.82$ eV/atom indicating that Eu marginally favors Mg site for the substitution than B site. The formation energy for cases (a) and (b) are 25.74 eV and 19.53 eV respectively, indicating again that case (b) is more favored, i.e., Eu atom prefers to replace Mg atom than B atom in agreement with our experimental results. Experimental results predict existence of Eu^{3+} ion in the doped system and therefore it is expected that Eu may substitute B in MgB_4O_7 but our results indicate the contrary.

The electronic band structure and corresponding site projected density of states for pristine MgB_4O_7 are shown in Fig. 14. Our electronic structure calculations show that pure MgB_4O_7 is a large band gap (5.81 eV) insulator. The valence bands are mostly from O-2*p* states and span entire valence band region. The O-2*p* states hybridize majorly with B-2*p* with minor contribution from Mg-3 (*sp*) states. The conduction bands are relatively widely dispersed and are contributed by B-2*p* and Mg-3*s*

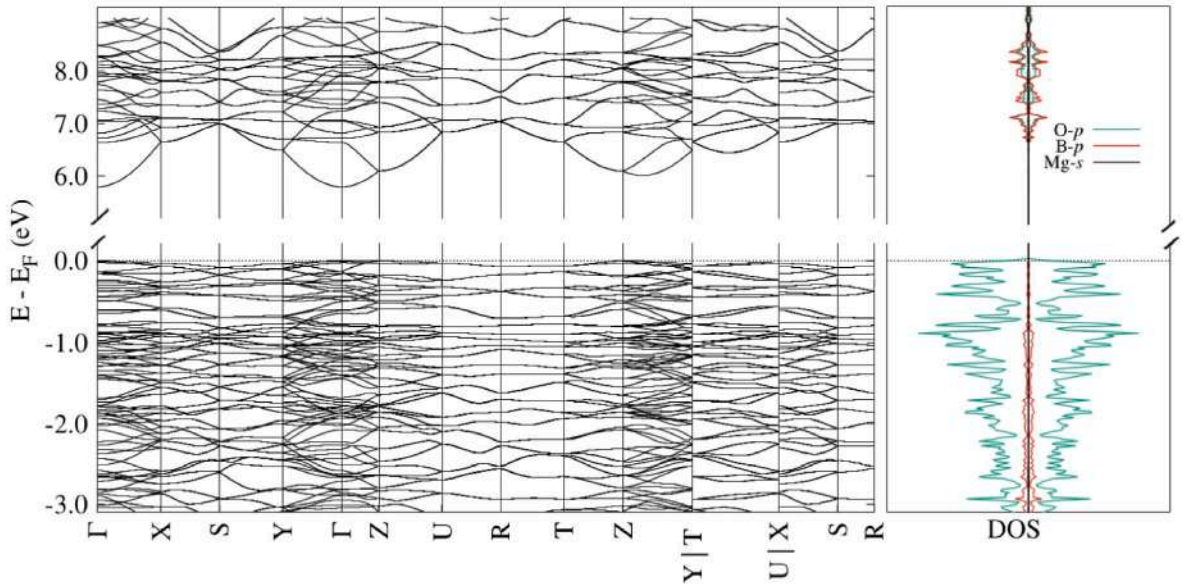

Fig. 14. (color online) Electronic band structure and site projected density of states (DOS) for pure MgB_4O_7. DOS for majority and minority spins are shown separately in the left and right panels respectively.

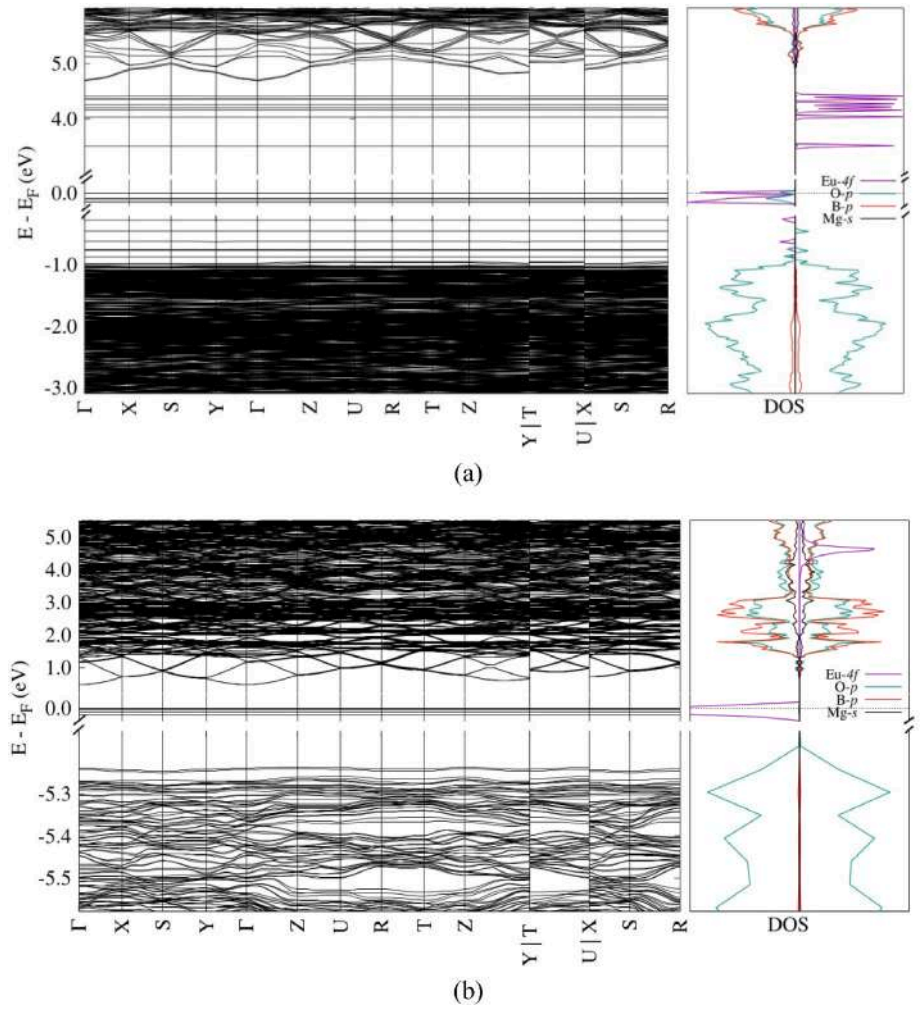

Fig. 15. (color online) Electronic band structure and site projected density of states (DOS) for (a) Eu doped at B site in MgB_4O_7 without Hubbard U, (b) Eu doped at Mg site in MgB_4O_7 without U, (c) Eu doped at Mg site in MgB_4O_7 with $U_{eff} = 2.25$ eV and (d) Eu doped at Mg site in MgB_4O_7 with $U_{eff} = 6.25$ eV. The band structure shows bands for both the spins while the left and right panels depict DOS for majority and minority spins respectively.

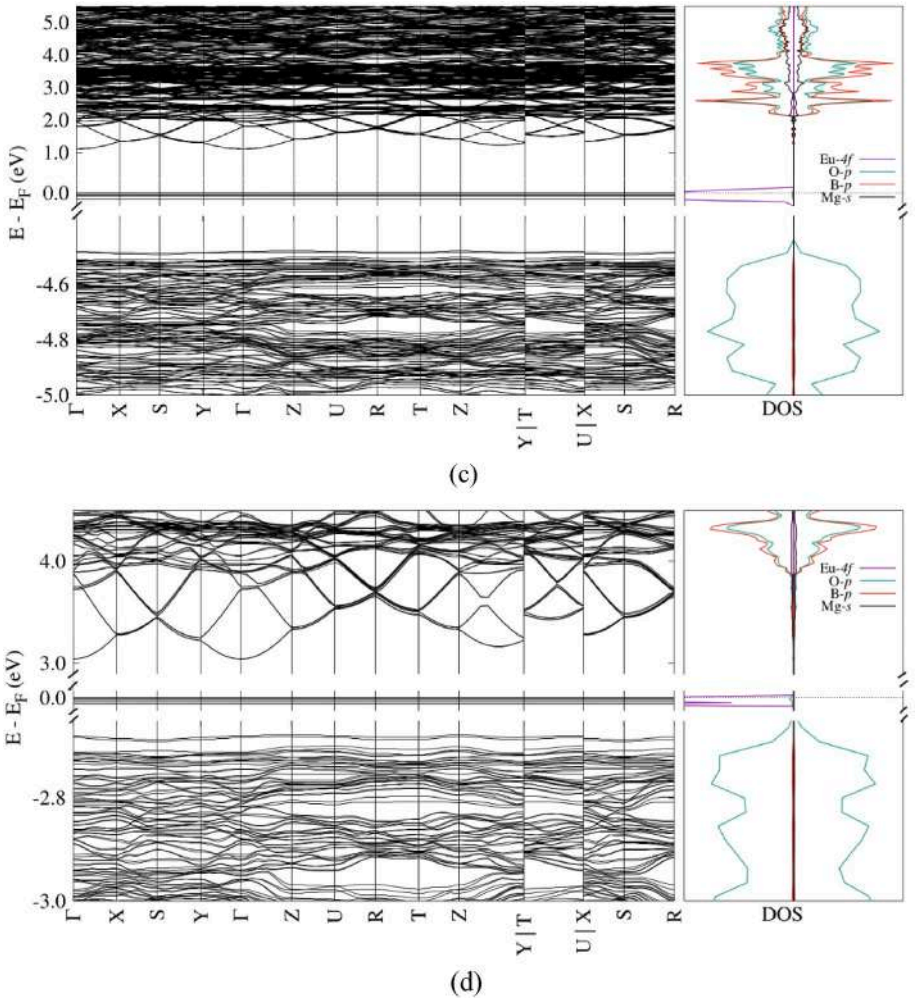

Fig. 15. (*continued*).

states with minor O-*2p* orbital character. The optical response for pure MgB_4O_7 is mainly from O-*2p* states of the valence band to B-*2p* states or Mg-*3s* states of the conduction band. After Eu doping in MgB_4O_7, the location of the electronic states is significantly affected. In addition, the Eu site shows on-site exchange splitting due to the half-filled 4*f* shell with high magnetic moment of 6.98 μ_B. The 4*f* shell induces small spin polarization on its own *s*, *p* and *d* electronic states. The induced spin polarization on the neighbouring sites due to Eu-4*f* states is negligible due to highly localized nature of 4*f* wavefunctions. The exact location of the electronic states of all atoms including Eu-*4f* are sensitive to the choice of Hubbard U parameter. In order to optimize the computational time for tuning the Hubbard U parameter for Eu-*4f* states in MgB_4O_7:Eu (Eu substituted at Mg site), we have considered previously tuned U parameter by Kuneš et al. for Eu-*4f* states, i.e., U_{eff} = 6.25 eV. Two additional calculations – one without U and other with U_{eff} = 2.25 eV [33] are carried out to understand the general trend of the location of electronic states in the band structure.

We discuss the electronic structure of MgB_4O_7:Eu for four different cases, (a) Eu doped at B site without inclusion of U (Fig. 15 (a)), (b) Eu doped at Mg site without inclusion of U (Fig. 15 (b)), (c) Eu doped at Mg site with U_{eff} = 2.25 eV (Fig. 15 (c)) and (d) Eu doped at Mg site with U_{eff} = 6.25 eV (Fig. 15 (d)).

For the case (a), occupied Eu *4f* states for majority spin appear at valence band maximum and due to their highly localized nature, bands are flat. The majority 4*f* states span 0–1 eV spectrum below the Fermi energy and are immediately followed by O-*2p* states down in the valence band region. These majority spin 4*f* states act as donor states, since they give additional electrons to the system. These states also act as trapping sites for excited electrons from the valence bands. Defect levels due to Eu *4f* minority spin states appear in the region 3.5–4.5 eV above the Fermi level. The conduction bands, around 4.6 eV above the Fermi energy are mainly from B-*2p* states hybridized with Mg-3 (*sp)* states. For Eu at B site, without considering Hubbard U effect, the optical response is due to transition between Eu-*4f* (↑) to Eu-*4f* (↓) corresponding to wavelength in the region 275–365 nm.

For the case (b), where Eu is doped at Mg site and Hubbard U parameter is not considered, we find occupied O-*2p* states are distinctly separated by approximately 5 eV below the Eu-*4f* majority states which appear at the Fermi energy. This separation can be assigned to the charge transfer from O-*2p* states to Eu-*4f* states corresponding to wavelength of 250 nm approximately. This number corroborates well with our experimental result of photoluminescence excitation spectrum. The B-*2p* states in the conduction band are observed at 0.43 eV above the Fermi energy, whereas the peak in DOS of unoccupied Eu *4f* (↓) states is located at approximately 4.5 eV above the Fermi energy. For the photoluminescence considered between Eu-4f (↑) - Eu-*4f* (↓), the calculated emission wavelength spans a region 250–300 nm.

For case (c) where, Eu is doped at Mg site and the effective Hubbard parameter is considered as U_{eff} = 2.25 eV, the occupied O-*2p* states are observed at 4.5 eV below the Fermi energy and they are relatively closer to the Fermi energy in comparison to those in case (b). The majority Eu-*4f* states continue to stay at Fermi energy as in case (b) whereas unoccupied, minority spin Eu-*4f* are located approximately at 6.7 eV above the Fermi energy (not shown in the figure). In this case, the optical

response of the photoluminescence can occur with the wavelengths 275 nm and 185 nm, for O-*2p* → Eu-4f (↑) and Eu-4f (↑) → Eu-4f (↓) states respectively. The former agrees well with the experimental photoluminescence result.

For case (d), where we considered U_{eff} = 6.25 eV for Eu-*4f* states, with Eu doped at Mg site, we observe that all valence and conduction band states are shifted by around 2.5 eV towards higher binding energy with respect to the pure MgB_4O_7 structure, which is consistent with the earlier reports of doping of Eu atoms in phosphor systems [61,62]. In addition, the majority spin 4*f* states appear in the band gap region of the host whereas the minority spin 4*f* states are located approximately 10–11 eV above the Fermi energy (not shown in the figure). Since the valence band maximum is dominated by O-*2p*, the luminescence characteristics and optical response is due to transition between O-*2p* → Eu-4*f* (↑) states. Our calculated energy separation between O-*2p* and Eu-4f (↑) states is 2.58 eV, which corresponds to wavelength of 480 nm. This corresponds to charge transfer state seen in photoluminescence excitation spectra but the value does not agree with our experimental result.

Electronic structure calculations based on density functional theory provide single particle states which can provide an estimate for the transitions observed in experiments. Our calculations for estimating the optical response in all the cases (a)-(d) discussed above show that the charge transfer state from O-*2p* states to Eu-*4f* (↑) states is observed only when Eu is doped at Mg site. Depending on the value of the Hubbard U parameter, the state ranges from 250 nm to 480 nm in comparison with our experimental value of 280 nm, the closest being 275 nm for U_{eff} = 2.25 eV. The shortest Eu-*4f* (↑) - Eu-*4f* (↓), separation observed is ~3.5 eV for Eu doped at B site corresponding to 365 nm of optical transition. For Eu doped at Mg site, which is energetically more favorable, the transition Eu-*4f* (↑) - Eu-*4f* (↓) has range 250–300 nm when Hubbard U is not considered and 160–225 nm when U_{eff} = 2.25 eV. However, the limitations of DFT as a mean field theory, predicting the single particle like states need to be noted.

5. Conclusions

In summary, MgB_4O_7:Eu phosphor system has been successfully synthesized via hydrothermal route and its SHI induced TL dosimetric properties are studied systematically. The structural studies of SHI irradiated MgB_4O_7:Eu (1 mol %) reveal that although the phosphor material loses its crystallinity, the crystal structure of the phosphor remains unchanged. SRIM calculations represent the projectile ranges and nuclear and electronic energy losses of 100 MeV Ag^{7+} and Ni^{7+} ion beams which are responsible for the ionization and luminescence performance of material. Photoluminescence studies show emission bands in the orange-red region with prominent peaks at ~593 nm and ~625 nm attributed to the $^5D_0 \rightarrow {}^7F_1$ (MD) and $^5D_0 \rightarrow {}^7F_2$ (ED) transitions of Eu^{3+}ion. The relative intensity ratio of EDT and MDT provide information about the local site symmetry of europium ions in the matrix. The correlation between the ion beam fluence and photoluminescence properties is briefly discussed. A variation in PL intensity is observed upon ion beam irradiation and different fluence owing to modification of defect/luminescent centres. TL glow curves of the 100 MeV Ag^{7+} and Ni^{7+} ion irradiated beams show two prominent glow peaks. The TL peak intensity varies without any modification in its shape and position in the range of 1×10^{10} to 5×10^{12} ion/cm^2, which may be a result of modification of luminescent centres at various fluences of ion beams. Fading in the phosphor is only 10 % for Ag^{7+} ion irradiation and 12 % for Ni^{7+} ion irradiation over a period of two months for both the dominant peaks. Kinetic parameters which are responsible for the TL glow curve are calculated via peak shape method, whole glow peak method, and glow curve deconvolution method using Kitis equations. DFT computational studies are performed to know the electronic structure of Eu doped MgB_4O_7 phosphor. The optimized structural parameters and structure symmetry matches well with the experimental crystal structure obtained from XRD studies and photoluminescence studies respectively. Electronic structure studies and energetics reveal substitution of Eu at the Mg site in agreement with the experimental results. Overall, owing to the promising photoluminescence and thermoluminescence properties, Eu doped MgB_4O_7 phosphor may exhibit potential applications in the field of lighting applications and swift heavy ion dosimetry.

CRediT authorship contribution statement

Kishor H. Gavhane: Writing – original draft, Visualization, Methodology, Investigation, Data curation, Conceptualization. **M.S. Bhadane:** Software, Formal analysis. **Preeti P. Kulkarni:** Visualization, Software, Formal analysis. **Vikas Kashid:** Software, Investigation, Formal analysis. **V.S. Ghemud:** Resources, Formal analysis. **K. Hareesh:** Resources. **K. Asokan:** Resources. **Anjali Kshirsagar:** Writing – review & editing, Supervision, Formal analysis. **V.N. Bhoraskar:** Resources. **S.D. Dhole:** Writing – review & editing, Supervision, Resources, Project administration, Funding acquisition. **S.S. Dahiwale:** Writing – review & editing, Supervision, Resources, Project administration, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgments

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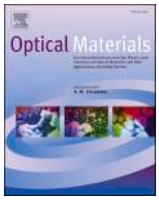

Research Article

Experimental and computational study of Cu_2FeSnS_4: An emerging quaternary semiconductor

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Ideality factor

ABSTRACT

The quaternary semiconductor Cu_2FeSnS_4 (CFTS) has attracted attention of the research community due to its optical and electrical properties, earth abundance and non-toxicity. CFTS powder has been successfully synthesized using solvothermal technique. X-ray diffraction peaks and Raman spectra confirm structural formation of the compound, and XPS studies determine the oxidation states of Cu, Fe, Sn and S to be +1, +2, +4 and −2 respectively. The scanning electron microscopy images show nanosheet array-like morphology and the stoichiometry ratio of 2:1:1:4 for Cu, Fe, Sn and S respectively is obtained from EDS measurements. Direct band gap of 1.52 eV has been estimated using the Tauc plot. The experimental findings have been supported computationally using density functional theory (DFT) based calculations performed within quantum espresso (QE) software. The stannite phase is observed to be the ground state and is in accordance with the experimental observation. The total density of states (DOS) and projected DOS show the contribution of each elemental species in valence and conduction bands. A direct band gap of 1.51 eV obtained from HSE06 hybrid functional is in good agreement with the Tauc plot result. Further, the cation defect formation calculations show that Cu vacancy is most likely to be formed among the cations. The computationally obtained absorption spectra confirms the application of CFTS as absorber layer in a solar cell. The electrical study of the *p*-CFTS and *n*-CdS junction is carried out using *J-V* response. The calculated ideality factor, series resistance and power conversion efficiency show promising application in photovoltaic industry. The present work fills the existing gap in the published literature of a systematic experimental and computational study of CFTS semiconductor, which has application in varied fields.

1. Introduction

The energy requirement of mankind is increasing day by day and fossil fuels alone cannot fulfill the requirement. Solar energy is considered to be the most promising supplementary source of energy due to its availability and various modes of its utilization. Solar photovoltaic (PV) technology harnesses solar energy with highest efficiency and is still under development. With the improvising technology and materials used, various generations of solar cell have been classified. At present, third and fourth generations of solar cells are being explored rigorously. The solar cells having highest efficiency based on silicon (Si), copper indium gallium selenide (CIGS) and cadmium telluride (CdTe) are either expensive or contain toxic materials or have materials with limited reserves. Hence, the research community is exploring eco-friendly materials with abundant reserves that can be synthesized easily and economically.

The quaternary semiconductor copper zinc tin sulfide (CZTS) having chemical formula Cu_2ZnSnS_4 is one such semiconductor with promising electric and optical properties for solar cell applications. After a decade of research, the efficiency of the CZTS solar cell could not match with the well-established competitors and therefore there exists a lot of scope to explore similar materials. One such quaternary semiconductor Cu_2FeSnS_4 (CFTS) is proving to be an alternative with similar optical absorption, band gap, electrical conductivity and structural stability.

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CFTS can be synthesized using various physical and chemical techniques like microwave synthesis, solvothermal route, sputtering, electrodeposition etc. Although CFTS has been explored experimentally, very less computational literature is available till date. The synthesis of CFTS thin films using RF magnetron sputtering has been discussed by Meng et al. [1]. The sputtered thin films have been annealed and then used for characterization. The thin films are found to be stoichiometric with stannite phase geometry and having a band gap of 1.1 eV. Trajic et al. have analyzed the vibrational properties of mechanochemically synthesized stannite Cu_2FeSnS_4 nanocrystals. They noticed the peaks corresponding to binary phases of FeS and SnS which disappeared when the milling time was longer than 90 min [2]. $Cu_2FT(S_{0.8}Se_{0.2})_4$ material was synthesized by melt quench technique and subsequently thin films were deposited using thermal evaporation method by Tripathi et al. [3]. Compositional, structural, morphological and optical properties are characterized using XRD, SEM, EDS, Raman spectroscopy, FTIR and UV–Vis–NIR spectroscopy and the material has been shown to have potential to be used as an absorber layer in solar cell with optimal band gap of 1.49 eV and a high absorption coefficient ($>10^4$ cm^{-1}). In another work, Cao et al. have discussed the use of polyvinylpyrrolidone (PVP) in growth of CFTS nanospheres using solvothermal method [4]. The nanospheres have size distribution between 0.4 μm and 0.6 μm with a band gap value of 1.33 eV. The photo-response study of these nanospheres suggested potential application in solar cells. The illumination current value has increased considerably post annealing the *p-n* junction. Ghosh et al. [5] have used spin coating route for deposition of Cu_2-II-Sn-S_4 (II = Fe, Co and Ni) thin films on ITO substrate and have studied their properties using Raman spectroscopy and electrochemical impedance spectroscopy. These authors have also carried out computational studies of electronic structure using WIEN2K software. The computationally obtained structural, stoichiometric and optical properties are in corroboration with those found experimentally, suggesting possible application in photoelectric devices. Recently Varku et al. have carried out numerical modeling of various loss mechanisms which degrade the performance of CFTS solar cell [6]. It is observed that radiative recombination dominates in the bulk of the CFTS layer.

The solvothermal synthesis method has upper hand due to its easy synthesis process and control over parameters for varying the morphology of the product. Nanowires, nanorods, nanosheets and nanospheres can be obtained by changing the solvent- solute concentrations, capping agent, synthesis time and temperature. We have therefore used solvothermal method for synthesizing CFTS powder. The structural, morphological and optical properties confirm the formation of CFTS nanosheet-like array with no secondary phases. In addition to the experiments, we have computationally explored CFTS using density functional theory based open-source software.

2. Methodology

2.1. Experimental details

The chemicals, viz. copper (II) chloride dihydrate ($CuCl_2{\cdot}2H_2O$), iron (III) chloride hexahydrate ($FeCl_3{\cdot}6H_2O$), tin (II) chloride dihydrate ($SnCl_2{\cdot}2H_2O$) and thiourea (SC $(NH_2)_2$) are used as Cu, Fe, Sn and S sources respectively. Polyvinylpyrrolidone (PVP) and ethylene glycol (EG) are used as capping agent and solvent respectively. CFTS nano particles have been synthesized using a simple solvothermal process. The precursors 1 mmol $CuCl_2{\cdot}2H_2O$, 0.5 mmol $FeCl_3{\cdot}6H_2O$, 0.5 mmol $SnCl_2{\cdot}2H_2O$ and 2 mmol thiourea $(SC(NH_2)_2)$ are mixed in stoichiometric proportion of 2:1:1:4 respectively, along with 0.2 gm PVP and 60 ml EG in a beaker. This mixture is magnetically stirred for 2 h to obtain a clear solution which is then transferred to a Teflon-lined stainless-steel autoclave. The autoclave is kept in a hot air oven for 24 h with the mixture temperature maintained at 180 °C, and then the product is naturally cooled to room temperature. The final black product is cleaned several times by repeating the cycle of dispersing in ethanol, centrifugation at 3000 rpm for 15 min and discarding the ethanol. Finally, the CFTS powder is obtained by dissolving the centrifuged product in ethanol, followed by drying at 60 °C for 5 h in a hot air oven.

The crystal structure of synthesized CFTS powder is analyzed by X-ray diffraction (XRD) (Bruker D8 Advance) using Cu-K_α (λ = 1.54 Å) radiation and Raman spectroscopy (RenishawInVia Raman microscope). A laser source having excitation wavelength of 532 nm is used for Raman analysis. UV–Vis–NIR spectrophotometer (JASCO, V-670) is used for recording the optical spectra. The morphology and chemical composition of CFTS nanoparticles is studied using scanning electron microscopy (SEM) and energy dispersive spectrometer (EDS) (JEOL JSM-6360-LA) techniques respectively. The chemical composition of the synthesized nanoparticles is examined with the help of X-ray photoelectron spectroscopy (XPS) (Thermo Scientific, K-Alpha+). The current density–voltage (*J-V*) characteristic curves for the device are obtained using a Xe-based light source solar simulator with simulated 1 Sun AM 1.5 G illumination and Keithley 2450 source meter.

2.2. Computational details

The computational work is carried out based on density functional theory (DFT) [7,8] as implemented in Quantum Espresso (QE) [9,10] package, using the projector augmented wave (PAW) method [11] with plane wave basis set with an energy cut-off of 70 Ry for expansion. The lattice parameters of CFTS unit cell consisting of 16 atoms is varied to get the optimized cell by minimization of the total energy of the system. The structure has been relaxed to fulfill the energy convergence criteria of 10^{-5} Ry for electronic self-consistency and force convergence of 10^{-3} Ry/Å for ionic relaxation with the **k**-mesh of 6 × 6 × 3 for reciprocal space integration. Perdew-Burke-Ernzerhof (PBE) [12] generalized gradient approximation (GGA) for the exchange-correlation energy functional has been employed during optimization while to compare the theoretical band gap with experimental results, we have used Heyd-Scuseria-Ernzerhof (HSE06) [13] hybrid functional after optimization. We have then adopted a ladder approach: use of DFT to optimize the structure and get the electron energy values, subsequent single shot GW calculation for better estimate of band gap followed by solution of Bethe-Salpeter equation (BSE) to get the absorption spectrum [14,15].

Experimentally the vacancy defects are more dominant than other point defects; moreover, the vacancy concentration is very small. Therefore, the vacancy formation energy calculations are performed on a 2 × 2 × 1 super cell consisting of four unit cells (16 Cu, 8 Fe, 8 Sn and 32 S atoms) with 70 Ry energy cut-off for plane wave expansion and 3 × 3 × 3 **k**-mesh for reciprocal space integration. The super cell is not relaxed after the removal of an atom in order to mimic the experimental vacancy defect, where the parent structure remains unaltered.

3. Results and discussion

3.1. Structural analysis

3.1.1. XRD, Raman and XPS analysis

The XRD pattern in Fig. 1 shows the peaks appearing at 2θ = 28.49, 32.84, 36.98, 40.93, 47.50 and 55.95 corresponding to (112), (200), (202), (114), (220) and (312) planes of tetragonal stannite phase respectively. These values match well with the JCPDS file 44-1476. The impurities like FeS, Cu_2SnS_4, Cu_2FeS_4 and CTS are absent in the sample as no peaks of these compounds are observed in the XRD pattern. The estimated average crystallite size of synthesized CFTS is around 20 nm, calculated using the Scherrer formula. The lattice parameters '*a*' and '*c*' are calculated to be 5.43 Å and 10.77 Å respectively, which give the distortion coefficient ($\varepsilon = c/2a$) as 0.99. The lattice parameter values agree with the JCPDS file 44-1476 data viz. $a = 5.45$ Å and $c = 10.73$ Å with the $\varepsilon = 0.98$. The calculated lattice parameters are within an error of < 0.5% of the standard values, a slight deviation in the calculated lattice parameters and those in the JCPDS file may be due to the

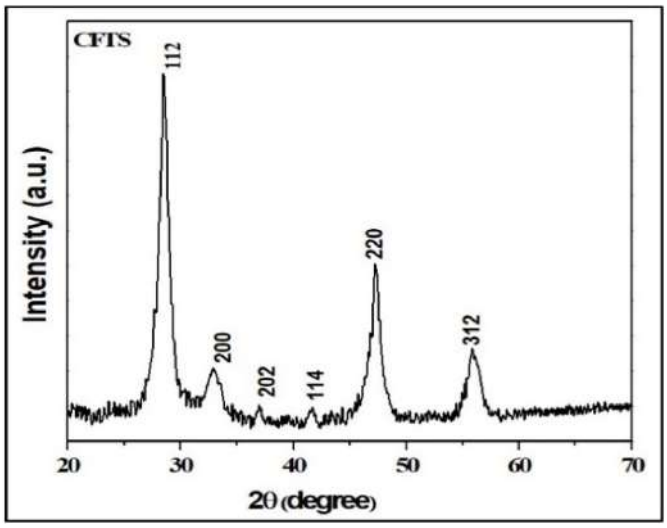

Fig. 1. XRD pattern of synthesized CFTS powder.

difference in the synthesis method.

The Raman spectrum in Fig. 2 is used to confirm the phase and the symmetry of the crystal structure, and the strength of chemical bonds in synthesized CFTS sample. The Raman spectrum from 150 cm^{-1}–500 cm^{-1} shows the strongest peak positioned at 318 cm^{-1} and an additional shoulder peak at 285 cm^{-1}. The most intense peak seen at 318 cm^{-1} is attributed to the characteristic A_1 mode representing symmetric vibrations of sulfur atoms in CFTS [16,17]. The pure anion-mode of the sulfur atoms around the copper cation is represented by the shoulder peak at 285 cm^{-1}. The peaks at 190, 269, 298, 307 and 473 cm^{-1} as reported in existing literature corresponding to secondary phases SnS, $Cu_{2-x}S$, Cu_2SnS_3, SnS_2 and $CuFeS_2$ respectively, along with some other peaks of similar impurities are absent in our sample [18]. The presence of characteristic peaks along with absence of secondary/impurity peaks indicates good crystallinity and pure phase of synthesized CFTS powder. These results are supportive to the XRD findings.

The XPS full scan spectrum shown in Fig. 3 is analyzed and is used to study the elemental composition and respective oxidation states of the constituent elements in the as-synthesized CFTS powder. Figs. 4 (a) – (d) show the XPS survey spectrum depicting the peaks associated with four

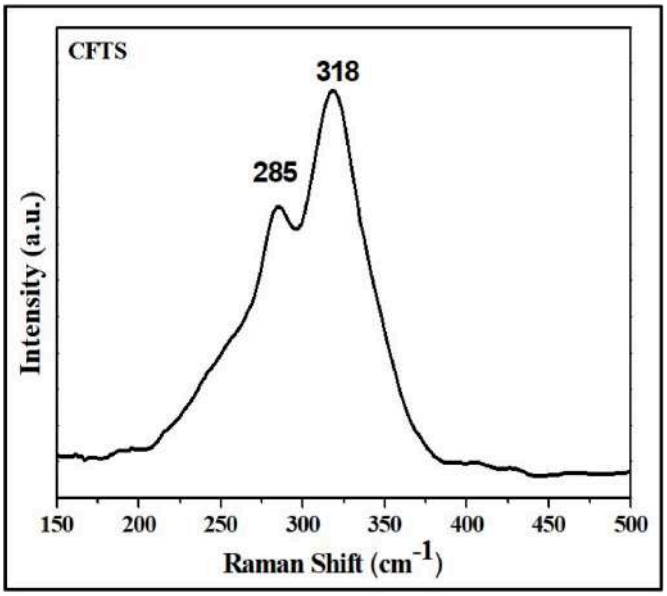

Fig. 2. Raman spectrum of CFTS powder showing absence of impurities.

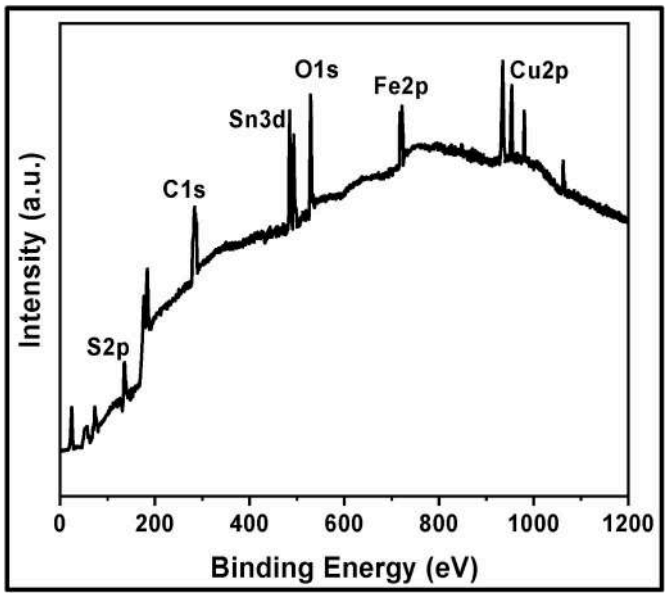

Fig. 3. XPS full scan spectrum of CFTS showing major peaks.

constituent elements (Cu, Fe, Sn, and S) of CFTS. The XPS PEAK 41 software is used for the fitting of XPS spectrum of the constituent elements of CFTS sample. The two symmetric and narrow peaks at 932.14 eV and 951.87 eV in XPS spectrum of Cu:*2p* correspond to $2p_{3/2}$ and $2p_{1/2}$ respectively. The separation between the peaks is calculated to be 19.73 eV and is attributed to the Cu^+ state configuration [19]. The Fe peaks located at 711.52 eV and 725.90 eV correspond to $2p_{3/2}$ and $2p_{1/2}$ respectively, along with the center peak at 715.5 eV arising due to Sn:$2p_{3/2}$ [20,21].

The Sn:*3d* spectrum shows peaks Sn:$3d_{5/2}$ and Sn:$3d_{3/2}$ at 486.57 eV and 495.09 eV respectively. The separation between these two peaks is found to be 8.52 eV, indicating the presence of Sn^{4+} state in the compound [22–24]. The spectrum of *S:2p* displays two peaks at 161.47 eV ($2p_{3/2}$) and 162.49 eV ($2p_{1/2}$) with the difference in binding energy of 1.02 eV [22]. This observation is consistent with S^{2-} state in the CFTS compound [19]. From the peak positions and the binding energy values calculated from the spectrum in Fig. 3, we can confirm the standard oxidation states of the elements Cu, Fe, Sn, and S to be +1, +2, +4 and − 2 respectively [19,22–24].

3.1.2. Geometry optimization

The quaternary semiconductors are generally found to exhibit tetragonal structure with either kesterite or stannite phases, depending on the lattice sites occupied by the atoms. For the present study, we have simulated and optimized both kesterite and stannite phases of tetragonal CFTS, and the stannite phase is found to have total energy lower by 48 meV, suggesting it to be more stable. The ground state crystal structure of stannite phase CFTS is depicted in Fig. 5. The unit cell consists of four copper (Cu), two iron (Fe), two tin (Sn) and eight sulfur (S) atoms placed at *4d*, *2a*, *2b* and *8i* Wyckoff positions respectively. The structure shows *I4-2m* symmetry of space group 121, in accordance with our experimental results. The tetragonal structure has lattice parameters $a = 5.57$ Å and $c = 11.08$ Å with the distortion coefficient having a value of 0.99, which is in good agreement with our experimental results with a deviation of 2–3% in lattice parameters.

3.2. Surface morphology analysis

The microscopic characterization of CFTS powder is done using scanning electron microscopy (SEM). The SEM images of CFTS powder with different magnifications are shown in Fig. 6. The SEM images show

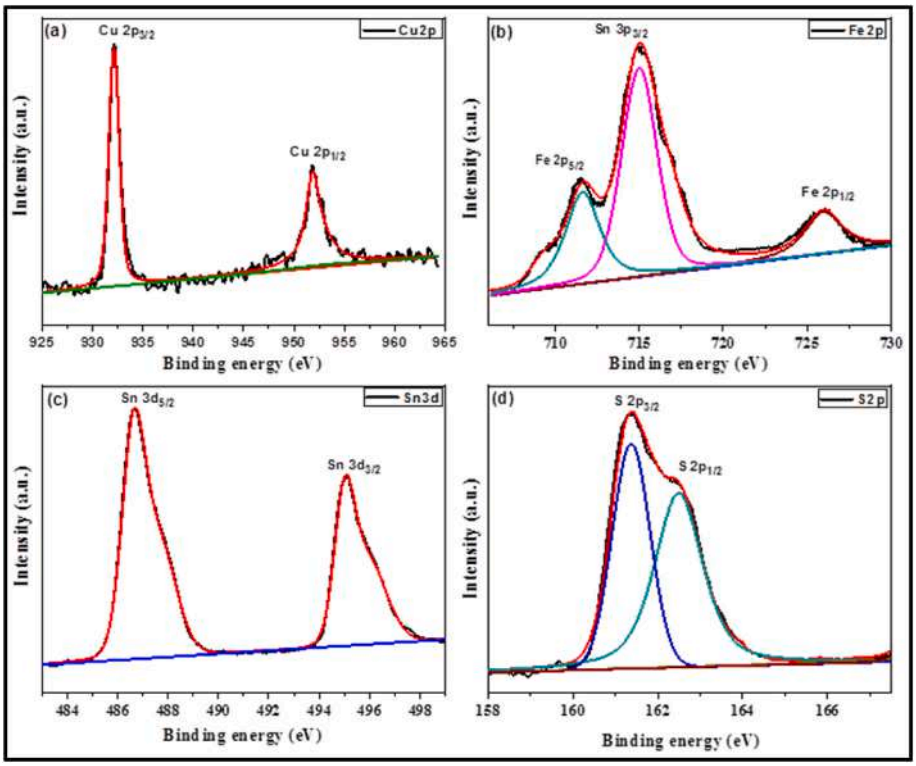

Fig. 4. XPS spectra of CFTS sample showing (a) *Cu:2p*, (b) *Fe:2p*, (c) *Sn:3d* and (d) *S:2p* states.

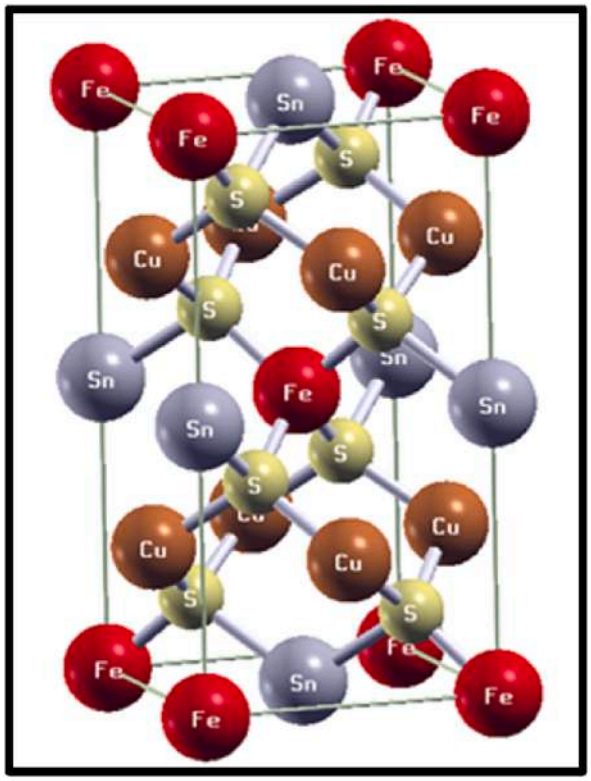

Fig. 5. Crystal structure showing atomic arrangement of tetragonal CFTS.

that PVP has played a key role as a surface ligand, which has resulted in the nucleation and growth of the final CFTS nanosheet array. The surface morphology of CFTS powder shows the formation of nanosheet-like arrays grown radially. Each bundle of nanosheet consists of several rods and further magnification shows the formation of flakes. These flakes are 1–2 μm in length and about 500 nm in diameter with a thickness of about 50 nm. The uniform morphology of the nanosheet array may be arising due to the absorbance of PVP on the faces of surface atoms, which restricts the growth in that direction.

3.3. Elemental composition analysis

The stoichiometric composition of the synthesized CFTS powder has been analyzed using EDS spectra (Fig. 7(a)) and color mapping images are shown in Fig. 7(b). The inset table clearly shows the composition of the sample according to the weight and atomic percentage. The atomic percentages of Cu, Fe, Sn and S are 25.52, 12.40, 13.23 and 48.84 respectively. The recorded atomic ratios of Cu:Fe:Sn:S agree well with the theoretical value of 2:1:1:4. This indicates that the synthesized CFTS powder has the required stoichiometry.

3.4. Optical response analysis

3.4.1. UV–Vis–NIR spectra

The optical properties of the synthesized CFTS powder are studied using the absorption spectra recorded in the wavelength range of 200–1400 nm. Fig. 8 (a) shows the response of CFTS recorded for the ultraviolet (UV), visible and near infrared (NIR) radiation. It is observed that the CFTS nanosheet array exhibits a wide absorption in the UV and visible region with the absorption tails extending into longer wavelength regions.

Electronic structure calculations using HSE06 show that the valence band maximum (VBM) and conduction band minimum (CBM) occur at Γ point indicating that CFTS is a direct band gap semiconductor. The Tauc plot shown in Fig. 8 (b) is used to estimate the optical band gap of the CFTS nanosheet array. CFTS is known to have a direct band gap from existing literature. Our computational studies also support this conjecture. Hence a graph is plotted for $(\alpha h\nu)^2$ versus $h\nu$, where α, h and ν are the absorption coefficient, Planck's constant and the frequency of the

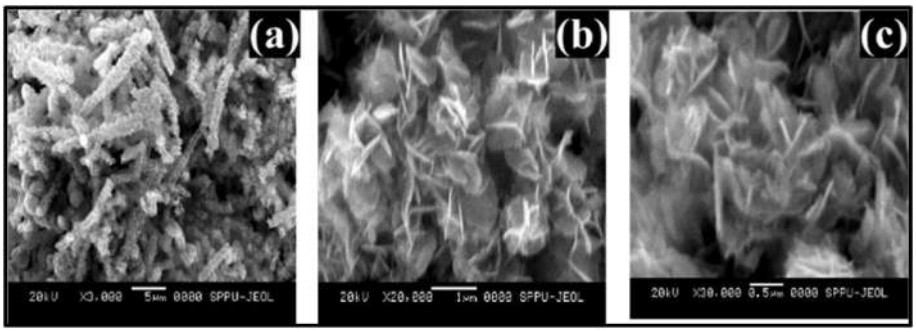

Fig. 6. SEM images of CFTS powder showing uniform surface morphology for various magnifications of (a) 5 μm, (b) 1 μm and (c) 0.5 μm.

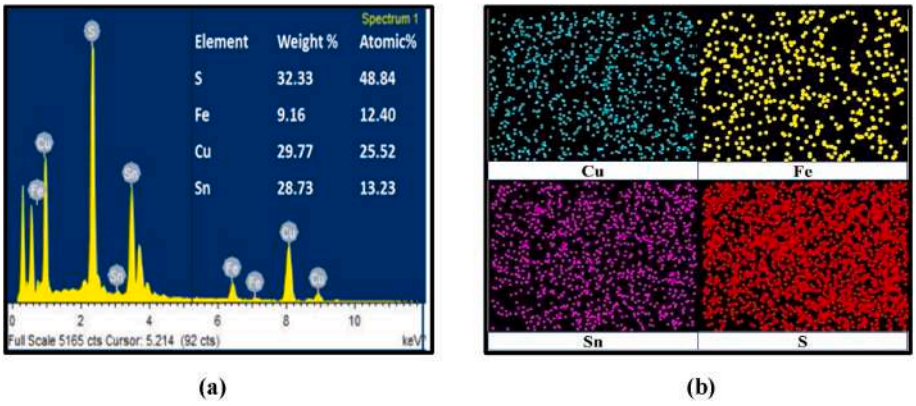

Fig. 7. **(a)** EDS spectra showing elemental composition of CFTS powder and **(b)** Color mapping of elements.

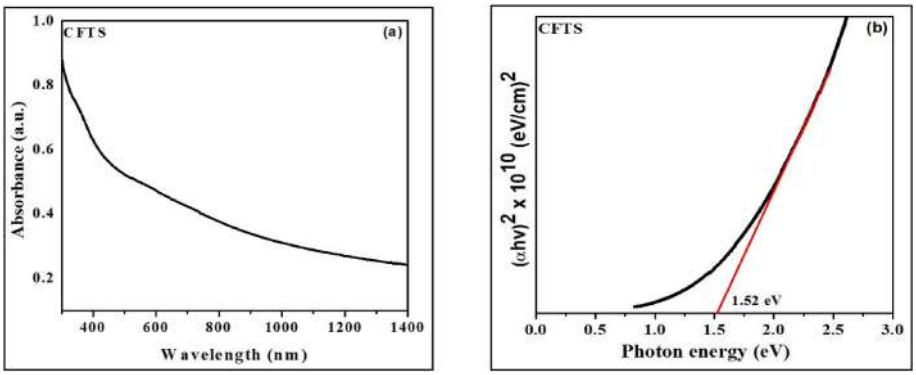

Fig. 8. **(a)** Absorption spectra of CFTS powder and **(b)** Tauc plot showing the band gap of the synthesized sample.

absorbed radiation, respectively. The straight-line nature of the plot in Fig. 8 (b) indicates that the material has a direct band gap. The band gap value of 1.52 eV is found by extrapolating the straight line to intersect the x-axis, which is in good agreement with the literature value [19,25] and our theoretical value 1.51eV as discussed in the following section.

3.4.2. Absorption spectrum

The absorption spectrum of CFTS, shown in Fig. 9, is obtained computationally using the ladder approach including the excitonic effects. It is well-known that the solar spectrum has maximum intensity in the visible and near-infrared region of electromagnetic spectrum. The highest intensity peaks of CFTS absorption spectrum are observed at 1.5 eV, 1.8 eV and 2.5 eV, corresponding to the maximum absorption of respective radiations. The absorption intensity reduces beyond 5.5 eV. This suggests that the radiations within the visible region of solar spectrum are completely absorbed by CFTS, which makes it an ideal material as absorber in solar cell.

3.4.3. Density of states

The total density of states (DOS) plot of CFTS is shown in Fig. 10. The Fermi level has been shifted to zero for plotting purpose. In case of a semiconductor, the placement of valence and conduction bands plays a key role in deciding the optical behavior of the material. The energy states on the left of zero are occupied levels with the valence band maximum around −0.8 eV, while those on the right of zero are unoccupied levels with the conduction band minimum at 0.71 eV. The separation between the valence band maximum and conduction band minimum depicts the band gap of CFTS, which is found to be 1.51 eV in very good agreement with our experimental results. In order to understand the contribution of each atomic species to the bands of interest i.e. valence and conduction bands, the site projected density of states are analyzed.

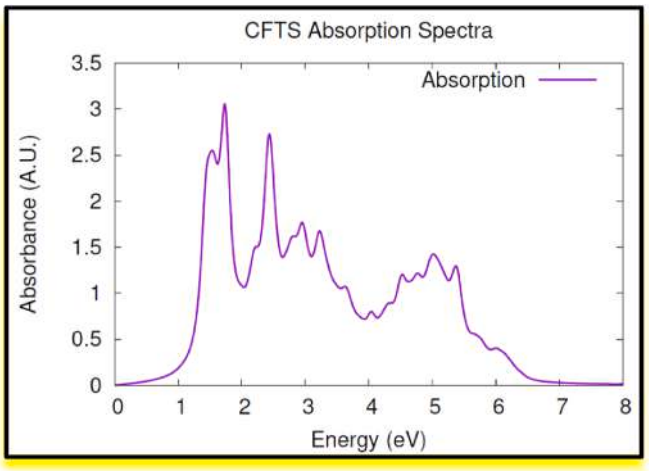

Fig. 9. Computed absorption spectrum of CFTS.

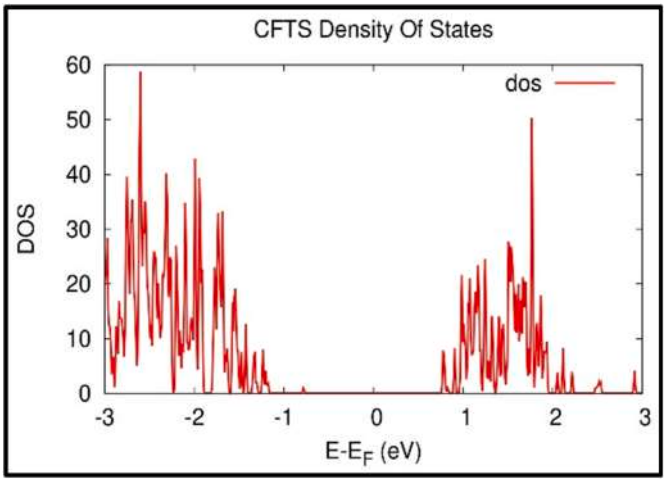

Fig. 10. Density of states plot of CFTS with Fermi level shifted to zero.

The band gap is deduced from DOS, but the site projected DOS (PDOS) plot is an important tool to understand the contribution of every atom to the total DOS. It is observed from the computation that each atom of a species (Cu, Fe, Sn or S) has equal contribution irrespective of its position in the unit cell. Fig. 11 shows the contribution of each atomic species viz. Cu, Fe, Sn and S, in the total DOS. It is clearly seen that the valence band of CFTS primarily arises from S-*p* states with good contribution from Fe-*d* states and lesser contribution from Cu-*d* states near the valence band maximum while Fe-*d* states primarily contribute near the conduction band minimum with lesser contributions from S-*p* and Sn-*s* states.

3.5. Defect formation

Experimentally synthesized structures are known to have some defects with variation in the concentration and type of defect. In case of quaternary semiconductors containing Cu, the Cu vacancy is seen to be prominent and forms secondary phases with other elements. In order to understand and support these general observations, we have studied the vacancy formation energies of cations. For the defect study we have used supercell approach, as the defect concentration is very less in experiments. The supercell is constructed using 4 unit cells and one atom of each species is removed from the structure at a time. The structure so obtained is not relaxed, as experimentally the defect site does not alter the parent crystal structure. The energy of vacancy formation (E_v^i) for

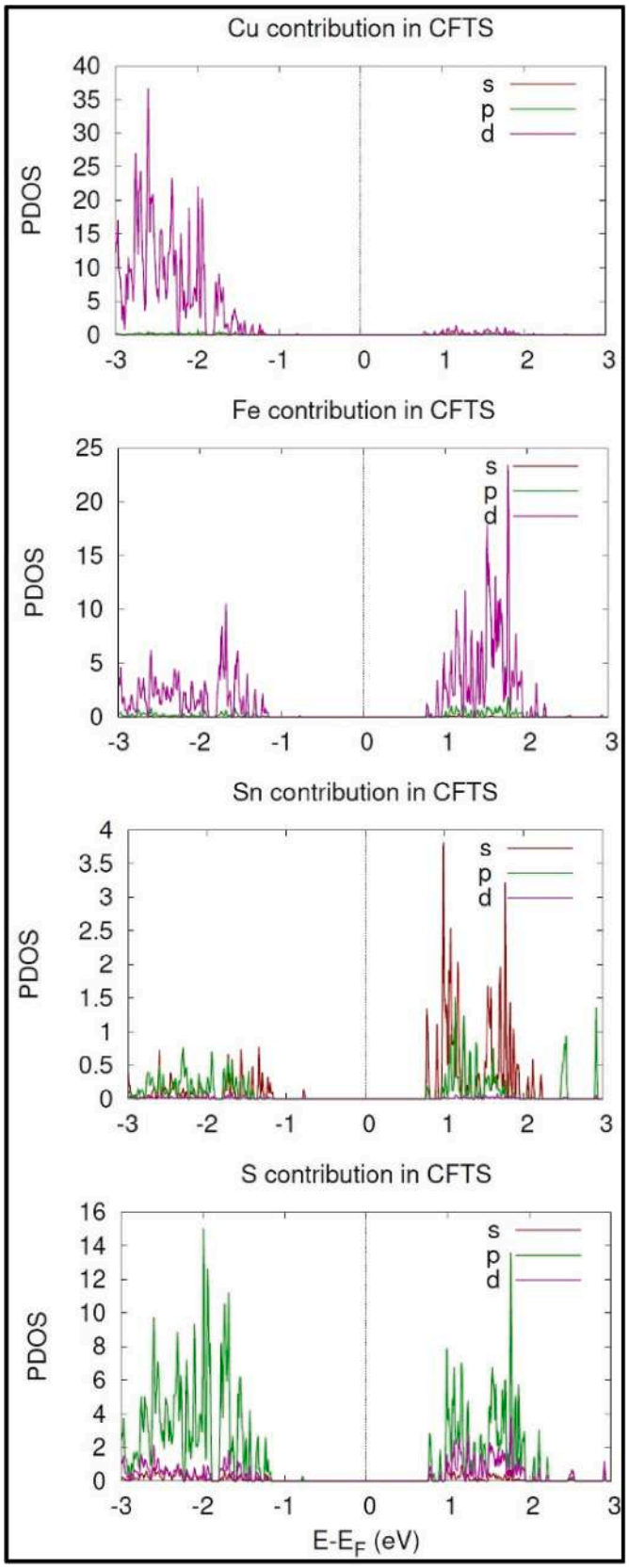

Fig. 11. PDOS plots showing contribution from each atomic species to the total DOS. Note that the scale on the y-axis is different for each plot.

species i is calculated using the following formula:

$$E_v^i = E_{tot}^v - E_{tot} - n_i\mu_i \quad (1)$$

where E_{tot}^v is the total energy of the super cell with vacancy, E_{tot} is the total energy of the super cell without vacancy,n_i is number of atoms removed (for our case $n_i = 1$) and μ_i is the chemical potential of the species i.

The values of vacancy formation energies for all cations in CFTS have been listed in Table 1. It is observed that E_v^{Cu} has the least value i.e. Cu vacancy is most likely to form. Conversely, Sn vacancy is the least probable vacancy with highest formation energy of 1.336 eV.

3.6. Current density-voltage response study

The synthesized CFTS powder is used in the form of thin film for the *J-V* study. Initially CdS is synthesized using chemical bath deposition (CBD) method and is deposited on FTO coated soda lime glass. This film is annealed, and CFTS is then deposited as a thin layer using electrophoretic deposition (EPD) method. The Ag contact is made on CFTS, which acts as the positive terminal, and the FTO is used as the negative terminal. The actual CFTS-CdS cell and the block diagram of CFTS/CdS cell are shown in Fig. 12 (a) and (b) respectively. The *J-V* characteristics of the cell is studied using Xe-based light source solar simulator with simulated 1 Sun under AM 1.5 G illumination and Keithley 2450 source meter.

The *J-V* response of the *p*-type CFTS and *n*-type CdS cell is studied in dark and light conditions at room temperature. The *J-V* response in Fig. 13 (a) shows the difference in the current for dark and light conditions. It is clearly observed that the junction response increases when the light is incident on the sample. The source region is used for finding out the J_{SC}, V_{OC}, *FF* and *PCE* of cell. The magnified fourth quadrant shown in Fig. 13 (b) gives the J_{SC}, V_{OC}, J_m and V_m as 3.25 mA/cm^2, 780 mV, 2.73 mA/cm^2 and 400 mV respectively. Using these values, *FF* is calculated to be 0.43 using the following equation:

$$FF = \frac{V_m \times J_m}{V_{OC} \times J_{SC}} \quad (2)$$

The efficiency for this device is calculated using the following equation:

$$\eta = \frac{V_{OC} \times J_{SC} \times FF}{P_{in}} \times 100\ \% \quad (3)$$

The calculated efficiency is 1.09%, using the input power of the source as 100 mW/cm^2.

The series resistance of 102 Ω is also calculated by taking the slope in Fig. 13 (b), near V_{oc}. Further ideality factor (n) of the p-n junction is calculated from the *ln (J)* vs. *V* graph (Fig. 14) using the following formula:

$$n = \frac{q}{mk_BT} \quad (4)$$

where q is the charge on electron, m is the slope of *ln (J)* vs. *V* graph, k_B is the Boltzmann's constant and T is the temperature at which the study is carried out.

The ideality factor value of 1 denotes the ideal diode. The ideality factor of 1.54 is calculated for the light condition. This shows that when light is incident on the CFTS-CdS junction, its current increases and diode nature improves.

Table 1
Cation (Cu, Fe and Sn) vacancy formation energies for CFTS.

E_v^{Cu} (eV)	E_v^{Fe} (eV)	E_v^{Sn} (eV)
0.533	0.874	1.336

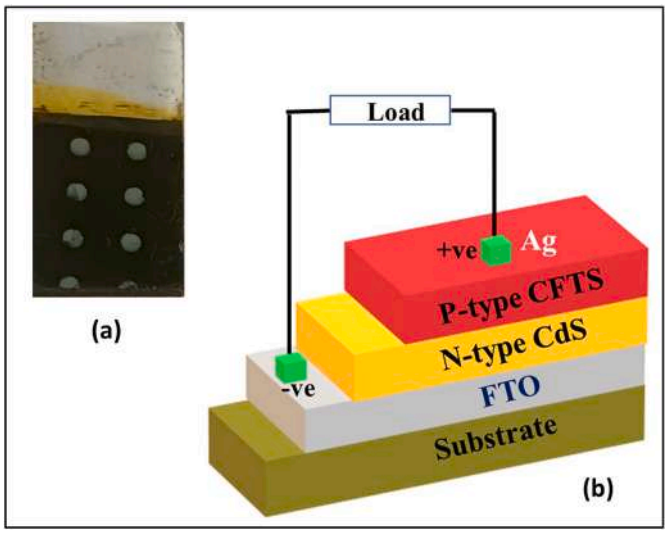

Fig. 12. (a) Photo of actual CFTS-CdS cell, **(b)** layer wise block diagram of the cell.

4. Conclusions

CFTS powder has been successfully synthesized using the simple solvothermal method. The XRD result matches with the standard stannite phase of tetragonal structure of CFTS powder, with no impurity peaks. The Raman peaks have confirmed the presence of only characteristic peaks of CFTS along with the absence of secondary phases. The XPS peaks are in agreement with the literature values confirming the oxidation states of the constituent elements. The XRD data has been used as starting point for the computational study using DFT. The ground state of the bulk-CFTS is found to be a stannite structure with distortion coefficient close to the experimental value. PVP has played a key role in nucleation and in forming the nanosheet array-like morphology of CFTS, observed using SEM images. The elemental composition ratio of the synthesized CFTS powder in the EDS result confirms stoichiometry of the compound to be close to the ideal value of 2:1:1:4 (Cu:Fe:Sn:S).

The optical spectrum recorded for the sample has been processed for the Tauc plot. The Tauc plot shows the direct band gap nature of the synthesized powder with an optical band gap of 1.52eV. The computationally obtained absorption spectrum also confirms the application of CFTS as absorber layer in a solar cell. The DOS plot and band structure agree with the experimental results showing a direct band gap of 1.51eV for the bulk CFTS structure at center of the Brillouin zone namely the Γ point. The site projected DOS plots resolve the valence and conduction bands to clarify the contribution of each atomic species to the optical properties. Finally, an attempt has been made to study the vacancy type point defect in CFTS using a supercell approach. This result shows that the Cu vacancy is the most probable with least formation energy. The *J-V* curve shows a crucial increase in current after illumination along with reduction in resistance and an ideality factor of 1.54, confirming the possible application as a solar cell. The series resistance and efficiency of the device is found to be 102 Ω and 1.09% respectively.

To summarize, the quaternary semiconductor CFTS has been studied experimentally and computationally. The CFTS nanosheet array may be used as the absorber material of a solar cell due to its direct band gap nature. Further characterization of electrical properties for optimization of *J-V* response needs to be carried out.

CRediT authorship contribution statement

V.S. Ghemud: Conceptualization, Methodology, Software, Investigation, Writing – original draft. **P.R. Jadhav:** Validation, Investigation, Resources. **P.T. Kolhe:** Investigation. **P.N. Shelke:** Resources. **S.S.**

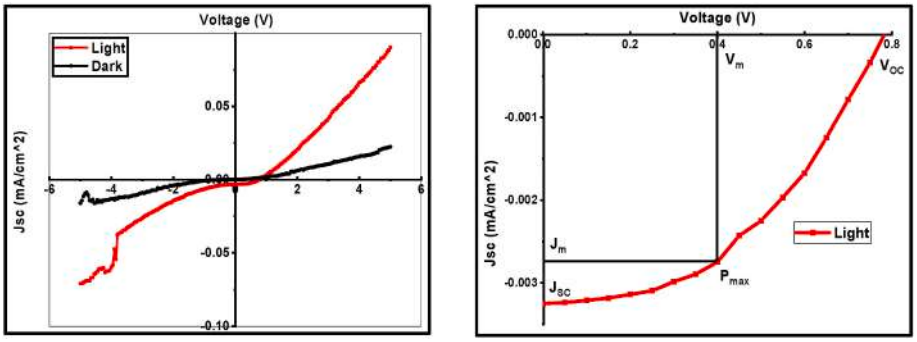

Fig. 13. **(a)** *J-V* characteristic study of CFTS-CdS junction on FTO substrate, **(b)** magnified fourth quadrant for fill factor calculation.

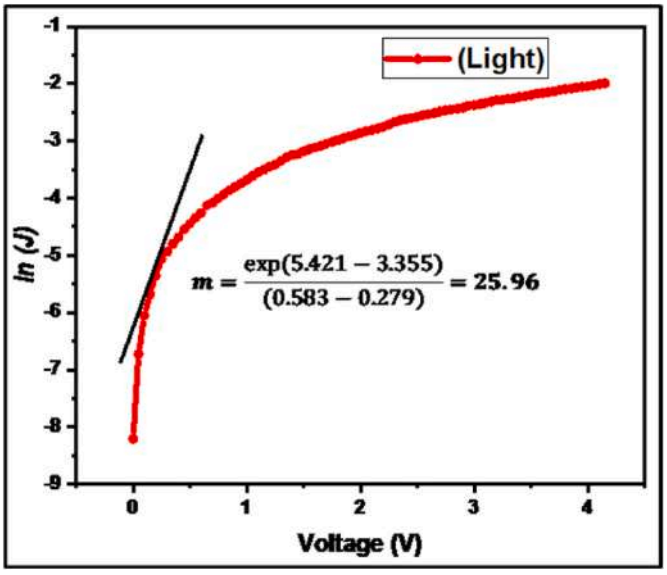

Fig. 14. *ln (J)* vs. *V* plot depicting the slope calculation used further for ideality factor calculation.

Dahiwale: Formal analysis, Investigation, Resources, Writing – review & editing, Supervision. **Anjali Kshirsagar:** Formal analysis, Investigation, Resources, Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in the paper.

Data availability

Data will be made available on request.

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Green Synthesized TiO_2 and Applications as Anode Material for DSSC and Battery: Mini Review

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Abstract:

In the past few decades, interest in nano-biotechnology has grown significantly. In nano-bio technology, how biological species plays role in the field of nanotechnology is studied and how these are useful for further applications. Nanomaterials are superior to bulk materials in terms of their chemical, optical, physical, electrical, and photovoltaic properties. Metal oxide nanomaterials are easily produced adhering to green chemistry principles. Both, top-down and bottom-up approach are being reported to prepare nanomaterials. The desired morphology and controlled synthesis are still challenging. The majority of bio-species contain phytochemicals that are helpful in reducing the size of metal oxide nanoparticles.

The green synthesis method is a promising, environmentally compatible, and beneficial at economical level as well. In the present context, a present review emphasized on the photoanode materials like TiO_2 prepared using the green synthesis process, as well as applications for batteries and dye sensitized solar cell (DSSC). These biosynthesized TiO_2 has potential applications in the field of energy.

Keywords: green synthesis, TiO_2, DSSC, battery

1. Introduction :

Since last few decades, interest in the developing field of nanotechnology has soared. Nano word refers to the minuscule, that is one billionth of a metre size. Such nanomaterials have numerous uses in the fields of medical, cosmetics, energy, biological fields such as anti-bacterial, anti-cancer, anti-microbial applications etc. [1-4]. The several chemical approaches are reported in the literature for the synthesis of different kinds of materials like metal, semiconductors, organic materials, oxides, inorganic materials etc. [5],[6].

In last few decades, scientists are fascinated by TiO_2 due to its versatile scientific properties in the field of renewable energy. TiO_2 nanoparticles (NP) have various biomedical [7] as well as energy applications in photocatalysis, photodegradation of hazardous materials, [8] gas sensors, lithium ion batteries, [9-11] dye sensitized solar cell,[12-14] photoelectrochemical properties, water splitting for hydrogen generation [15-17].

The most distinctive metal oxide TiO_2, is hydrophobic by nature, thermally stable, corrosion-resistant, and has good oxidation property. Further, TiO_2 is an environmentally benign material since it is nonflammable and

nontoxic. Its crystalline nature is mainly observed in three phases anatase, rutile and brookite having higher energy band gap as 3.2eV, 3.0eV and 2.96eV respectively. Among these rutile is most stable state and others are metastable state. However, when anatase TiO_2 is heated above 500C, the phase changes to rutile one [18], [19].

Researchers are engaged various chemical methods as sol-gel, anodization, chemical bath deposition, hydrothermal etc. for synthesis of TiO_2 to acquire one dimensional nanostructures [20-23]. Often most of these chemical approaches are costly and do not follow the basic principles of green chemistry. During chemical synthesis, most of the times there is possibility of absorption of some hazardous compounds that may have negative effects in medicinal applications. Further, these techniques are time-consuming, damaging to the environment, and have an adverse impact on business, economy and economic growth [24-27].

The best solution to address all of these problems is to adopt green synthesis, which uses harmless, nonhazardous chemicals at low temperatures and low pressure. This paper explores green TiO_2 production and examines how it can be used for various energy applications, such as battery and DSSC. Fig 1 depicts brief overview of green synthesis method.

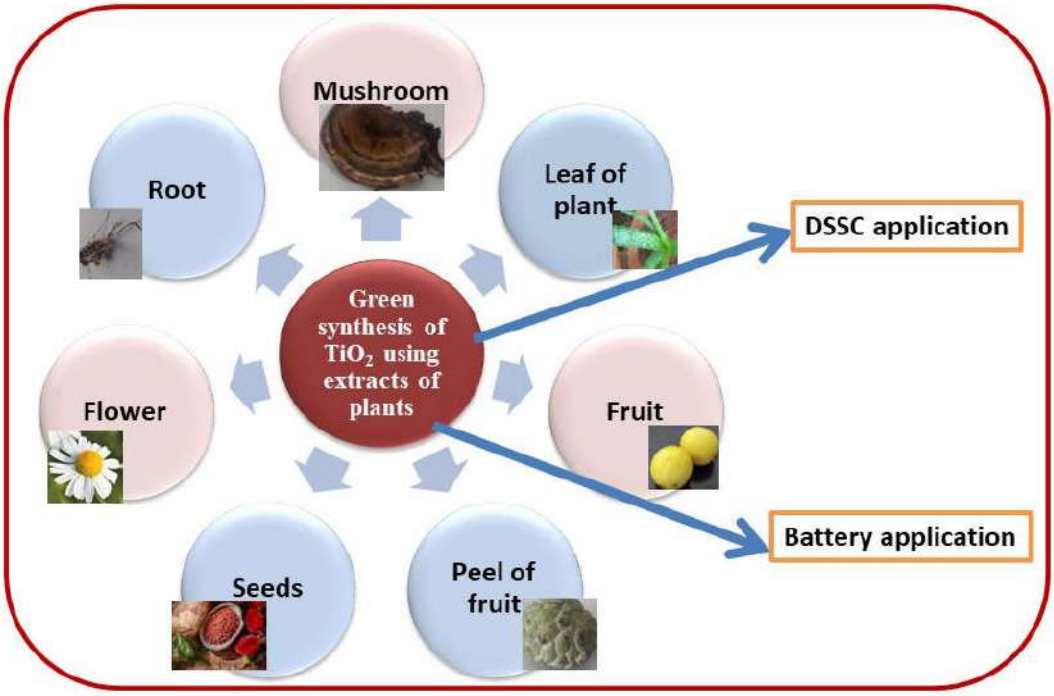

Fig 1: Brief overview of green synthesis of TiO_2 using parts of plant.

2. Green synthesis of TiO_2:

As per the principles of green chemistry, biological components are used in one of the green synthesis approach. During chemical synthesis there is a possibility of production of agglomerated and unstable particles [24]. This cost-effective and ecofriendly synthesis approach leads to synthesize stable and small sized less agglomerated nanoparticles of metals and metal oxides. Plant extracts made from leaf, fruit, flower, seeds and root components are

the most beneficial in the context of the green synthesis technique. [28], [29] addition microorganisms, bacteria, yeast, algae are also used. These extracts contain amino acids, alkaloids, flavones, aldehydes, enzymes, ketones, proteins, phenolics, polysaccharides, terpenoids, tannins, saponins, hydroxyl group, carbohydrates and vitamins. Terpenoids and proteins are examples of phytochemicals, which are a crucial component of plant extract. These phytochemicals initiate the process by activating the precursors. Additionally, the presence of alkanoids, organic functional groups, and phenolics in plant extract reduces nanoparticle agglomeration and serves as a reducing agent [18], [30], [31].

Yanjing Li generated 3D tripyramid titanium dioxide TiO_2 architectures using aloe extracts and a hydrothermal process. Firstly amorphous TiO_2 of rod-like morphology was prepared using aloe extracts and then it is further reacted in Teflon lined reactor with deionized water at 180C for 3h to generate 3D tripyramid anatase TiO_2 architectures [32]. The advanced hydrothermal approach was used by Sundrarajan to synthesize TiO_2 nanoparticles from leaf extract of Morinda citrifolia. The (110) lattice plane of tetragonal rutile TiO_2 phase is showing higher intensity peak of XRD at 27.3°. The existence of TiO_2 nanoparticles and a little amount of anthraquinone and phenolic compounds in the leaf extract were confirmed by the FTIR results. UV–Vis DRS absorption spectroscopy of nanoparticles, depicted a strong band at 423 nm clearly shows that nanoparticles were formed. By virtue of the stabilizing (capping) agent leaf extract, SEM images with EDX spectra clearly indicate the size of the nanoparticles, which range from 15 to 19 nm in good quasi-spherical form [33].

During the synthesis of TiO_2, the effect of pH was investigated, and it was changed using Matricaria chamomilla flower extract. In addition to pH change, flower extract worked as stabilizing and capping agent for TiO_2 nanoparticles. XRD confirmed anatase tetragonal phase of TiO_2. Further UV absorption spectra for biosynthesized TiO_2 synthesized at pH 10 revealed an energy gap of 3.03 eV. FESEM pictures depicted cauliflower morphology formed due to linking of 10-20 nm sized small particles enhancing its surface energy and minimizing agglomeration [34].

The natural biomolecule pectin, which is present in the extract as excess water drawn from soaked Bengal gram beans, has a significant role during synthesis of TiO_2 nanoparticles. The most of primary cell walls contains pectin which functions as a bulky complexing reagent. The bulky complex prevents agglomeration and aids in the formation of a homogeneous particle size distribution. After calcination, it results in TiO_2 nanoparticles having higher surface area [35]. Annona squamosal fruit peel extract was used to prepare rutile TiO_2 nanoparticles. These biosynthesized TiO_2 particles revealed spherical morphology having size ~23nm as per TEM characterizations [36].

In the review paper of Balasooriya, honey is described as a good reducing and stabilising agent that enhances reaction rate and reduces particle agglomeration [37]. Further, at a lower temperature 37 C, an environmental isolate of Bacillus mycoides played key role in transformation of titanium hydroxide to titanium dioxide. The obtained TiO_2 particles had anatase polymorphic structure and spherical morphology of size~ 40-60nm. The solar cell properties of Quantum dots-sensitized solar cells made with biosynthesized tio2 particles were similar to those of chemically synthesized TiO_2 [38].

Nanoparticles of TiO_2 were produced by sol-gel method and *Bixa orellana* seed extract *acting* as a capping agent during the synthesis. This Mesoporous TiO_2 structure was subjected to BET analysis, which revealed

increased pore size and high surface areas. Using HRTEM, the size of green synthesized TiO_2 was determined to be 13 nm while, XRD pattern affirmed the brookite and anatase phases of the material [39]. In 2016, Ekar et al. reported mixed phase anatase and rutile of TiO_2 Nanorods (NRs), prepared using the extract of Phellinus linteus mushroom. These TiO_2 nanorods have surface area 114.16 g/cm^2 and 3.7nm pore diameter[40] .

Wu et al., reported the method of synthesis, which adheres to the green approach, deals with hydrothermal reaction without the use of a challenging Teflon-lined autoclave, or a highly alkaline solution, or a longer reaction period. In this procedure, Inorganic Ti resources were effectively dissolved by the hydrogen peroxide at room temperature and the resultant titanium peroxide solution was simply boiled to produce TiO_2 nanosheets of anatase phase. As per TEM and HRTEM analysis, edge lengths of 20–50 nm and a 5 nm thickness were noted for petal like TiO_2 nanosheets [41].

3. Characterization techniques :

Physical characterization techniques include the use of XRD to determine particle size, FESEM to examine morphology, and UV spectroscopy to determine energy band gap. The reduced agglomeration and increased surface area result in good crystallinity, small particle size, and improved electrochemical performance. Electrochemical performances were assessed through the use of cyclic voltammetry, electrochemical impedance measurements, and galvanostatic charge-discharge tests in an ECC-Air test cell [34].

4. Applications of green synthesized TiO_2:

4.1 Battery application

Recent applications appeal for more power and energy density, which TiO_2 with its high lithium storage capacity and electronic conductivity can provide. Furthermore, TiO_2 is nontoxic and can be easily synthesized having various morphologies in 0D, 1D, 2D and 3D. Bulk TiO_2 has a theoretical capacity of 335 mA hg^{-1}, whereas lithium titanate spinel has a capacity of 175 mA hg^{-1}. TiO_2 was used as an anode material for lithium batteries because its anatase crystal structure is more stable, resulting in better electrochemical performance. Taking into these considerations TiO_2 is suitable as anode materials of lithium batteries [42].

The nano-sized TiO_2, free from aggregation increases the surface area, the electrode/electrolyte contact area, shortens the path lengths for both Li-ion and electron transport lowering the specific current density, which contributes significantly in improving the performance and cycling stability of the cell. This is extremely beneficial in terms of increasing the electrical conductivity and diffusion coefficient of Li ions in the structure[35] .

Yeast and glucose as a bio-templates were used to produce a novel macroporous anatase TiO_2 having pore size 2.5-3 nm with mesopores of size 4-51 nm by sol-gel technique. Due to the easy intercalation/de-intercalation of Li ions, the material served as an electrode material for Li-ion batteries with good capacity retention. Carbon was coated on TiO_2 by chemical vapor deposition method in order to improve electrode performance and cycling stability of electrode. After 80 discharge–charge cycles, the cycling capacity increased upto 318 mA h g^{-1} at 0.1 C. Accordingly, Chang etal confirmed TiO_2 with a carbon coating exhibited higher cycle stability and rate efficiency [43].

The green method of biosynthesizing TiO_2 nanoparticles with Matricaria chamomilla flower extract was utilized to test/check them as air cathodes for lithium-air batteries.

TiO_2 synthesized using flower extract of Matricaria chamomilla was used for battery application. The air electrode was prepared using this Bio synthesized TiO_2 on nickel foam showed a full discharge capacity of 2000 mAh g^{-1} and a specific capacity of 500 mAh g^{-1} after 30 stable cycles. Further, no Li_2CO_3 or other side reaction products were seen due to the presence of a carbon-free cathode [34].

The electrochemical performance of TiO_2 nanoparticles prepared using dry Bengal gram beans (C. arietinum L.) extract, as anode in a Li-ion battery was evaluated in half-cell configuration (Li/Bio synthesized TiO_2) between 1 and 3 V at current density 33 mA g^{-1}. The electrochemical performance within these limits exhibited high reversible capacity 164 mAh g^{-1} and 98% capacity retention after 60 cycles [35]. In addition, carbon is incorporated in this biosynthesized TiO_2 to check its electrochemical properties. For 60 cycles, TiO_2 electrochemical cell exhibited 208 mAh g^{-1} discharge capacity and 100 % columbic efficiency. However, the percentage increase in discharge capacity for TiO_2/C is 5.6% as compared to results obtained for TiO_2 over 60 cycles [44]. TiO_2 synthesized using the sol-gel method and a sodium alginate biopolymer as a template agent was used to fabricate electrode for battery application showed high specific capacity of approximately 275mAh g^{-1} and remarkable cycling stability, with more than 85% of the capacity remaining after 100 cycles [45]. For TiO_2 nanopetals obtained by Wu etal, at the current density of 20 mA g^{-1}, the initial Li insertion and extraction capacities are 382 mAh g^{-1} and 326 mAh g^{-1} respectively. Also, there is one pair of potential plateaus at 1.7 and 1.9V in the process of Li insertion and extraction. At the current density of 400 mA g^{-1}, TiO_2 retains 93% of its initial charge capacity after 50 cycles. Good cycle stability was observed with TiO_2 nanopetal structure as anode material for battery application [41].

4.2 DSSC application of TiO_2:

The DSSC characteristics of TiO_2 produced from green and titanium precursors are shown in Table I.

Sr. No	Green Precursor	Synthesis route	Morphology Size in nm	Phase	Dye	Jsc mA/cm^2	Voc mV	FF	Efficiency %	Ref
1	Bixa orellana seed extract	Sol-gel	Spherical ~13nm	Mixed brookite + anatase	N719	9.0	506	65	2.97	[39]
2	extract of Phellinus linteus mushroom	Green chemical synthesis	Nanorod	nanocrystalline anatase and rutile	N719	8.18	690	67	3.80	[40]
3	grapes, extracts	Green Synthesis	nanorods like TiO_2 nanostructures	anatase	N719	9.95	663	65	4.33	[46]

4	pineapple	Green Synthesis	nanorods like TiO_2 nanostructures	anatase	N719	9.67	653	65	4.11	[46]
5	orange	Green Synthesis	nanorods like TiO_2 nanostructures	anatase	N719	9	649	66	3.89	[46]
6	Citrus limon juice extract	Sol-gel	Mesoporous 15nm	anatase	N719	9.10	776	65	4.55	[47]
7	Averrhoa bilimbi Fruit extract	Green Synthesis	aggregated nanoparticleof irregular shape	anatase	N3	11.6	845	53	5.2	[48]
8		microwave assisted sol-gel synthesis	Crystalline mesoporous nanoparticle	anatase	N719	1.28	693	76.7	6.58	[49]

The Sun is the primary energy source in our solar system, and it is also the most abundant, pollution free, cleanest of all renewable energy sources. Direct electricity production from sunlight is possible with solar cells, also known as photovoltaic cells. There are numerous varieties of solar cells that have been developed, including silicon-based, polymer based, thin-film-based, DSSC, quantum dot sensitized solar cells and perovskite solar cells. Due to its affordable, non-toxic, and easy fabrication processes, the DSSC is seen to be the most favourable of these [50].

A DSSC is a sandwiched cell of photoanode of light harvesting molecules (TiO_2) decorated with dye molecules on surface, a Pt counter electrode and redox I/I_3 electrolyte. Titanium dioxide having wide band gap, semi-transparent, porous, efficient electron acceptor, having novel microstructure and effective diffusion coefficient are used as photoanode material. Desorption technique was used to measure the amount of dye loading by TiO_2, and the results showed substantially higher dye loading for TiO_2 nanoparticles generated from *Bixa orellana* seed extract (G-TNP). DSSC characteristics of these N719 sensitised TiO_2 nanoparticles showed 188% rise in Photovoltaic conversion efficiency [39]. Ekar et al. produced TiO_2 nanorod having anatase and rutile phase to generate maximum efficiency 3.8 % using N719 dye [40].

Without having a negative effect on the environment, citrus limon juice extract was essential in improving DSSC performance. TiO_2 prepared using citrus limon extract, lowered the size of TiO_2, increased its surface area, and improved its dye loading capacity. Thus N719 dye-sensitized solar cell fabricated using these TiO_2 nanoparticles, demonstrated an efficiency of 4.55% [47]. Senthamarai etal reported green synthesis of one dimensional TiO_2 nanorods using grapes, pineapple and orange fruit extract. Among these, photoanode of TiO_2

nanorod prepared using grape extract and sensitised with N719 dye for DSSC characteristics exhibited 4.33% solar conversion efficiency [46].

Abisharani et al. employed an eco-friendly, green synthesis method to successfully produce TiO_2 nanoparticles from Averrhoa bilimbi extract. N3 sensitized Photoanode was developed utilising these TiO_2 nanoparticles to test DSSC characteristics with PEG polymer electrolyte and 5.2% photoconversion efficiency was generated [48]. Microwave aided sol gel synthesis using a 600W power source produced mesoporous anatase TiO_2 particles. DSSC characteristics were noted for photoanode of TiO_2 nanoparticles sensitized with N719 dye exhibiting light conversion efficiency 6.6% under one sun illumination [49].

5. Conclusion :

As per the guidelines of green chemistry principles, different green sources used during synthesis, such as plant extract, bacteria, seeds, flowers, and algae, exhibiting substantial differences in their morphologies, surface areas, porosities, and other characteristics.

In case of green synthesis major cost will be of metal salts, here the cost of reducing/capping agent is minimized. Use of plant extract or kitchen waste during synthesis is cost effective and environment friendly. This fact highlights the environmental benefits of "green" synthesis over conventional techniques of nanoparticle generation. With a few constraints, the production of metallic nanoparticles using biospecies has a great potential and several advantages over conventional approaches.

Plant extracts used during green synthesis act as a good capping/reducing agent minimizing surface area as well as agglomeration of TiO_2 nanoparticles. For rechargeable batteries to operate with high capacity, TiO_2 must have a highly porous structure of good surface area which can be attained easily using green synthesis.Through a green technique, pure anatase TiO_2 could be produced at low cost and without any significant environmental problems, having significant applications in DSSC and batteries.

Conflicts of Interest: The authors declare no conflict of interest.

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(54) Title of the invention : METAL-ORGANIC FRAMEWORKS (MOFS) FOR SELECTIVE CAPTURE AND RELEASE OF GASEOUS POLLUTANTS

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(61) Patent of Addition to Application Number Filing Date	:NA :NA
(62) Divisional to Application Number Filing Date	:NA :NA

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(57) Abstract :
The invention presents a Metal-Organic Frameworks (MOFs) for Selective Capture and Release of Gaseous Pollutants. The present invention comprising of a structured arrangement resulting from the coordination of metal nodes with organic ligands, wherein the Metal-Organic Framework (MOF) demonstrates notable affinity and specificity for distinct gaseous pollutants. The metal nodes, encompassing zinc, copper, iron, and aluminium, synergize with organic ligands selected to confer specificity for gaseous pollutants like sulphur dioxide, nitrogen oxides, carbon dioxide, methane, or volatile organic compounds. A technique for producing Metal-Organic Frameworks (MOFs) geared toward selectively trapping gaseous pollutants, involving the steps of selecting metal nodes and organic ligands based on their coordination chemistry, and subjecting them to controlled synthesis conditions, resulting in the formation of a crystalline MOF structure hosting specific binding sites for targeted gaseous pollutants. The post-synthetic modification to heighten the MOF's selectivity and affinity for particular gaseous pollutants. A regeneration module where the MOF undergoes conditions conducive to pollutant removal, ensuring its reusability for subsequent capture-release cycles. Accompanied Drawing [FIG. 1-2]

No. of Pages : 21 No. of Claims : 10

FORM 1 THE PATENTS ACT 1970 (39 of 1970) and THE PATENTS RULES, 2003 **APPLICATION FOR GRANT OF PATENT** (See section 7, 54 and 135 and sub-rule (1) of rule 20)	(FOR OFFICE USE ONLY)

	Application No.	
	Filing date:	
	Amount of Fee paid:	
	CBR No:	
	Signature:	

1. APPLICANT'S REFERENCE / IDENTIFICATION NO. (AS ALLOTTED BY OFFICE)	

2. TYPE OF APPLICATION [Please tick (✓) at the appropriate category]

Ordinary (✓)		Convention ( )		PCT-NP ( )	
Divisional ( )	Patent of Addition ( )	Divisional ( )	Patent of Addition ( )	Divisional ( )	Patent of Addition ( )

3A. APPLICANT(S)

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3B. CATEGORY OF APPLICANT [Please tick (✓) at the appropriate category]

Natural Person (✓)	Other than Natural Person		
	Small Entity ( )	Startup ()	Others ()

4. INVENTOR(S) [Please tick (✓) at the appropriate category]

Are all the inventor(s) same as the applicant(s) named above?	Yes (✓)	No ()

If "No", furnish the details of the inventor(s)

Name in Full	Nationality	Country of Residence	Address of the Inventor
Same as Applicant			

5. TITLE OF THE INVENTION

"METAL-ORGANIC FRAMEWORKS (MOFS) FOR SELECTIVE CAPTURE AND RELEASE OF GASEOUS POLLUTANTS"

6. AUTHORISED REGISTERED PATENT AGENT(S)	IN/PA No.	
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~~**8. IN CASE OF APPLICATION CLAIMING PRIORITY OF APPLICATION FILED IN CONVENTION COUNTRY, PARTICULARS OF CONVENTION APPLICATION**~~

Country	Application Number	Filing date	Name of the applicant	Title of the invention	IPC (as classified in the convention country)

9. IN CASE OF PCT NATIONAL PHASE APPLICATION, PARTICULARS OF INTERNATIONAL APPLICATION FILED UNDER PATENT CO-OPERATION TREATY (PCT)

International application number	International filing date

10. IN CASE OF DIVISIONAL APPLICATION FILED UNDER SECTION 16, PARTICULARS OF ORIGINAL (FIRST) APPLICATION

Original (first) application No.	Date of filing of original (first) application

11. IN CASE OF PATENT OF ADDITION FILED UNDER SECTION 54, PARTICULARS OF MAIN APPLICATION OR PATENT

Main application/patent No.	Date of filing of main application

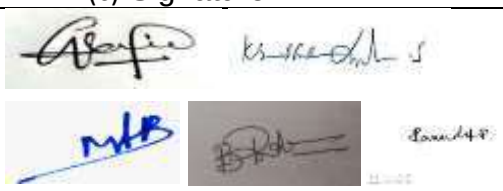
12. DECLARATIONS

(i) Declaration by the inventor(s)

(**In case the applicant is an assignee**: the inventor(s) may sign herein below or the applicant may upload the assignment or enclose the assignment with this application for patent or send the assignment by post/electronic transmission duly authenticated within the prescribed period).

I/We, the above named inventor(s) is/are the true & first inventor(s) for this Invention and declare that the applicant(s) herein is/are my/our assignee or legal representative.

(a) Date 12/11/2023

(b) Name	(c) Signature
1. Dr. Ganji Saidulu 2. Dr. Surapaneni Krishna Mohan 3. Dr. Manisha Atul Bora 4. Dr. B. Padma 5. Dr. Ramudu Pochamoni	

(ii) Declaration by the applicant(s) in the convention country

(In case the applicant in India is different than the applicant in the convention country: the applicant in the convention country may sign herein below or applicant in India may upload the assignment from the applicant in the convention country or enclose the said assignment with this application for patent or send the assignment by post/electronic transmission duly authenticated within the prescribed period)

I/We, the applicant(s) in the convention country declare that the applicant(s) herein

~~is/are my/our assignee or legal representative.~~

~~(a) Date~~

~~(b) Signature(s)~~

(c) ~~Name(s) of the signatory~~

(iii) Declaration by the applicant(s)

I/We the applicant(s) hereby declare(s) that: -

- ☐ ~~I am/~~ We are in possession of the above-mentioned invention.
- ☐ The ~~provisional~~/complete specification relating to the invention is filed with this application.
- ☐ ~~The invention as disclosed in the specification uses the biological material from India and the necessary permission from the competent authority shall be submitted by me/us before the grant of patent to me/us.~~
- ☐ There is no lawful ground of objection(s) to the grant of the Patent to me/us.
- ☐ ~~I am~~/we are the true & first inventor(s).
- ☐ ~~I am/we are the assignee or legal representative of true & first inventor(s).~~
- ☐ ~~The application or each of the applications, particulars of which are given in Paragraph-8, was the first application in convention country/countries in respect of my/our invention(s).~~
- ☐ ~~I/We claim the priority from the above mentioned application(s) filed in convention country/countries and state that no application for protection in respect of the invention had been made in a convention country before that date by me/us or by any person from which I/We derive the title.~~
- ☐ ~~My/our application in India is based on international application under Patent Cooperation Treaty (PCT) as mentioned in Paragraph-9.~~
- ☐ ~~The application is divided out of my /our application particulars of which is given inParagraph-10 and pray that this application may be treated as deemed to have been filed on DD/MM/YYYY under section 16 of the Act.~~
- ☐ ~~The said invention is an improvement in or modification of the invention particulars of which are given in Paragraph-11.~~

13. FOLLOWING ARE THE ATTACHMENTS WITH THE APPLICATION

(a) Form 2

Item	Details	Fee	Remarks
Complete/ ~~Provisional~~ specification) #	No. of pages: 16		
No. of Claim(s)	No. of claims: 10 No. of pages: 03		
Abstract	No. of pages: 01		
No. of Drawing(s)	No. of drawings: 02 No. of pages: 01		

In case of a complete specification, if the applicant desires to adopt the drawings filed with his provisional specification as the drawings or part of the drawings for the complete specification under rule 13(4), the number of such pages filed with the provisional specification are
required to be mentioned here.

(b) Complete specification (in conformation with the international application)/as amended before the International Preliminary Examination Authority (IPEA), as applicable (2 copies).

(c) Sequence listing in electronic form

(d) Drawings (in conformation with the international application)/as amended before the International Preliminary Examination Authority (IPEA), as applicable (2 copies).

(e) Priority document(s) or a request to retrieve the priority document(s) from DAS (Digital Access Service) if the applicant had already requested the office of first filing to make the priority document(s) available to DAS.

(f) Translation of priority document/Specification/International Search Report/International Preliminary Report on Patentability.

(g) Statement and Undertaking on Form 3

(h) Declaration of Inventorship on Form 5

(i)Power of Authority

(j)**Total fee ₹…….in Cash/ Banker's Cheque /Bank Draft bearing No..... Date on ……. Bank.**

I/We hereby declare that to the best of my/our knowledge, information and belief the fact and matters slated herein are correct and I/We request that a patent may be granted to me/us for the said invention.

Dated this 12th day of November 2023

Signature:

Name: Dr. Ganji Saidulu et. al.

To,

The Controller of Patents

The Patent Office, at Chennai

Note: -

* Repeat boxes in case of more than one entry.
* To be signed by the applicant(s) or by authorized registered patent agent otherwise where mentioned.
* Tick ()/cross (x) whichever is applicable/not applicable in declaration in paragraph-12.
* Name of the inventor and applicant should be given in full, family name in the beginning.
* Strike out the portion which is/are not applicable.

* For fee: See First Schedule”;

FORM 2

THE PATENTS ACT, 1970

(39 of 1970)

&

The Patent Rules, 2003

COMPLETE SPECIFICATION

(See section 10 and rule 13)

TITLE OF THE INVENTION

METAL-ORGANIC FRAMEWORKS (MOFS) FOR SELECTIVE CAPTURE AND RELEASE OF GASEOUS POLLUTANTS

We, applicant(s)

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The following specification particularly describes the nature of the invention and the manner in which it is performed:

FIELD OF THE INVENTION

[001] The invention, in general, relates to the technology field of hybrid porous materials, and methods. More particularly, the present invention relates to a Metal-Organic Frameworks (MOFs) for Selective Capture and Release of Gaseous Pollutants.

BACKGROUND OF THE INVENTION

[002] The following description provides the information that may be useful in understanding the present invention. It is not an admission that any of the information provided herein is prior art or relevant to the presently claimed invention, or that any publication specifically or implicitly referenced is prior art.

[003] In the face of escalating environmental concerns, the quest for innovative solutions to address air quality issues has led to the development of Metal-Organic Frameworks (MOFs) as a promising avenue for the selective capture and release of gaseous pollutants. Conventional methods for managing air pollution often encounter challenges in achieving high selectivity and efficiency, necessitating the exploration of advanced materials and technologies.

[004] As the understanding of MOFs and their applications continues to evolve, their potential in mitigating air pollution and contributing to sustainable environmental practices becomes increasingly evident. Metal-Organic Frameworks (MOFs) represent a class of materials at the forefront of addressing the critical challenge of gaseous pollutant removal from the air.

[005] Accordingly, on the basis of aforesaid facts, there remains a need in the prior art to provide a Metal-Organic Frameworks (MOFs) for Selective Capture and Release of Gaseous Pollutants, therefore, it would be useful and desirable to have a system, method, and process to meet the above-mentioned needs.

SUMMARY OF THE PRESENT INVENTION

[006] In view of the foregoing disadvantages inherent in the known types of conventional methods and techniques, are now present in the prior art, the present invention provides a Metal-Organic Frameworks (MOFs) for Selective Capture and Release of Gaseous Pollutants, which has all the advantages of the prior art and none of the disadvantages.

[007] To MOFs, characterized by their crystalline structures formed through the precise coordination of metal nodes with organic ligands, present a unique class of materials with tuneable properties. The synergy between metal nodes, including zinc, copper, iron, and aluminium, and carefully chosen organic ligands imparts MOFs with exceptional affinity and specificity for particular gaseous pollutants. These pollutants encompass a spectrum ranging from sulphur dioxide and nitrogen oxides to carbon dioxide, methane, and volatile organic compounds.

[008] The synthesis of MOFs involves intricate processes, with metal nodes and organic ligands being selected based on their coordination chemistry. Under controlled synthesis conditions, these components amalgamate to form a crystalline structure with distinct binding sites tailored for targeted

gaseous pollutants. To further enhance MOF performance, post-synthetic modifications can be employed, augmenting selectivity and affinity.

[009] Deploying MOFs in a capture and release system involves integrating them into an adsorption chamber for selective pollutant capture and a desorption chamber for controlled release back into the environment. This structured approach ensures that MOFs, equipped with regeneration capabilities in a dedicated module, can be reused across multiple capture-release cycles. The intersection of materials science, environmental engineering, and chemical synthesis in the realm of MOFs holds promise for a cleaner, healthier future.

[010] In this respect, before explaining at least one object of the invention in detail, it is to be understood that the invention is not limited in its application to the details of set of rules and to the arrangements of the various models set forth in the following description or illustrated in the drawings. The invention is capable of other objects and of being practiced and carried out in various ways, according to the need of that industry. Also, it is to be understood that the phraseology and terminology employed herein are for the purpose of description and should not be regarded as limiting.

[011] These together with other objects of the invention, along with the various features of novelty which characterize the invention, are pointed out with particularity in the disclosure. For a better understanding of the invention, its operating advantages and the specific objects attained by its uses, reference should be made to the accompanying drawings and

descriptive matter in which there are illustrated preferred embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[012] The invention will be better understood and objects other than those set forth above will become apparent when consideration is given to the following detailed description thereof. Such description makes reference to the annexed drawings wherein:

[013] FIG. 1, demonstrates a Metal-Organic Frameworks (MOFs) for Selective Capture and Release of Gaseous Pollutants, in accordance with an embodiment of the present invention.

[014] FIG. 2, illustrates a Metal-Organic Frameworks (MOFs) for Selective Capture and Release of Gaseous Pollutants, in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[015] While the present invention is described herein by way of example using embodiments and illustrative drawings, those skilled in the art will recognize that the invention is not limited to the embodiments of drawing or drawings described and are not intended to represent the scale of the various components. Further, some components that may form a part of the invention may not be illustrated in certain figures, for ease of illustration, and such omissions do not limit the embodiments outlined in any way. It should be understood that the drawings and detailed description thereto are not intended to limit the invention to the particular form disclosed, but on the contrary, the invention is to cover all modifications, equivalents, and

alternatives falling within the scope of the present invention as defined by the appended claims. As used throughout this description, the word "may" is used in a permissive sense (i.e. meaning having the potential to), rather than the mandatory sense, (i.e. meaning must). Further, the words "a" or "an" mean "at least one" and the word "plurality" means "one or more" unless otherwise mentioned. Furthermore, the terminology and phraseology used herein is solely used for descriptive purposes and should not be construed as limiting in scope. Language such as "including," "comprising," "having," "containing," or "involving," and variations thereof, is intended to be broad and encompass the subject matter listed thereafter, equivalents, and additional subject matter not recited, and is not intended to exclude other additives, components, integers or steps. Likewise, the term "comprising" is considered synonymous with the terms "including" or "containing" for applicable legal purposes. Any discussion of documents, acts, materials, devices, articles and the like is included in the specification solely for the purpose of providing a context for the present invention. It is not suggested or represented that any or all of these matters form part of the prior art base or are common general knowledge in the field relevant to the present invention.

[016] In this disclosure, whenever a composition or an element or a group of elements is preceded with the transitional phrase "comprising", it is understood that we also contemplate the same composition, element or group of elements with transitional phrases "consisting of", "consisting", "selected from the group of consisting of, "including", or "is" preceding the recitation of the composition, element or group of elements and vice versa.

[017] The present invention is described hereinafter by various embodiments with reference to the accompanying drawings, wherein reference numerals used in the accompanying drawing correspond to the like elements throughout the description. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiment set forth herein. Rather, the embodiment is provided so that this disclosure will be thorough and complete and will fully convey the scope of the invention to those skilled in the art. In the following detailed description, numeric values and ranges are provided for various aspects of the implementations described. These values and ranges are to be treated as examples only and are not intended to limit the scope of the claims. In addition, a number of materials are identified as suitable for various facets of the implementations. These materials are to be treated as exemplary and are not intended to limit the scope of the invention.

[018] In accordance with an embodiment for the present invention, with their intricate crystalline structures, MOFs offer a versatile and tuneable platform for the selective capture and release of specific airborne contaminants, presenting a promising solution to advance air quality management. At the core of MOFs lies their unique composition as a crystalline lattice formed by the coordinated linkage of metal nodes with organic ligands.

[019] The present invention pertains to a Metal-Organic Frameworks (MOFs) for Selective Capture and Release of Gaseous Pollutants as disclosed in figure.1, the present invention comprising of a crystalline structure formed by the coordination of metal nodes with organic ligands, wherein said MOF

exhibits high affinity and selectivity towards specific gaseous pollutants. The metal nodes are selected from the group consisting of zinc, copper, iron, and aluminium, and the organic ligands are selected to impart selectivity for gaseous pollutants such as sulphur dioxide, nitrogen oxides, carbon dioxide, methane, or volatile organic compounds. A method for the synthesis of Metal-Organic Frameworks (MOFs) for the selective capture of gaseous pollutants, comprising the steps of selecting metal nodes and organic ligands based on their coordination chemistry, and subjecting them to controlled synthesis conditions to form a crystalline MOF structure with specific binding sites for targeted gaseous pollutants. The method further comprising the step of post-synthetic modification to enhance the selectivity and affinity of the MOF towards specific gaseous pollutants.

[020] In accordance with an embodiment for the present invention, the selection of these metal nodes, which may include zinc, copper, iron, and aluminium, along with tailored organic ligands, is crucial in determining the MOF's chemical affinity and selectivity. This deliberate design allows researchers to customize MOFs for capturing various gaseous pollutants prevalent in the atmosphere. The synthesis of MOFs is a meticulous process involving the strategic selection of metal nodes and organic ligands based on their coordination properties. Under controlled synthesis conditions, these components undergo precise reactions to form a structured MOF with predetermined binding sites.

[021] In accordance with an embodiment for the present invention, the resulting crystalline framework is engineered to exhibit high affinity for

specific pollutants, ensuring an effective and targeted capture mechanism. To further optimize MOF performance, post-synthetic modifications may be employed. These modifications introduce additional functionalities or enhance existing ones, aiming to improve selectivity, adsorption capacity, and overall pollutant capture efficiency. This iterative approach in MOF development allows researchers to fine-tune their properties to meet the demands of diverse pollutant removal applications.

[022] In accordance with an embodiment for the present invention, Deploying MOFs in a capture and release system involves integrating them into an adsorption chamber for selective pollutant capture and a desorption chamber for controlled release. This dynamic system enables MOFs to efficiently capture pollutants in one phase and release them in another under controlled conditions. The incorporation of a regeneration module ensures the MOF can be revitalized, making it ready for subsequent capture-release cycles. Environmental Impact and Sustainability as MOFs offer a promising avenue for sustainable environmental practices by providing a reusable and regenerable solution for air quality management.

[023] Furthermore, this wearable technology represents Their ability to capture pollutants selectively and efficiently, coupled with the potential for multiple use cycles, aligns with the principles of green chemistry and contributes to the reduction of environmental impact. The applications of MOFs for selective capture and release extend to various industries, including environmental remediation, industrial processes, and even indoor air quality management. As research in this field advances, MOFs may

emerge as pivotal components in combating air pollution and contributing to a cleaner, healthier global environment.

[024] It is to be understood that the above description is intended to be illustrative, and not restrictive. For example, the above-discussed embodiments may be used in combination with each other. Many other embodiments will be apparent to those of skill in the art upon reviewing the above description.

[025] The benefits and advantages which may be provided by the present invention have been described above with regard to specific embodiments. These benefits and advantages, and any elements or limitations that may cause them to occur or to become more pronounced are not to be construed as critical, required, or essential features of any or all of the embodiments.

[026] While the present invention has been described with reference to particular embodiments, it should be understood that the embodiments are illustrative and that the scope of the invention is not limited to these embodiments. Many variations, modifications, additions and improvements to the embodiments described above are possible. It is contemplated that these variations, modifications, additions and improvements fall within the scope of the invention.

We Claim:

1. A Metal-Organic Framework (MOF) designed for the selective capture of gaseous pollutants, comprising:

a crystalline structure formed by the coordination of metal nodes with organic ligands,

wherein said MOF exhibits high affinity and selectivity towards specific gaseous pollutants.

2. The MOF as claimed in claim 1, wherein the metal nodes are selected from the group consisting of zinc, copper, iron, and aluminum, and the organic ligands are selected to impart selectivity for gaseous pollutants such as sulfur dioxide, nitrogen oxides, carbon dioxide, methane, or volatile organic compounds.

2. A method for the synthesis of Metal-Organic Frameworks (MOFs) for the selective capture of gaseous pollutants, comprising the steps of:

a. selecting metal nodes and organic ligands based on their coordination chemistry; and
b. subjecting them to controlled synthesis conditions to form a crystalline MOF structure with specific binding sites for targeted gaseous pollutants.

4. The method as claimed in claim 3, further comprising the step of post-synthetic modification to enhance the selectivity and affinity of the MOF towards specific gaseous pollutants.

5. A system for the capture and release of gaseous pollutants using Metal-Organic Frameworks (MOFs), comprising:

a. an adsorption chamber, wherein the MOF is deployed to selectively capture gaseous pollutants, and
b. a desorption chamber, wherein controlled conditions are applied to release captured pollutants from the MOF back into the environment.

6. The system as claimed in claim 5, further comprising a regeneration module wherein the MOF is subjected to conditions facilitating the removal of captured pollutants, rendering the MOF reusable for subsequent capture-release cycles.

7. A method for the selective release of captured gaseous pollutants from Metal-Organic Frameworks (MOFs), comprising the step of:

a. subjecting the MOF to controlled conditions such as temperature, pressure, or gas composition;
b. allowing the desorption of captured pollutants and enabling the MOF for reuse in subsequent capture cycles.

8. The method as claimed in claim 7, wherein the controlled conditions for the release of gaseous pollutants are optimized to ensure minimal energy consumption and environmental impact during the desorption process.

9. A Metal-Organic Framework (MOF)-based filter or absorbent material for the removal of gaseous pollutants from air or gas streams, wherein said filter or absorbent material incorporates MOFs with tailored selectivity for specific pollutants, providing an efficient and sustainable solution for air purification.

10. The MOF-based filter or absorbent material as claimed in claim 9, wherein the filter or absorbent material is integrated into ventilation systems, industrial processes, or gas purification systems to enhance pollutant removal efficiency and reduce environmental emissions.

Dated this 12th day of November 2023

Signature:

Applicant(s)

Dr. Ganji Saidulu et. al.

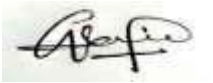
ABSTRACT

METAL-ORGANIC FRAMEWORKS (MOFS) FOR SELECTIVE CAPTURE AND RELEASE OF GASEOUS POLLUTANTS

[027] The invention presents a Metal-Organic Frameworks (MOFs) for Selective Capture and Release of Gaseous Pollutants. The present invention comprising of a structured arrangement resulting from the coordination of metal nodes with organic ligands, wherein the Metal-Organic Framework (MOF) demonstrates notable affinity and specificity for distinct gaseous pollutants. The metal nodes, encompassing zinc, copper, iron, and aluminium, synergize with organic ligands selected to confer specificity for gaseous pollutants like sulphur dioxide, nitrogen oxides, carbon dioxide, methane, or volatile organic compounds. A technique for producing Metal-Organic Frameworks (MOFs) geared toward selectively trapping gaseous pollutants, involving the steps of selecting metal nodes and organic ligands based on their coordination chemistry, and subjecting them to controlled synthesis conditions, resulting in the formation of a crystalline MOF structure hosting specific binding sites for targeted gaseous pollutants. The post-synthetic modification to heighten the MOF's selectivity and affinity for particular gaseous pollutants. A regeneration module where the MOF undergoes conditions conducive to pollutant removal, ensuring its reusability for subsequent capture-release cycles.

Accompanied Drawing **[FIG. 1-2]**

Dated this 12th day of November 2023

Signature: 

Applicant(s)

Dr. Ganji Saidulu et. al.

FORM 3

THE PATENTS ACT,
1970 (39 of 1970)
and
THE PATENTS RULES, 2003

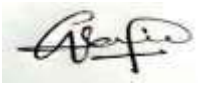
STATEMENT AND UNDERTAKING UNDER SECTION 8

(See section 8; Rule 12)

1. Name of the applicant(s).	I/We, Dr. Ganji Saidulu et. al., all are citizen of India, Address of one of the Applicant: Associate Professor, Department of Chemistry, J. B. Institute of Engineering and Technology, Bhaskar Nagar, Yenkapally (V), Moinabad(M), R.R. District, Hyderabad, Telangana, India -500075.
2. Name, address and nationality of the joint applicant.	(i) that I/We have not made any application for the same/substantially the same invention outside India Or (ii) ~~that I/We who have made this application No… dated alone/jointly with ..... , made for the same/ substantially same invention, application(s) for patent in the other countries, the particulars of which are given below:~~

Name of the Country	Date of Application	Application No.	Status of the Application	Date of Publication	Date of grant
-	-	-	-	-	-

3. Name and address of the assignee	(iii) that the rights in the application(s) has/have been assigned to …… none …… …… …… that I/We undertake that upto the date of grant of the patent by the Controller, I/We would keep him informed in writing the details regarding corresponding applications for patents filed outside India within six months from the date of filing of such application. **Dated this 12th day of November 2023**

4. To be signed by the applicant or his authorized registered patent agent.	**Signature:** 
5. Name of the natural person who has signed.	Dr. Ganji Saidulu et. al. **Name of the Applicant(s)**
	To The Controller of Patents, The Patent Office, at Chennai
Note.- Strike out whichever is not applicable;	

A Metal-Organic Framework (MOF) designed for the selective capture of gaseous pollutants

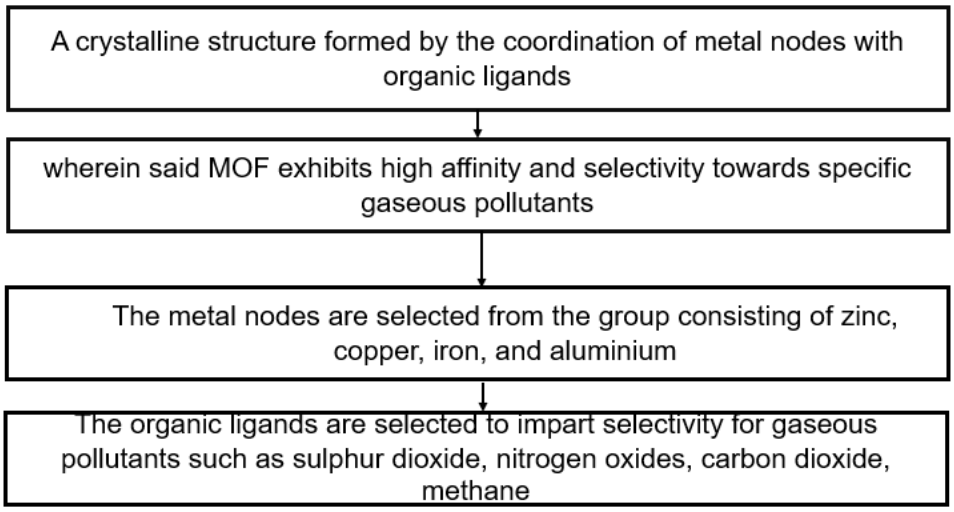


Figure. 1

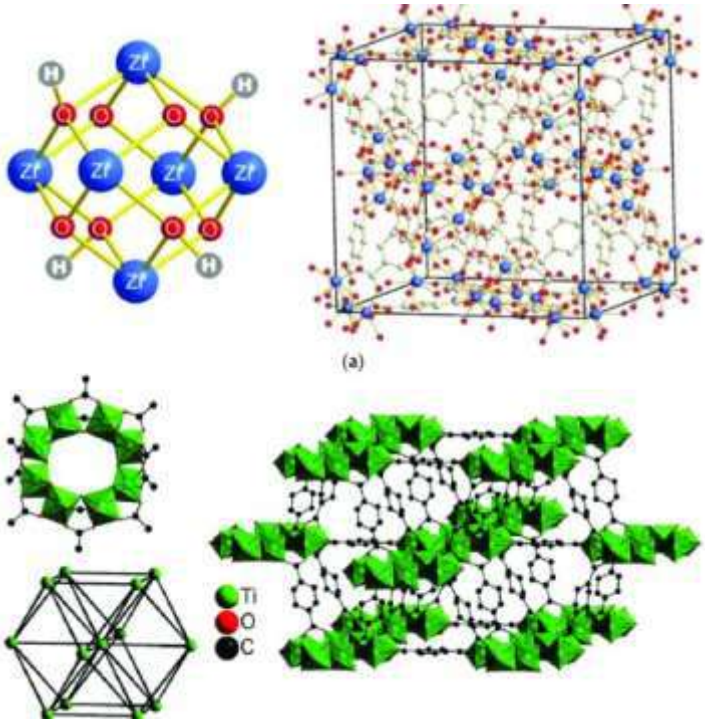


Figure. 2

Dated this 12th day of November 2023

Signature:

Applicant(s) Name: Dr. Ganji Saidulu et. al.

FORM- 5

THE PATENTS ACT, 1970

(39 of 1970)

&

The Patents Rules, 2003

DECLARATION AS TO INVENTORSHIP

[See Section 10(6) and Rule 13(6)]

1. NAME OF THE APPLICANT(S)

I/We, Dr. Ganji Saidulu et. al., all are citizen of India, Address of one of the Applicant: Associate Professor, Department of Chemistry, J. B. Institute of Engineering and Technology, Bhaskar Nagar, Yenkapally (V), Moinabad(M), R.R. District, Hyderabad, Telangana, India -500075.

hereby declare that the true and first inventor(s) of the invention disclosed in the complete specification filed in pursuance of ~~my~~ / our application numbered _____ dated 12-11-2023 ~~is~~/are

2. INVENTOR(S)

(a) NAME	**(b) NATIONALITY**	**(c) ADDRESS**
1. Dr. Ganji Saidulu	Indian	Associate Professor, Department of Chemistry, J. B. Institute of Engineering and Technology, Bhaskar Nagar, Yenkapally (V), Moinabad(M), R.R. District, Hyderabad, Telangana, India - 500075
2. Dr. Surapaneni Krishna Mohan	Indian	Professor, Department of Biochemistry, Panimalar Medical College, Hospital & Research Institute, Varadharajapuram, Poonamallee, Chennai - 600123, Tamil Nadu, India
3. Dr. Manisha Atul Bora	Indian	Associate Professor, Department of Chemistry, Bharatiya Jain Sanghtana's Arts, Science and Commerce College, Wagholi, Pune, 412207
4. Dr. B. Padma	Indian	Assistant Professor, Department of Chemistry, University Post Graduate College, Osmania University, Telangana, Secunderabad, India - 500003
5. Dr. Ramudu Pochamoni	Indian	Assistant Professor, Department of Chemistry, Palamuru University, 509001

~~3. DECLARATION TO BE GIVEN WHEN THE APPLICATION IN INDIA IS FILED BY THE APPLICANT(S) IN THE CONVENTION COUNTRY: -~~

N.A.

~~We the applicant(s) in the convention country hereby declare that our right to apply for a patent in India is by way of assignment from the true and first inventor(s).~~

Dated this 12th day of November 2023

Dr. Ganji Saidulu et. al.

Applicant(s)

To,
The Controller of Patents
The Patent Office, Chennai

FORM 9

THE PATENT ACT, 1970
(39 of 1970)
&
THE PATENTS RULES, 2003

REQUEST FOR PUBLICATION

[See section 11A (2) rule 24A]

I/We **Dr. Ganji Saidulu,Dr. Surapaneni Krishna Mohan,Dr. Manisha Atul Bora,Dr. B. Padma,Dr. Ramudu Pochamoni** hereby request for early publication of my/our [Patent Application No.] TEMP/E-1/91210/2023-CHE

Dated **12/11/2023 00:00:00** under section 11A(2) of the Act.

Dated this(Final Payment Date):----------
Signature
Name of the signatory

To,
The Controller of Patents,
The Patent Office,
At Chennai

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J Mater Sci: Mater Electron (2024) 35:53

Role of thermal heat-treatment to achieve a highly polycrystalline and compact α-MoO_3 thin films

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ABSTRACT

Molybdenum trioxide (MoO_3) thin film layers have been deposited via wet-chemical spin coating technique. The suitability to obtain a highly crystalline and compact MoO_3 thin films by a post-deposition annealing treatment is investigated. The most stable α-orthorhombic phase of MoO_3 with preferential bragg reflection (002) was revealed with structural analysis. The energy bandgap decreased to the annealed samples from 3.05 to 2.92 eV is related to the particle size enhancement. The Raman peak exhibited at 819 cm^{-1} to 500 °C annealed layer was identified to (Mo–O–Mo) symmetric stretching mode (A_g). The surface morphology studied by FESEM confirms the presence of well-adherent, void-free, densely packed granules with a uniform size of particles suitable for making thin back contact buffer layers CdTe devices. Furthermore, all the samples were observed to be uniformly and densely deposited without voids over a larger area. Electrical measurements, current density-voltage and capacitance-voltage were performed to calculate the ideality factor (η), barrier height (Φ_b), carrier concentration and flat band potentials. The increase in carrier concentration with rising annealing temperature confirms the growth of low-defect MoO_3 layers with enhanced crystallinity. The results reported herein are promising and may have potential role to develop low-resistive back contact to CdTe for photovoltaic devices.

1 Introduction

Molybdenum trioxide (MoO_3) is a transitional metal oxide with wide bandgap and a high work function ~ 6.7 eV [1, 2]. Energy bandgap of MoO_3 thin films depends on the growth deposition techniques under varying deposition conditions [3–5]. MoO_3 is found to be present in orthorhombic α-MoO_3 [6], metastable mono-clinic β-MoO_3 [7], and hexagonal h-MoO_3 phases [8]. According to phase diagram and reported experimental studies orthorhombic MoO_3 phase has the most thermodynamically stable crystal structure due to the low potential energy [9]. MoO_3 exhibits a unique double-layered crystal structure, and each sublayer is built by sharing the corner MoO_6 octahedral units, and MoO_6 octahedra units share edges to

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ES Energy & Environment

(https://www.espublisher.com/journals/id/es-energy-environment) Volume ,
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A Role of Growth Potential to Enhance the Physical and Electrical Properties of Electrodeposited Cadmium Sulfide Thin Films

Authors Authors and affiliations

Aparna S. Ukarande, Sachin V. Desarada, Maruti V. Salve, Priyanka U. Londhe, Dipmala P. Sali, Shivaji M. Sonawane, Ganesh R. Bhand, Shweta Chaure, and Nandu B. Chaure

Abstract

We report the growth of cadmium sulfide (CdS) thin films via cost-effective cathodic electrodeposition using a three-electrode configuration in an aqueous electrolyte. The optimal growth potential of CdS was determined using cyclic voltammetry. The influence of growth potentials (-1.2 – -1.4 V) on the optical, structural, morphological, and compositional properties was examined by employing diverse characterization techniques. The results illustrated that the growth potentials significantly affected the crystallographic structure, orientation, and optical measurements. A hexagonal polycrystalline structure with a preferred (101) orientation was observed for the samples deposited at all potentials. The optical direct bandgap of the CdS samples was estimated to be in the range, 2.25 to 2.45 eV, with a transmittance of over 85% for the sample obtained at -1.2 V. CdS thin films obtained by electrodeposition demonstrate superior optical and electrical properties over a large area, thereby providing a promising buffer layer for the development of thin-film solar cell devices.

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UGC-Malaviya Mission Teacher Training Centre *(Former UGC-HRDC), Sant Gadge Baba Amravati University, Amravati*

She/He achieved **A** *Grade in the proctored examination held on 25th Nov. 2023*

Prof. Dr. Mohammad Atique	Dr. G. V. Korpe	Mr. Yashwant Shitole	Dr. D. D. Khedkar
Director, UGC-MMTTC,	Principal	President	ST-FDP Coordinator
Sant Gadge Baba Amravati	Shri Shivaji Science College,	Maharashtra Information	Shri Shivaji Science College,
University, Amravati (MS)	Amravati	Technology Support Centre	Amravati

Date : 25th Nov. 2023 Certificate ID EI:STFDP-541

Grades as Per UGC Guidelines:
A>75%; B>60%; C>50% and F Below 50% (Not Eligible)

CERTIFICATE OF PARTICIPATION

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24th, February, 2024

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This is to certify that **Prof./ Dr./Mr./Mrs./Ms.** Shivaji Madhukar Sonawane
from Department of physics, Savitribai phule Pune University, Pune-411007
has participated in the International Seminar On Energy Applications held on Saturday 24th February 2024 at the Department of Physics, Savitribai Phule Pune University, Pune, Maharashtra, India.

Chaure.

Prof. Nandu B. Chaure
Co-ordinator

Prof. Sanjay D. Dhole
Head, Dept. of Physics, SPPU

Dnyaneshwar Gramonnati Mandal Ale, Santwadi, Kolwadi's

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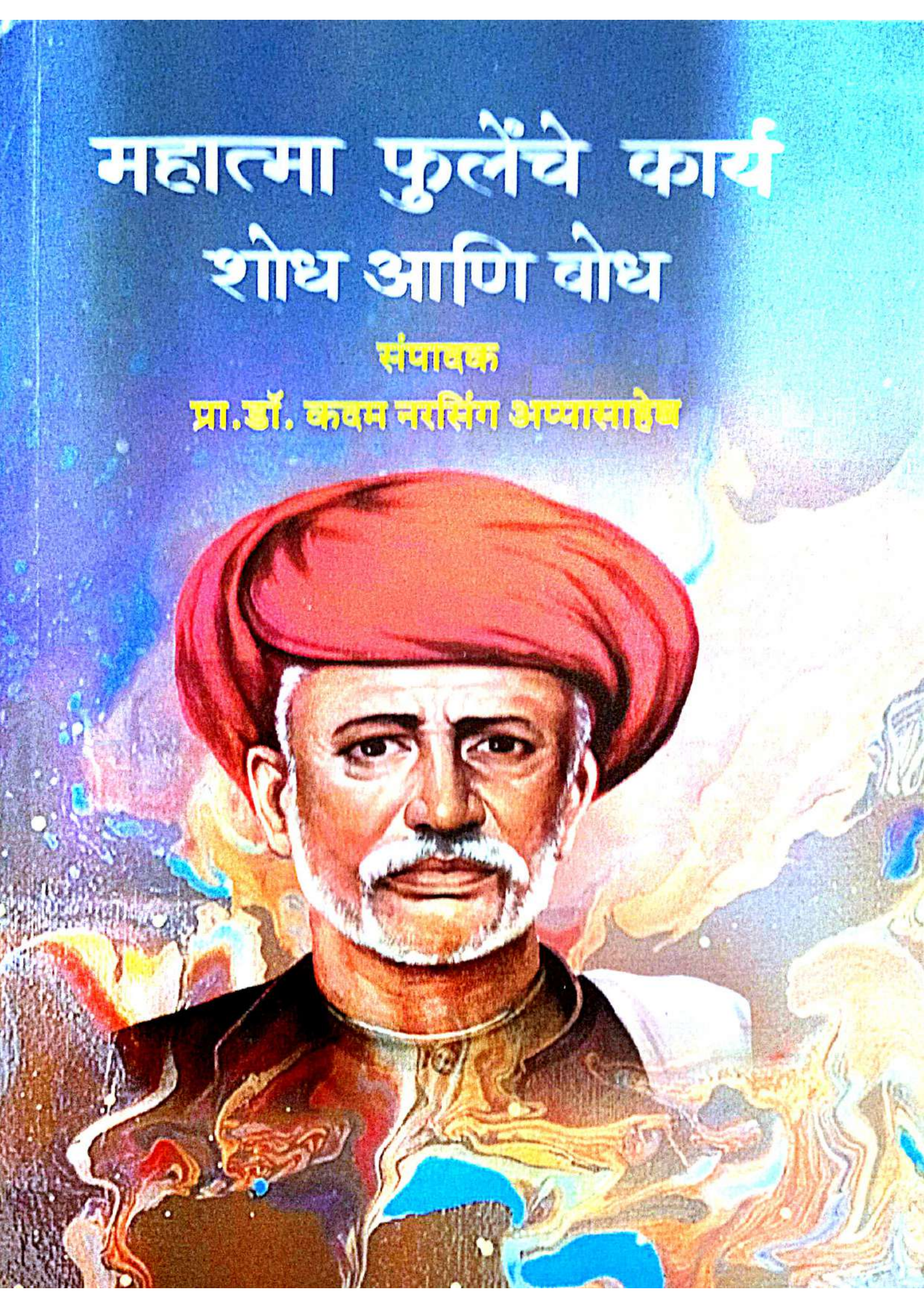
Dr. R. B. Bhise	*Prof. (Dr.) Sandesh Jadkar*	*Dr. P. G. Jadhav*
Co-ordinator & Head of Department	Chairman, BOS in Physics, SPPU	Principal

महात्मा फुलेंचे कार्य शोध आणि बोध

संपादक
प्रा.डॉ. कवम नरसिंग अप्पासाहेब



डॉ. विकास बहुले
-मराठी विभाग

महात्मा फुलेंचे कार्य शोध आणि बोध

संपादक
प्रा.डॉ. कदम नरसिंग अप्पासाहेब

तनिष्क पब्लिकेशन

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डॉ. विकास बापूराव बहुले

प्रस्तावना: महात्मा जोतिराव फुले हे कृतिशील विचारवंत होते. पूर्वास्पृश्य, स्त्रिया आणि शेतकरी या तिन्ही वर्गाच्या गुलामगिरीच्या आवाजाविषयी प्रस्थापितांच्या विरुद्ध सर्वप्रथम आवाज उठविणारे समाजसुधारक म्हणजे जोतिबा फुले होत. धार्मिक, आर्थिक, सामाजिक आणि शैक्षणिक विषयांवर माडलेले त्यांचे विचार काळाच्याही पुढे जाणारे होते. ते प्रसंगी मार्मिक आणि बंडखोर होते. विवेकनिष्ठता, बुद्धिप्रामाण्यवाद, निरपेक्षपणा, समग्रता ही त्यांच्या लेखनाची वैशिष्ट्ये होत. धर्म, शिक्षण, स्त्रीमुक्ती, कृषिसुधारणा, ग्रामीण विकास इत्यादी क्षेत्रात त्यांचे विचार मार्गदर्शक ठरतात. तत्कालीन जनतेच्या दुःख, दारिद्र्याचे मूळ त्यांच्या अज्ञानात असल्याचे महात्मा फुले दाखवून देतात. स्त्रियांना, दलित, शोषित, गरीब वर्गाला व्यवहारोपोयोगी शिक्षण देऊन त्यांना आत्मनिर्भर करण्याचा आग्रह महात्मा फुले तत्कालीन इंग्रज सरकारला करतात. मानवतावादी, विज्ञानवादी व पुरोगामी दृष्टिकोनातून त्यांनी समग्र समाज परिवर्तन करण्याचा प्रयत्न केला. जोतिबांचे तत्त्वज्ञान हे मानवाची प्रतिष्ठा, मानवी समानता, हक्कांसाठी सदैव स्मरणात राहणारे आहे.

भारतीय शैक्षणिक परंपरा : शिक्षण हा जीवनाचा आधार आहे. समाजपरिवर्तनाचे साधन आहे. शिक्षण ही अन्न, वस्त्र आणि निवारा या मूलभूत गरजांइतकीच महत्त्वाची गरज आहे. आपली भारतीय संस्कृती जशी प्राचीन आहे तशीच आपली शिक्षणप्रणाली सुद्धा प्राचीन कालखंडापासून प्रचलित आहे. भारतीय समाज चातुर्वर्ण्य समाजव्यवस्थेत गुरफटला गेला होता. ब्राह्मण, क्षत्रिय, वैश्य आणि शुद्र या व्यवस्थेत ब्राह्मण अध्ययन-अध्यापन, क्षत्रिय-युद्ध, वैश्य-व्यापार, शुद्र- तिन्ही वर्गाची सेवा करावी अशी विषमतावादी समाजव्यवस्था होती. भारतात शिक्षण हे ब्राह्मण-क्षत्रिय-वैश्य या तीन समाजाची मक्तेदारी होती. स्त्री व शूद्रांना विद्याप्राप्तीचा अधिकार नव्हता. शिक्षण घेतल्याने, स्त्रीच्या विचाराने वागल्यास घरातील शांती नष्ट होते असे पूर्वग्रहदूषित संकेत होते. वैदिककाळात उपनयन ह्या संस्काराशिवाय कोणत्याही बालकांस ज्ञानार्जन करता येत नसे. व्यक्तिगत, सामजिक, धार्मिक, शारीरिक गुणांचा,

जीवनाचा उत्कर्ष साधणे, सत्य, सेवा, कष्ट, शिस्त, नम्रशिलता यांसारख्या नैतिक गुणांचे संवर्धन करणे हेच शिक्षणाचे मुख्य ध्येय मानले जाई. प्राचीन भारतीय शिक्षणपद्धतीत आयुर्वेद, वेदांगे, अभियांत्रिकीचे शिक्षण दिले जाई. संगीत, चित्रकला, वाद्यवादन या कलाही भारतीयांना अवगत होत्या. संस्कृत ही शास्त्रीय शिक्षणाची भाषा होती आणि वैदिक काळात आद्य-हिंदू धर्म हा धार्मिक रूढीवादी होता. वैदिक वाङ्मय आर्यांना पूज्य वाटत असे, म्हणून प्रारंभीच्या वेळी उपनयन हा धार्मिक समारंभ केला जाई. मुला-मुलीचे उपनयनसंस्कार झाल्यावर गुरुकुलात १२ वर्षे रहावे लागे. गुरु हा आध्यात्मिक पिता असल्याने आईवडिलांपेक्षाही त्याला अधिक मान होता. अध्यापन पद्धती प्रगत होत्या. निसर्ग सानिध्यात देवालय, गोल घुमट, बारवा, तळी अशा पाणवठ्याच्या सार्वजनिक ठिकाणी मौखिक विद्यादान दिले जाई. हे शिक्षण संस्थाबाह्य स्वरूपाचे होते. जलव्यवस्थापनाबरोबरच साहित्य आणि कलांचीही निर्मिती केली जाई. शूद्रातिशूद्र आणि सर्व वर्णातील स्त्रियांना पुरुषप्रधान संस्कृतीने शिक्षण नाकारले होते. शूद्र जातीतील मुलांना आपल्या जातीचा धंदा चालविण्यासाठी आवश्यक ते शिक्षण आपल्या बापाकडून शिकण्याची केवळ मुभाच नव्हे तर सक्ती होती. स्त्रियांनाही चूल व मूल या त्यांच्या 'घर' या वर्तनाशी संबंधित विद्या व कला शिकाव्याच लागत.

बौद्धकाळात गौतम बुद्धांनी मानवतावादी दृष्टिकोनातून धम्माची स्थापना केल्यामुळे पुरुषांबरोबरच स्त्रियांनादेखील स्वातंत्र्य असून विद्यार्जन करता येत होते. याच कालखंडात तक्षशीला व नालंदा विद्यापीठांची स्थापना झाली. त्यांनी वैदिक कर्मकांड, यज्ञयाग, पुरोहितशाहीला झुगारून राजघराण्यातील स्त्रियांबरोबरच दास, गुलाम, वेश्या, गणिकांना आपल्या संघात प्रवेश दिला त्यामुळे पुरुषांबरोबर स्त्रियाही शिक्षण घेऊ लागल्या. 'नवीन श्रमणास भिक्षुत्त्वाची दीक्षा दिली की त्याला दहा वर्षेपर्यंत त्रिपिटकादिकांचे सांगोपांग शिक्षण वृद्ध भिक्षुने दिले पाहिजे, असे बुद्धाने नियम घालून दिले होते. त्यामुळे शिक्षणाचे कार्य प्रत्येक मठात अविरत चालत असे; कारण नवीन नवीन श्रमणांना भिक्षुत्त्वाची दीक्षा देण्याचे काम सतत सुरु असे. प्रथम प्रथम नव भिक्षुंनाच बौद्ध उपाध्याय शिकवीत असत, पण समाजातील मुलांचे शिक्षण पहिल्यापासूनच आपल्या देखरेखीखाली घेण्याने धर्मप्रसाराचे कार्य असा अनुभव येऊ लागल्यामुळे बौद्ध मठातून सर्वांनाच शिक्षण देण्याचे कार्य सुरु झाले. हिंदूंची आतापर्यंतची ज्ञात असलेली सर्व इसवी सनानंतरच्या नवव्या शतकानंतरची आहे. तेव्हा ती काढण्याची कल्पना बौद्ध विहारातील शिक्षण संस्थांनवरून हिंदूंना सुचली असावी असे मानण्यास काहीच हरकत नाही; कारण बौद्धांच्या मठ-शिक्षणसंस्था पाचव्या शतकातच भरभराटीस आल्या

होत्या.

बिहार प्रांतात नालंदा महाविहार आणि इतर महान मठ ही बौद्ध शिक्षणाची केंद्रे होती त्यात धर्मनिरपेक्ष कला आणि विज्ञान तसेच धर्मशास्त्र समाविष्ट होते. बौद्ध विहारात संघाची शिस्त तसेच शिक्षण, आध्यात्मिक व्यवसाय आणि प्रगत तात्त्विक चर्चा शिकवल्या जात. मनुस्मृतीत शूद्रांनी वेद पठण केले तर त्यांच्या कानात कढलेले शिसे ओतावे अशी मनुस्मृतीची आज्ञा होती. स्त्रीने सदासर्वकाळ पुरुषाच्या अधीनतेतच राहावे, संपत्ती-शिक्षणाचा अधिकार नाकारला गेला. पुरुषसत्ताक कुटुंबपद्धतीने पुरुषाची वासनातृप्तीचे साधन म्हणूनच तिच्याकडे धार्मिक, सामाजिक आणि मानसिक बंधने लादली गेली. मुघलकालीन शिक्षणप्रणालीत सरकारी राजवटीबरोबर धार्मिक शिक्षण संस्थांचे असल्याने राजघराण्यातील राजकन्या व स्त्रियांना महालातच लिहिणे, वाचणे शिकविले जाई. सर्वसामान्य स्त्री शिक्षणापासून वंचित होती. स्त्रियांचे संपूर्ण जीवन पडद्याआड बंदिस्त होते. अकबराने शिक्षण पद्धतीमध्ये आमूलाग्र बदल केले. ग्रंथालये व मदरशांसारखी सुरुवात करून इस्लाम धर्मांबरोबरच भारतीय तत्त्वज्ञान, खगोल, राज्य आणि कृषिविषयक शास्त्रांचा अभ्यासक्रमात समावेश केला. मुघलकालात मुस्लीम शिक्षणपद्धतीचे प्राबल्य होते. हिंदू राजवटीत इ.स. पूर्व १२०० ते इ.स.पूर्व ६०० पर्यंतच्या काळात राजदरबारी ब्राह्मणांचे महत्त्व वाढल्याने यज्ञ, धार्मिक विधींचे महत्त्व आले. स्त्रियांचे स्थान व दर्जा घसरला. शिक्षण पद्धतीतही महत्त्वाचे बदल घडून आले. गुरुकुल पद्धती जाऊन 'आश्रम पद्धती' विकसित झाली. आश्रमात वेदाभ्यासाबरोबरच नीतीशास्त्र, इतिहास, युद्धशास्त्र असे विविध विषय शिकवले जात.

पेशवेकालीन राजवटीत स्त्री आणि शूद्रांची अवस्था अतिशय दयनीय होती. पेशव्यांचा जोर शिक्षणापेक्षा ब्राह्मणग्राह्यांच्या धर्मकारणावर अधिक होता. त्यामुळे दक्षिणा वाटप आणि अस्पृश्यतेचे काटेकोरपणे पालन करणे हे पेशवाईची राजधानी पुण्यात सर्रासपणे घडत होते. वर्णाश्रमधर्मांमुळे जाती जातींत श्रेष्ठ-कनिष्ठतेच्या भिंती उभ्या झाला. पुस्तकाच्या मलपृष्ठावरील चामड्यास स्पर्श झाला तर विटाळ होतो, असे मानीत असे. छापील कागदास शिवणे हे अपवित्र नि धर्मबाह्य वर्तन आहे अशी लोकांत समजूत असे. गाईचासुद्धा विटाळ मानण्यात येई. वरी मुले आपली दप्तरे एका कोनऱ्यात ठेवीत. घुबड शब्दासारखे अमंगल शब्द बरात उच्चारण्याने विटाळ होतो व इतर जातींच्या विद्यार्थ्यांच्या स्पर्शांमुळे शिवाशिव होते असा समज असे. ती शिवाशिव काढण्यासाठी शाळकरी मुले घरी येताच सचैल स्नान करीत आणि शुद्ध होत. ढेरभर मापेच्या पळीने माणूस अपवित्र होतो; एवढेच नव्हे तर त्याचे ब्राह्मणत्वही जाते असे समजले ब्राह्मण

मानीत असत.[१]

१८१८ मध्ये पेशवाईचा अंत झाला. ब्रिटिशांच्या राजवटीला सुरुवात झाली. १९ व्या शतकाच्या पूर्वार्धात ब्रिटिशांनी आपली सत्ता स्थापन करण्याच्या राजकीय हेतूने एक शिक्षण व्यवस्था जन्माला घातली. त्यामुळे परस्पर सहकार्याने देशातील आधुनिक शिक्षण व्यवस्था उभी राहिली. भारतीय समाजावर इंग्रजी राजवटीचा, विचारांचा, संस्कृतीचा दूरगामी परिमाण झाला. एकोणिसाव्या शतकाचे वैशिष्ट्य म्हणजे जगाचे पाश्चात्यीकरण होय. भारतातील जुनी शैक्षणिक परंपरा, संस्कृत व अरेबिक वाङ्मय, विद्या, कला, गणित, विज्ञान परंपरा पुनरुज्जीवित करून त्यांच्यासह नवीन युरोपियन विज्ञानाचे शिक्षण भारतात दिले पाहिजे असे काही विद्वानांचे मत होते. शिक्षण म्हणजे पाश्चात्य व ते इंग्रजीतून द्यायचे हा लॉर्ड मकेलेचा ठाम विचार होता. आधुनिक शिक्षण, पण ते एतद्देशीय भाषांतून द्यावे, इंग्रजीही त्या जोडीला असावी असाही एक मतप्रवाह होता. एकोणिसाव्या शतकातील भारतातील शैक्षणिक इतिहास काही व्यक्तींच्या नावाशी निगडीत झालेला आहे. त्यामध्ये डेव्हिड हॅरे, राजाराम मोहन रॉय, विल्यम कॅरी, जोतिराव फुले या विभूती होत. मुलींच्या शाळा काढून जोतिबांनी स्त्री-शिक्षणात प्रचंड कार्य केले. दादा गोरे म्हणतात की, महात्मा फुले हे फक्त कर्ते सुधारक नव्हते. ते द्रष्टे सुधारक होते. काळाच्या पुढे जाऊन ते विचार करीत होते असे दिसते...शिक्षणाचे महत्त्व फुले यांना समजले होतेच. म्हणून तर दलित स्त्रियांसाठी पुण्याला पहिली शाळा म.फुले यांनी सुरु केली. भटगिरीला विरोध करणारे महात्मा फुले शिक्षणासाठी 'अन्नदान करावे, भिक्षान्न मागावे' असे म्हणतात,ही बाब लक्षात घ्यावीच लागते.[२]

शैक्षणिक सुधारणांचा इंग्रजी कालखंड : 'व्यापारी म्हणून आले आणि राज्यकर्ते बनले' असे इंग्रज राजवटीबद्दल नेहमी बोलले जाते. व्यक्तिमूल्ये, ईहवाद, राष्ट्रवाद यासारख्या पाश्चात्य विचारसरणीने भारतभर वैचारिक मन्वंतर घडवून आणले. इंग्रजी शिक्षण घेऊन बाहेर पडलेला तरुण वर्ग उदारमतवादी, भौतिकवादी तसेच विवेकवादी बनला. समाजसुधारणेचे विचार घेऊन बाळशास्त्री जांभेकर, दादोबा पांडुरंग, लोकहितवादी, चिपळूणकर, आगरकर, गोखले, रानडे, महर्षी शिंदे यांसारखे समाजसुधारकांचा वर्ग तयार झाला. समाजातील अस्पृश्यता, बालविवाह, विधवाविवाह, केशवपन, सतीची चाल, सार्वजनिक शिक्षण या सामाजिक समस्यांवर लक्ष केंद्रित केले. इंग्रजी राजवटीने त्यांच्या राजकीय विचारांबरोबर मूल्यव्यवस्थाही भारतीय समाजात रूढ केली. ईस्ट इंडिया कंपनीने युरोपातील आधुनिक शास्त्रांचे शिक्षण त्यांना भारतात सुरू करायचे होते. भारतात मुलकी खात्याचा अधिकारीच

शिक्षणव्यवस्था पाहात. त्यामुळे तो अधिकारी ज्या विचारांचा, त्या विचाराने तो वागे. राजा राममोहन रॉय, पांडुरंग तर्खडकर, बाळशास्त्री जांभेकर, जोतिबा फुले इत्यादींनी एलफिन्स्टन-सारख्या गव्हर्नर्समुळे महाराष्ट्रात शिक्षणाचा श्रीगणेशा केला याचा असेच म्हणावे लागेल. विल्यम केरी इ.स.१७९३ मध्ये भारतात आले. सर्वप्रथम त्यांनी१८०० मध्ये कलकत्त्याजवळ सेरामपूर येथे बऱ्याचशा मिशनरीच्या प्राथमिक शाळा सुरू केल्या. त्याचकाळात काही उदारमतवादी भारतीय आणि परकियांनी इंग्रजी शिक्षणाचा प्रसार होण्यासाठी अशासकीय शाळांची स्थापना केली. इंग्रजी भाषेच्या शिक्षणाचा प्रसार वेगाने व्हावा म्हणून ब्रिटिश पार्लमेंटने १८१३ साली हिंदी लोकांच्या वैज्ञानिक ज्ञान व सर्वांगीण विकासासाठी इंग्रजी शिक्षण देण्यासाठी चार्टर ॲक्ट पास करून घेतला. चार्टर ॲक्टनुसार भारतीय शिक्षणावर प्रतिवर्ष कमीत कमी एक लाख रुपये प्रतिवर्ष खर्चाला मंजुरी देण्यात आली. ही रक्कम इंग्रजी शिक्षणासाठी खर्च करावी की पारंपरिक यावर वाद होता मात्र देशाच्या कानाकोपऱ्यात इंग्रजी शिक्षणाच्या शाळा सुरु झाल्या. पुढे १८३५ मध्ये तत्कालीन गव्हर्नर लॉर्ड बेंटिंगने शिक्षण खाते सुरु केले. त्याच्याच मान्यतेने लॉर्ड मेकॅलेच्या नेतृत्त्वाखाली जाहिरनामा जाहीर झाला. त्यातूनच रंगाने भारतीय पण विचार, नितीमत्ता, बुद्धिमत्ता इग्रजी असलेला नवा वर्ग तयार करायचा होता. सर्वमान्य नवीन शिक्षणपद्धतीची सुरुवात होत गेली. लॉर्ड डलहौसीने १८५४ पर्यंत संपूर्ण हिंदुस्थानात माध्यमिक हायस्कूलच्या इमारती सरकारी अनुदानातून उभ्या केल्या.

१८५४ 'वूडचा खलिता' या अहवालामध्ये सर चार्ल्स यांनी पाश्चिमात्य ज्ञानावर भर द्यावा यावर शिफारस केली. भारतीयांना उपयुक्त ज्ञान देणे तसेच उच्च शिक्षणाचा प्रसार करण्यासाठी केलेल्या सूचना व शिफारशी अत्यंत महत्त्वाच्या ठरल्या. त्यांनी प्राथमिक ते विद्यापीठ स्तरापर्यंतचे शिक्षण नियंत्रित करण्यासाठी काही सूचना केल्या. त्यात विद्यार्थ्यांना इंग्रजी तसेच स्थानिक मातृभाषेतून शिक्षण देण्याची सूचना करण्यात आली. तसेच लंडन विद्यापीठाच्या धर्तीवर १८५७ मध्ये मद्रास, कलकत्ता, मुंबई या विद्यापीठांची स्थापना झाली. १८८२ चा भारतीय शिक्षण आयोगाची स्थापना लॉर्ड रिपन यांनी केली. ती विल्यम हंटर यांच्या अध्यक्षतेखाली झाली. त्यालाच हंटर आयोग म्हणून ओळखले गेले. आयोग. यामध्ये प्राथमिक, माध्यमिक, विद्यापीठीय शिक्षण, स्त्री शिक्षण यावर भर होता. आयोगापुढेच महात्मा फुले यांनी आपली कैफियत मांडली. इंग्रजांनी केलेले शिक्षणाचे सार्वत्रिकीकरण हे एक थोतांड होते, धूर्त कावा होता. अस्पृश्य, मागासवर्गाला शिक्षण देण्याचा हेतू नसून ब्रिटिश अभिरुची बाळगणारा, कमी पैशांत राबणारा विशिष्ट कारकुनांचा दुय्यम वर्ग निर्माण करण्यासाठी त्यांची धडपड सुरु

होती. या शिक्षणव्यवस्थेतील सर्वांत मोठा दोष म्हणजे जे स्वतःचे शिक्षण घेण्यास समर्थ आहेत त्यांनाच सरकारी शिक्षण मोफत मिळत होते. गरीब, कुणबी, शेतकरी वर्ग पिढ्यानपिढ्या अज्ञानाच्या अंधारात खितपत पडला होता.

इंग्रजी शिक्षणाचा फायदा सर्वप्रथम ब्राह्मण वर्गाने घेतला. मुलकी आणि लष्करी सेवेतील हुद्द्याच्या जागा पकडून एतद्देशीयांवर सत्ता गाजविण्यास सुरुवात केली. कनिष्ठ वर्गांच्या शिक्षणाविषयी सरकारचे मत अनुकूल नव्हते. ज्या सनातनी वर्गाला शिक्षण आपली मक्तेदारी वाटे, त्यांचा अस्पृश्यांच्या शिक्षणास कडाडून विरोध होता. त्यामुळे 'उच्चवर्णियांना विटाळ होत असेल तर महार मुलाला प्रवेश देऊ नये', असा ठराव मंजूर करून मुंबई सरकारने तो अंमलात आणला. इंग्रजी सत्तेलाच शिक्षण ही वरिष्ठ वर्गाची मक्तेदारी असावी असे मनोमन वाटत होते. अस्पृश्यांना शिक्षण नाकारणे हे सरकारचे सोयीचे धोरण असले तरी अमेरिकन मिशनऱ्यांनी धर्मप्रसाराच्या धूर्त हेतूने का होईना 'बॉम्बे नेटिव एज्युकेशनची' स्थापना करून शाळा काढल्या. शहरात व खेड्यातही आरोग्य सेवा व शिक्षणाचा प्रसार सुरु केला. भारतीय शिक्षणप्रणालीचा विकास ख्रिश्चन धर्माच्या तत्त्वाप्रमाणे व्हावा असे मिशऱ्यांची इच्छा होती. अस्पृश्य तसेच उच्च शिक्षित वर्ग हिंदू धर्माचा त्याग करून ख्रिश्चन धर्माकडे आकृष्ट होऊ लागला. सैनिक शहाणे होतील, डोईजड होतील, उठाव करतील म्हणून सैनिकांसाठीचे सक्तीचे शिक्षणच सरकारने बंद केले. जरी सार्वत्रिक शिक्षणाचे धोरण सरकारने आखले होते, तरी सरकारचा मुख्य हेतू कोट्यवधी हिंदी जनतेचा उद्धार करण्यापेक्षा साम्राज्याचे संवर्धन आणि दृढीकरण करण्याचाच अधिक होता. सरकारचे मोठमोठाले अधिकारी खालच्या वर्गातील जनतेच्या शिक्षणाला अनुकूल नव्हते. कनिष्ठ वर्गात शिक्षणाचा प्रसार करण्याचे प्रयत्न अयशस्वी व्हावेत, यासाठी ते बुद्धिपुरस्सर खटपटत असत.'

इंग्रजी भाषा आत्मसात केल्याने हिंदुस्थानातील युवकांची वैचारिक जडणघडण होऊन सांस्कृतिक आदान-प्रदान होऊ लागले. पाश्चात्य जगातील विचारवंतांचा प्रभाव येथील तरुणांवर पडला. कर्मकांड, अंधश्रद्धा, रूढी-परंपरा, पुरोहितशाही, सती प्रथा या हजारो वर्षे चालत आलेल्या चालीरीती निरर्थक वाटू लागल्या.

भारतीय नवशैक्षणिक क्रांतीचे जनक : भारतात इंग्रजी सत्ता स्थिर झाल्यावर आणि इंग्रजी शिक्षणाच्या सार्वत्रिक प्रचाराने, आरोग्य सेवा, इंग्रजी भाषा, सत्ता, नोकरी, पैसा, टापटीप राहणीमानामुळे तरुण वर्ग ख्रिस्ती धर्माकडे आकर्षिला जाऊ लागला. शिक्षणाने मनुष्याला सत्यासत्याचा आणि आपल्या हिताचा विचार करण्याची बुद्धी प्राप्त होते. स्वाभिमानाची जाणीव जागृत होते. आधुनिक पाश्चात्य पद्धतीच्या शिक्षणाचा

शूद्रातिशूद्र झाल्याने शिक्षण क्षेत्रात एक नवी क्रांती घडून आली. ब्रिटिशांनी सुरु केलेले शिक्षण फक्त उच्चवर्णीयांच्याच हिताचे होते. तरीही शिक्षण हे सुधारणेचे मूळ असले. या विचाराने प्रेरित झालेल्या समाजसुधारकांनी हजारो वर्षांची परंपरा मोडीत काढली. महात्मा फुले, डॉ. बाबासाहेब आंबेडकर, आगरकर, महर्षी कर्वे, शाहू छत्रपती इत्यादी राजे-समाजसुधारकांनी परिवर्तनाच्या हेतूने शूद्रातिशूद्र व स्त्रिया यांना नाकारले होते शिक्षण देण्यास सुरवात केली. जोतिरावांनी धार्मिक, सामाजिक, शैक्षणिक, आर्थिक विषयांवर बंडखोर व मार्मिक, विवेकनिष्ठ विचार मांडलेले आहेत. या आधुनिक विचारांनी नवे तत्त्वज्ञान भारतात उदयास आले. जोतिबांनी जन्मसिद्ध श्रेष्ठत्वाला कडाडून विरोध केला. तत्कालीन समाजव्यवस्थेतील जनतेच्या दारिद्र्याचे, दुःखाचे मूळ अज्ञान असल्याचे शोधून काढले.

विद्येविना मति गेली। मतिविना नीति गेली ।।
नीतिविना गति गेली। गतिविना वित्त गेले ।।
वित्तविना शूद्र खचले। इतके अनर्थ एका अविद्येने केले ।।

शिक्षणातून नवा संघर्षप्रवृत्त माणूस निर्माण व्हावा आणि नवा समाज घडावा हीच जोतिबांची इच्छा होती. महात्मा जोतिबा फुले यांचे शैक्षणिक विचार हे स्वातंत्र्य, समता आणि बंधुभाव या त्रयीवर नितांत भरवसा ठेवणारे होते. सामाजिक विषमतेच्या विरोधात आवाज उठविणारे म. फुले हे महापुरुष होते. महात्मा फुले महाराष्ट्राचे मार्टिन ल्यूथर म्हणून ओळखले जातात. ते मानवतावादी विचाराचे होते. नवशैक्षणिक प्रणालीला तत्कालीन सनातनी गुंडांनी विरोध केला.या नवस्थित्यंतराचा बीमोड केला. जोतिबा बंडखोर होते. त्यांनी धर्म आणि समाजाची पर्वा केली नाही. शैक्षणिक क्षेत्रात जोतिबाचा त्याग आणि कष्टाचा बोलबाला झाला. नवशैक्षणिक विचारप्रणालीचा पाया जोतिबांनी घातला. जात, धर्म, लिंग, शारीरिक अपंगत्व यांचा अडसर दूर करून शिक्षण हे तळागाळातील शेवटच्या घटकापर्यंत पोहचले पाहिजे हा त्यांचा विचार होता. शिक्षण परिवर्तनाचे माध्यम असून ते सार्वत्रिक असावे हा क्रांतिकारी विचार जोतिबांनी सर्वप्रथम मांडला व कृतीत आणला. जोतिबांच्या मते, "शिक्षणाच्या अभावी माणूस नैतिक-बौद्धिकदृष्ट्या पंगू तर होतोच, शिवाय व्यावहारिक क्षेत्रांतही त्याची पीछेहाट होते. जे शिकत नाहीत ते दुसऱ्याच्या ओंजळीने पाणी पितात, स्वतः विचार करु शकत नाही. जीवनाचा सर्वांगीण आस्वाद घेऊ शकत नाहीत. त्यांचा आत्मविश्वास, ध्येयवाद, पुढाकारवृत्ती, आत्मनिर्भरता व चिकित्सकवृत्ती त्यांना सोडून जाते. कर्तृत्वाची नवनवी क्षेत्रे ते पादाक्रांत करु शकत नाहीत. हे शिक्षित उच्चवर्णीयांच्या पथ्यावर पडते. धार्मिक

कार्यकांड, आर्थिक शोषण आणि सामाजिक उपेक्षा अशिक्षित कष्टकऱ्यांच्या डोक्यावर ते मुशाल थोपू शकतात. शिक्षणाच्या अभावी सामान्य माणसांची अवस्था ते पुच्छविहीन पशूप्रमाणे करुन सोडतात.[५]

स्त्री शिक्षणाची पुनर्तपेठ : १९ व्या शतकात ब्राह्मण वर्गाशिवाय इतर सर्व समाज निरक्षरच होता. ही मक्तेदारी संपुष्टात आणण्यासाठी सर्वप्रथम नेटिव्ह फिमेल स्कूल, पुणेची स्थापना केली. भेदाभेद, उच्च-नीच, स्पृशास्पृश्य, सोवळेओवळे यांसारख्या कर्मठ कल्पनांवर हल्ला चढविला. स्त्री-शूद्रातिशूद्राला गुलामगिरीतून मुक्त करण्यासाठी त्यांना शिक्षणातूनच आपल्या हक्काचे भान प्राप्त होईल यावर जोतिरावांचा ठाम विश्वास होता. त्यांनी हिंदू स्त्रीला तिच्या प्राचीन गुलामगिरीतून मुक्त करण्याचा निर्धार केला. शास्त्राप्रमाणे शूद्र आणि स्त्रीला विद्येचा अधिकार नव्हता. त्यांना शिक्षण देणे म्हणजे देव,धर्म व समाजाविरुद्ध बंड करणे होते. स्त्रिया शिकू लागल्या तर त्या आकारांच्या आळ्या बनून जेवताना घरातील पुरुषांच्या ताटात पडतात, शिकलेल्या विवाहित मुली लवकर विधवा होतात असा धार्मिक पूर्वग्रह होता. सनातनी वर्गाचा रोष पत्करून त्यांनी १८४८ मध्ये पुण्यात भिडेवाड्यात मुलींची पहिली शाळा काढली. स्वतंत्रपणे मुलींची शाळा काढणारे ते पहिले भारतीय होत. आधी सावित्रीबाई यांना शिकवले साक्षर केले. स्त्रीशिक्षणाच्या कार्याची सुरुवात महात्मा फुले यांनी अशी आपल्या घरातूनच केली. ह्या शाळेत सर्व जातीच्या मुली होत्या. पण तरी देखील सावित्रीबाई यांनी आपल्या कार्यात माघार घेतली नाही. शाळेतील अशिक्षित मुलींना शिकवण्याचे, साक्षर करण्याचे काम सावित्रीबाई करत होत्या. सावित्रीला पहिली स्त्री शिक्षिका बनवले.सत्यशोधक दिनकरराव जवळकर जोतिबांच्या कार्याचा गौरव करताना म्हणतात की, 'जोतिरावांनी केलेल्या श्रमाचे फळ आज पुण्याच्या हुजूरपागेतील गर्ल्स हायस्कूलमध्ये पहावयास सापडत आहे व हजारो भटांच्या लेकी-सुना त्यातून 'मनुष्य' होऊन बाहेर पडत आहेत. जोतिरावांनी नेट धरला नसता तर 'ब्राह्मण जात रानटी आहे' म्हणून 'ब्राह्मणवाडा' गावाच्या दूर बसविण्याची पाळी आली असती. ही शाळा स्थापन करतेवेळी जोतिरावांचे वय अवघे २१ वर्षांचे होते. ६ वर्षाखाली 'सत्यशोधक' म्हणवून घ्यायला मोठे मी मी म्हणवणारे भीत होते; पण पाऊणशे वर्षांपूर्वी हा २१ वर्षांचा माळ्याचा मुलगा जगावरील गुलामांची खडकाळ हृदये, आपल्या थोर पुण्याईचे बीजारोपण करुन बगीच्याची बहार आणावयास सिद्ध झाला.[६]

प्राथमिक शिक्षण मोफत आणि सक्तीचे: लॉर्ड रिपन या उदारमतवादी व्हाइसरॉयच्या कारकिर्दीत भारतातील शिक्षण समस्येची पाहणी व उपाययोजना

सुचविण्यासाठी सर विलियम हंटर याच्या अध्यक्षतेखाली एक शिक्षण आयोग नेमला होता. त्यामध्ये वीसपैकी आठ सभासद भारतीय होते. या आयोगाने प्राथमिक शिक्षण, मागासलेल्या आदिवासी जाती-जमातींच्या शिक्षणाची शिफारस केली. त्यामध्ये महात्मा फुलेंनी आपल्या निवेदनात 'किमान १२ वर्षांपर्यंत प्राथमिक शिक्षण सक्तीचे असावे' असे सुचविले होते. हंटर आयोगाने मात्र 'प्राथमिक शिक्षण सक्तीचे असावे' अशी शिफारस केलेली नाही. लोकल सेस फंडापैकी निम्याहून अधिक भाग प्राथमिक शिक्षणावर खर्च करावा. शिक्षकाचे वेतन उदरनिर्वाहास पुरेसे असावे, प्राथमिक शाळांची संख्या वाढवावी. शिक्षक प्रशिक्षित असावा, प्राथमिक शिक्षण प्राप्त करणे हा प्रत्येक बालकाचा अधिकार आहे. त्यामुळे हे प्रत्येक बालकास मिळायलाच हवे यासाठी प्राथमिक शिक्षण सक्तीचे अणि मोफत करण्यात ह्या विचारांचा पुरस्कार महात्मा फुले यांनी केला. आज स्वातंत्र्योत्तर काळात सरकारने प्राथमिक शिक्षण मोफत आणि सक्तीचे केले आहे. त्याचे बीज दूरदृष्टी लाभलेल्या जोतिबांच्या विचारधारेत दिसून येते. भारतामध्ये प्राथमिक शिक्षण मोफत अणि सक्तीचे करण्यात यावे हा विचार मांडणारे महात्मा फुले पहिले भारतीय होत.

शिक्षणात त्रिभाषा सूत्राचा अवलंबः त्रिभाषा सूत्रास जरी आजच्या कालावधीत मान्यता दिलेली असली तरी १९ व्या शतकातच म. फुले यांनी त्रिभाषा सूत्राचा अवलंब शिक्षणात करावा यावर भर दिला होता. मराठी (मातृभाषा), इंग्रजी (परकीय भाषा) आणि हिंदी (राष्ट्रभाषा) या भाषा सूत्रांचा शिक्षणात वापर करून नवीन तरबेज, कौशल्यपूर्ण, व्यक्तिमत्त्व विकासावर आधारित विद्यार्थीवर्ग घडविणे हेच ध्येय होते.

राष्ट्र निर्माणासाठी शूद्रांना शिक्षण : जोतिबांचे शैक्षणिक कार्य म्हणजे हिंदू धर्मावर हल्लाच होता. महारमांगांसाठी शाळा काढून सावित्रीला शिक्षिका म्हणून नेमणे ही अपवित्र, अपूर्व गोष्ट ठरली. बहुजनांना शिक्षण देऊन आपल्या हक्कांसाठी व आंतरिक गुणांच्या स्वउन्नतीसाठी जागृत करणे हा प्रथम उद्देश होता. सामाजिक विषमतेचे मूळ असलेल्या वर्णव्यवस्था व जातिव्यवस्था जोतिबांना मान्य नव्हती. महार, मांग आदि लोकांस अध्यापन करणाऱ्या मंडळींच्या १८५३ च्या सभेचा वृतांतात लिहिले आहे की, 'या देशात अज्ञान हा दुष्ट रोग आहे. यास औषधयोजना करून घालवावा असे कोणाच्या मनात आल्यास मध्ये जातिभेद, भाषाभेद इत्यादी अडचणी येतात म्हणून यास काढण्यास कोणी धजावत नाही. आता सारेच लोक दुखांत पडतील पाहून त्यातून कोणाचे शांतवन आधी करावे याची भ्रांती पडते. परंतु नीट विचार करून पाहिले असता कोणासही सहाय्य

न करिता उगीच बसावे हे उचीत नसावे. फार दुःख ज्यावर असेल त्याचा बंदोबस्त प्रथम करावा. जातिभेदामुळे अनिवार्य दुःखे महार, मांग इत्यादी लोकांस सोसावी लागतात. पाणी सर्व लोकांच्या जगण्यास मुख्य कारण म्हणूनच त्यास संस्कृत भाषेत जीवन असे म्हणतात. ते देखील त्यास भिक्षा घातल्याप्रमाणे उंच जातींनी घातल्याखेरीज मिळत नाही. मग आवांतर पदार्थ तर कोठून ? याजकरिता या लोकांची दाद विद्याद्वारानेच लागेल असे मनात वागवून यांसच प्रथम शिकविण्याची योजना करणे ही गोष्ट उत्तम आहे असे मला वाटते.[७]

शिष्यवृत्ती व वसतिगृहांची सोय: जोतिबांच्या शैक्षणिक कार्याचा बोलबाला झाल्याने पुणे ग्रामीण परिसर, ठाणे, मुंबई भागातील विद्यार्थ्यांना पुण्यात पाठविण्याची इच्छा होऊ लागली. त्यासाठी निवासव्यवस्था महत्त्वाची होती. फुलेंनी सुशिक्षणगृह नावाचे बोर्डिंग काढले. सावित्रीबाई त्याची काळजी घेत. गरीब मुले निशुल्क तर श्रीमंतांची मुलांकडून शुल्क मिळत असे. हुशार व गरीब विद्यार्थ्यांना शिष्यवृत्ती देण्याचीही पद्धतीही जोतिबांनी सुरु केली

औद्योगिक व तांत्रिक व्यावसायिक शाळा उभारणे : कोणत्याही समाजाच्या आर्थिक गरजा असतात. यावर आधारितच सामाजिक दर्जा असतो. सर्वसामान्य माणूस शिक्षणाचा केंद्रबिंदू मानून जोतिबांनी मूलगामी, व्यवसायाभिमुख, नैतिक शिक्षणाला प्राधान्य दिले. हंटर आयोगापुढे मांडलेल्या साक्षीत जोतिबांनी सरकारच्या निदर्शनास आणून दिले की, पारंपरिक शिक्षणाबरोबरच ग्रामीण भागात व्यावसायिक, तांत्रिक शिक्षण देणे आवश्यक आहे. कॉलेजातून सरसकट पदव्या घेऊन बाहेर पडणाऱ्या तरुणांना नोकरी मिळणे स्पर्धेचे होईल. त्यावर उपाय म्हणून तांत्रिक व व्यावहारिक शिक्षण देऊन त्याला स्वयंरोजगार उपलब्ध करून स्वयंपूर्ण बनविण्यासाठी प्रयत्न करणे.

शिक्षणप्रणालीत बदल करणे: मेकॉलेच्या 'शिक्षण हे वरच्या वर्गापासून खालच्या वर्गापर्यंत पाझरत आले पाहिजे' (फिल्टर डाऊन थेअरी ऑफ एज्युकेशन) या खलित्यास जोतिबांनी कडाडून विरोध केला. कारकून वर्ग तयार करणाऱ्या शिक्षणप्रणालीला विरोध करून तळागाळातील शेवटच्या घटकाचा सर्वांगीण विकास करणारी शिक्षणप्रणाली त्यांना अभिप्रेत होती. इंग्लंडमध्ये उदारमतवादी धोरणामुळे चर्च, धार्मिक संस्था, सरंजामदारांनी, उच्च वर्गाने गरिबांच्या शिक्षणासाठी पुढाकार घेतला. भारताची परिस्थिती विपरीत होती. ज्ञानाच्या सार्वत्रिकीकरणाला पुरोहित ब्राह्मणशाहीचा विरोध होता. साहजिकच येथे शिक्षण हे उच्चवर्गाची मक्तेदारी होती. पुण्यातील तत्कालीन

विद्वान महादेव मोरेश्वर कुटे आयोगासमोर आपले गाऱ्हाणे मांडताना म्हणतात की, 'महारो-अछूतो को पाठशालाओं में प्रवेश देने की माँग महारो-अछूतों ने नही की है, यह तो भावुक अंग्रेज अधिकारियों और देशी अव्यवहारी सुधारकों का खोखला आंदोलन है."

भारतीय शहरी भागात ठराविक जातिपंथाचा एक छोटासा गट तयार झाला. गावगाड्यातील बहुजन वर्ग मात्र शिक्षणापासून वंचितच राहिला. तत्कालीन तिजोरीत जमा होणारा शेतसारा शेतकऱ्यांकडून येत असल्याने फुलेंच्या मते प्रथम खालच्या वर्गातील लोकांना शिक्षण देऊन नंतर वरच्या वर्गातील लोकांना शिक्षण दयावे. 'आधी पाया मग कळस' अशा पद्धतीने शिक्षणप्रणाली असण्यावर म. फुलेंचा आग्रह होता. प्रथम उपेक्षितांना शिक्षण नंतर अपेक्षितांना शिक्षण' हे सूत्र अंमलात आणावे, यावर भर देण्यात आला.

समारोप : पाश्चिमात्य शिक्षणातून स्वातंत्र्य, समता, बंधुता या मूल्यांची ओळख भारतीयांना झाली. पारंपरिक व धार्मिक शिक्षण मागे पडून धर्मनिरपेक्ष शिक्षणाचा विकास झाला. इंग्रजी शिक्षण घेतलेल्या भारतीयांनी समाजातील अनिष्ट प्रथा नष्ट करून समाजजागृती निर्माण करून समाज सुधारण्याचे कार्य केले. महात्मा फुलेंनी भारतात पुणे येथे स्वतंत्रपणे मुलींची पहिली शाळा काढून स्त्री शिक्षणाची मुहूर्तमेढ रोवली. तत्कालीन समाजव्यवस्थेतील जनतेच्या दारिद्र्याचे, दुःखाचे मूळ अज्ञान असल्याचे शोधून काढले. सर्व थोर शिक्षणतज्ज्ञांनी, विचारवंतांनी, समाजसुधारकांनी सामाजिक, शैक्षणिक विचारांचे महत्त्व सांगून सर्वसामान्य जनतेला जगण्याची दशा आणि दिशा देण्याची कामगिरी केली. महात्मा फुलेंचे शैक्षणिक विचार प्रासंगिक आहेत. ते येणाऱ्या भविष्यकालीन समस्यांचे निराकरण व उत्तम दिशादर्शक आहेत.भारतामध्ये प्राथमिक शिक्षण मोफत आणि सक्तीचे करण्यात यावे हा विचार मांडणारे महात्मा फुले पहिले भारतीय होत. शिक्षणातील बदलत्या प्रवाहांचा विचार करता महात्मा फुलेंनी भारतीय शिक्षणप्रणालीत मन्वंतर घडवून आणले.

संदर्भग्रंथ :

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उत्सव

प्रकाशक : इतिहासाचार्य वि.का.राजवाडे संशोधन मंडळ, धुळे

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।। संशोधक।।

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* प्रकाशक *

श्री. संजय मुंदडा

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अक्षरजुळणी : सौ. सीमा शिंत्रे, पुणे.

टीप : या नियतकालिकेतील लेखकांच्या विचारांशी मंडळ व शासन सहमत असेलच असे नाही.

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५८) आत्मचरित्र – आत्मकथनांचे माध्यमांतर
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५९) आदिवासी नियतकालिकांचे मराठी साहित्यातील योगदान
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Vikasbahule@gmail.com चलभाष-९७६४२२३३२०

प्रास्ताविक :

स्वातंत्र्योत्तर शैक्षणिक क्रांतीने तळागाळातील माणूस बोलता झाला. आपल्या जीवनात काहीतरी सांगण्यासारखे आहे याचे आत्मभान त्याला शिक्षणामुळे प्राप्त झाले. आपले जीवनानुभव तो साहित्यामध्ये मांडू लागला. सामान्य माणूस, त्याची बोली, त्याचा परिसर साहित्याच्या केंद्रस्थानी येऊ लागला. समता, स्वातंत्र्य, न्याय आणि स्वाभिमान या मानवी मूल्यांमुळे राष्ट्र, समाज आणि व्यक्तीच्या जीवनात क्रांतिकारक बदल झाला. विषमतेमुळे उपेक्षित समाजामध्ये वेदना आणि विद्रोहाने पेट घेतला. १९६० नंतर उदयाला आलेल्या वाङ्मयीन प्रवाहांमध्ये दलित, ग्रामीण, स्त्रीवादी, ख्रिस्ती, मुस्लिम, आणि आदिवासी साहित्याचे प्रवाह क्रमाक्रमाने मराठी साहित्याला येऊन मिळाले. या प्रवाहांना लाभलेले सामाजिक समर्थन पाहता मराठी साहित्याची श्रीमंती लक्षात येते. मराठीत नवी विचारधारा, नवे लेखक, नवे लेखन उदयास आले. स्वातंत्र्योत्तरकाळात दलित, आदिवासी, भटक्यांच्या समस्यांना न्याय देण्यासाठी आदिवासी, दलित नियतकालिके सुरु झाली. शिक्षणाचा प्रसार, वाचन लेखनाची आवड, छापखाने या सर्व घटकांचा प्रभाव म्हणून नियतकालिकाच्या उदयाला व प्रसाराला उत्तेजन मिळाले. लोकशिक्षणाबरोबरच समाजात वैचारिक क्रांती घडवून आणण्याचे कार्य नियतकालिकांनी पार पाडले. दलित साहित्याप्रमाणेच नियतकालिकांनी आदिवासी साहित्यलेखनाला सुरुवात करून मराठी साहित्यात नव्याने संस्कृती, मूल्ये, रूढी-परंपरांची भर घातली. त्यामुळे या नियतकालिकांचे योगदान मोलाचे ठरते.

मराठी नियतकालिकांची परंपरा :

प्रबोधन ही मानवी बुद्धी आणि वृत्तीशी निगडीत प्रक्रिया आहे. प्रबोधनातून परिवर्तन अपेक्षित असते. १६ व्या शतकात मुद्रणक्रांती झाल्यामुळेच पाश्चात्य संस्कृती व विचाराने भारतीय प्रबोधनास सुरुवात झाली. लोकशाही शासनव्यवस्था असलेल्या देशांमध्ये वृत्तपत्रे, नियतकालिके ही समाजाची गरज बनू लागली. इंग्रजी राजवटीबरोबर भारतात ज्या कित्येक गोष्टी आल्या त्यात नियतकालिकेही आली. मुद्रणकला ही नियतकालिक सुरु होण्याचे एक साधक कारण बनली. ख्रिस्ती मिशनरी, सनातन विरुद्ध सुधारक या संघर्षात नवविचार तसेच हिंदूविरोधी मत प्रचाराचे खंडन करण्यासाठी नियतकालिकांचा उदय झाला. 'नियमित प्रकाशित होते ते नियतकालिक' असे सर्वसाधारणपणे म्हणता येईल. मराठी साहित्याचे अभ्यासक डॉ. सु. रा. चुनेकर म्हणतात की, ''अभिरुची उत्पन्न करणे आणि त्या अभिरुचीला सातत्याने खाद्य पुरवणे हे नियतकालिकाचे कार्य असते.''[१] मराठी भाषेत नियतकालिकांची परंपरा मोठी आहे. विचारस्वातंत्र्य हाच सामाजिक प्रगतीचा पाया असतो. १९ व्या शतकात इंग्रजी राजवटीत मराठी भाषिकांना इंग्रजी भाषेचा आणि त्यातील विचार, संस्कृती, जीवनमूल्यांचा जवळून परिचय झाला. त्याचा परिणाम म्हणून महाराष्ट्रात प्रबोधनाला सुरुवात झाली. सर्वात प्रथम अभिजनांनी अभिव्यक्त होण्यासाठी वृत्तपत्रे व नियतकालिकांचा वापर सुरु केला. प्रारंभीच्या काळात ज्ञानप्रसार हीच भारतीय नियतकालिकांची प्रेरणा होती. दर्पणकार बाळशास्त्री जांभेकरांनी 'दिग्दर्शन'(१८४०) नावाच्या मासिकाचा पहिला अंक काढून मराठी नियतकालिक युगाचा प्रारंभ केला. पुढे लोकहितवादींची शतपत्रे ज्यामध्ये प्रसिद्ध झालेले 'प्रभाकर' (१८४१), ज्ञानोदय (१८४२), ज्ञानप्रकाश (१८४९), ज्ञानविस्तार (१८६०), सत्यकथा(१९३३), वाङ्मयशोभा (१९३९), हंस (१९४६), साहित्य (१९४७), छंद (१९५४), आलोचना (१९६२) अस्मितादर्श (१९६८),वैखरी (१९६९), मनोरंजन, अभिरुची याच परंपरेतील असंख्य नियतकालिके निघाली. या नियतकालिकांनी अन्य भाषेतील सांस्कृतिक जीवन, कला, परंपरेतील ज्ञानभांडार मराठी भाषेत आणले. शिक्षण, व्यापार, शेती, आरोग्य, क्रीडा, पर्यटन, विज्ञान, चित्रपट, रंगभूमी अशा कितीतरी दैनंदिन विषयांवर नियतकालिके प्रसिद्ध होऊ लागली.

''मनोरंजन, चित्रा, मौज, सत्यकथा, धनुर्धारी, मराठा वैभव, केरळ कोकीळ, रत्नाकर, किर्लोस्कर, स्त्री, मनोहर, वसंत,

हंस, वाङ्मयशोभा, सह्याद्री, समाजस्वास्थ अशी नियतकालिके निघाली. त्यातील 'किर्लोस्कर' मासिकांनी फार महत्त्वाची कामगिरी केली आहे. सामाजिक, धार्मिक, आर्थिक, औद्योगिक सर्व क्षेत्रातील अत्यंत पुरोगामी लेख छापावयाचे, असा त्याचा बाणा होता. डॉ. केतकर, सावरकर, फडके अशा थोर लेखकांचे लेख अनेक वर्षे किर्लोस्करांनी छापले. स्त्रीजीवनसुधारणेविषयी त्यांचा कटाक्ष होता. अजूनही 'किर्लोस्कर' व 'स्त्री' या मासिकांनी आपली कीर्ती टिकवून धरली आहे.''[३] मराठी साहित्याच्या इतिहासात अजरामर झालेल्या साहित्यकृती ह्या नियतकालिका-तूच प्रसिद्ध झाल्याचे दिसून येते. स्वातंत्र्योत्तर काळात प्रसिद्धीच्या कालावधीनुसार साप्ताहिके, पाक्षिके, मासिके, त्रैमासिकांच्या संख्येत भर पडली आहे. मासिकापेक्षा जास्त कालावधीत प्रसिद्ध होणारी नियतकालिके ही वैचारिक प्रणालीशी निगडीत आहेत. नव्या कल्पना, संशोधन, सामाजिक, राजकीय, शैक्षणिक समस्या याविषयीची क्षमता असलेले लेखक व वाचक इथे कार्यरत असल्याचे दिसते. नियतकालिकांच्या स्वरूपावरून जसे, साप्ताहिक, पाक्षिक, मासिक, त्रैमासिक असे तर विषयावरून साहित्य, संशोधन, समीक्षेला वाहिलेली नियतकालिके असे प्रकार पडतात. नियतकालिकांच्या उद्दिष्टांवरून त्यांच्या कार्याचे स्वरूप लक्षात येते.

आदिवासी नियतकालिकांची वाटचाल आणि योगदान :नागर संस्कृतीपासून दूर व अलिप्त राहिलेले संबंधित प्रदेशातील मूळचे रहिवासी म्हणजे आदिवासी. पृथ्वीवरचा पहिला मानव म्हणून आदिवासींची ओळख आहे. अनुसूचीत जमातींना आदिवासी, मूळवासी, आदिम, आदिम जमाती व टोळ्या, वन्यजाती व गिरीजन अशी वेगवेगळी नावे दिली आहेत. १९६० नंतरच्या परिवर्तनवादी साहित्यप्रवाहांनी मराठी साहित्याला समृद्ध केले. आदिवासी साहित्यप्रवाह खऱ्या अर्थाने मराठी अस्मिता, मराठी माती व आदिमता प्राप्त जनसमूहाचा आक्रोश आहे. शेकडो वर्षापासून अडलेल्या, नाडलेल्या समाजाचा तो फुत्कार आहे. आदिम दुःख, यातना व भावविश्वाशी निगडीत हे साहित्य आहे. ''आदिवासी साहित्य हे वनसंस्कृतीचे नातलग साहित्य आहे. रानावनातील वंचितांचे ते साहित्य आहे. ज्यांच्या प्रश्नांना भूतकाळाने कधी उत्तरेच दिली नाहीत, अशा दुर्लक्षितांचे साहित्य आहे.''[३] जुन्या धर्मसंकल्पना, मानदंड, अर्थकारण, जुनी जीवनमूल्ये, विषमता, जाती, पंथ, दैववाद या सर्व घटकांना नवजाणीव आली. उपेक्षित जनतेला त्यामुळे एक व्यासपीठ उपलब्ध झाले. साहित्य, चळवळ, प्रसारमाध्यमे, संस्था आणि संघटना ह्यांच्या माध्यमातून प्रबोधनाचा विचार प्रभावीपणे मांडता येतो. साहित्याची चळवळ ही माणसाला स्वत्वाची जाणीव करून देते. नियतकालिक हा समाजाचा आरसा असते. समाजातील वास्तवदर्शी घटना, घडामोडींची प्रत्यक्ष माहिती देण्याचे काम नियतकालिके करतात. आदिवासी नियतकालिकांचा विचार करता, 'मधुवन', 'गोंडवाना', 'आदिवासी टाईम्स', 'फडकी', 'ढोल', 'हाकारा', 'आदिवासी मीना', 'बिरसा वार्ता', 'धवलेरी', 'वनवार्ता', 'सह्याद्री', 'आदिवासी संशोधनपत्रिका', 'आदिवासी भारत', 'तारपा', 'शब्दमशाल', 'कालतरंग', 'जव्हार वार्ताहर', 'जयसेवा' यांसारखी नियतकालिके सुरु झाली. आत्मभान प्राप्त झालेल्या या नवसाहित्यिकांनी सर्वप्रथम नियतकालिकातून अभिव्यक्त होण्याला सुरुवात केली. या नियतकालिकांनी सर्वप्रथम आदिवासींचे सामाजिक, राजकीय, आर्थिक प्रश्न, दुःख, रूढी, परंपरा मांडण्याचा प्रयत्न केला. आदिवासींचा विषय शेकडो वर्षांपासून कधी साहित्यात आलाच नव्हता. आदिवासी नियतकालिकांनी आदिवासी समस्या, विकास आणि सांस्कृतिक, राजकीय अंगाने लेखन केले आहे.

१९६० नंतर नियतकालिकांनी वाङ्मययीन क्षेत्र समृद्ध केले. पारंपरिक साहित्याला छेद देत नवसाहित्याला व्यासपीठ निर्माण करून दिले. तळागाळातील समाजाच्या ज्वलंत प्रश्नांना प्रसिद्धी दिली. विविध साहित्यप्रकारासाठी लेखन होऊ लागले. कथा, कविता, समीक्षा, वैचारिक विषयांना केंद्रस्थानी मानून नवलेखक लिहिते झाले. साठोत्तरी साहित्याप्रवाहांनी आपल्या जीवनजाणिवा सर्वप्रथम नियतकालिकांतून मांडायला सुरुवात केली. त्याचाच परिणाम म्हणून सामाजिक, सांस्कृतिक आणि राजकीय विषय साहित्यरूपाने नियतकालिकात येऊ लागले. समाजातील सर्व स्थरातील लोकांचे दुःख, समस्या, पिळवणूक याच नियतकालिकांनी साहित्यातून मांडली. नव्या लिहित्या पिढीचे आधुनिक विचार समाजात रुजू लागले. या साहित्याने मनोरंजनाला महत्त्व न देता अभिव्यक्तीला प्राधान्य दिले. आदिवासी साहित्यिकांचे साहित्य पुस्तकरूपाने प्रसिद्ध होण्याच्या अगोदर नवशिक्षित आदिवासी तरुणांनी लिहिलेले कथा, काव्य, एकांकिका, स्फुटलेखन हे नियतकालिकांनीच प्रसिद्ध केले. हीच खऱ्या अर्थाने आदिवासी साहित्याची सुरुवात म्हणावी लागेल. सर्व साहित्य चळवळी जीवनाच्या परिवर्तनाची मागणी करतात. आमचे साहित्य आम्हीच लिहू शकतो याच भूमिकेतून नियतकालिकात साहित्य लेखन झालेले आहे. आदिवासी नियतकालिकांचा विचार करताना खालील काही निवडक आदिवासी नियतकालिकांची वाटचाल व कामगिरी उल्लेखनीय ठरते.

मधुबन (१९५१) : गोंडवन साहित्य संस्थेचे मुखपत्र असलेले मधुबन हे मासिक १५ ऑगस्ट १९५१ रोजी श्री.तु.ना. काटकर यांनी सुरु केले. त्यांनी तत्कालीन कालखंडामध्ये स्त्री

विषमक सदे चालवून पुरुषप्रधान संस्कृतीचा रोष पत्करला. आदिवासी गोंडसह गोंच्या आदिवासी कथा क्रमशः प्रकाशित करणारे हे पहिले मासिक होय. गोंडांची मूळकथा, वृत्तान्त सह गोंडांची कथा अशा कथामाला या मासिकात प्रसिद्ध होत. कवितेमध्ये मराठीचंच नवी, देवळात, साक्षात्कार, गाणारा पक्षी, मूलनिवासी, तुम्हाले काय लाज?, मोहमयी, वशिष्याचा खेळ, स्त्री झोळी फाटकी आहे विषय हाताळले आहेत. ललित लेखनाबरोबरच काही वैचारिक लेख प्रसिद्ध झाले. आमच्या भूमीत आमची उपाशी कशे?, दुष्काळात तेरावा महिना, गोंड नव्हे लोढणे, आमच्या योजना कुणाच्या घशात? असे अग्रलेख प्रसिद्ध होत.

आदिवासी संशोधन पत्रिका (१९७९) : गोविंद गारे यांनी १९७९ मध्ये पुणे येथून सुरु केले. ते सहा महिन्यातून एकदा निघे. आदिवासींचे प्रश्न सोडविणे हाच मुख्य उद्देश हे पत्र सुरु करण्यामागचा होता. आदिवासी जमातीच्या समस्या, शिक्षण, आदिवासी साहित्य, कला व सांस्कृतिक जीवनावर प्रश्न व निबोजन असा संशोधनात्मक कार्य करणारे पत्र आहे. बोगस आदिवासी, आरक्षण बचाव, स्त्रियांचा प्रश्न, अंधश्रद्धा, चालीरीती, पारंपरिक प्रथा यांच्यामधील दोष शोधण्याचा प्रयत्न आदिवासी संशोधन पत्रिकेने केला. आदिवासी वृत्ते, संस्कृती आणि पुस्तक परीक्षणे आदिवासी संशोधन पत्रिकेने नियमितपणे प्रसिद्ध केली.

हाकारा (१९८०) : १९८० साली 'हाकारा' या त्रैमासिक नियतकालिकाची सुरुवात झाली. या नियतकालिकाने सर्वप्रथम आदिवासी कला, संस्कृती, परंपरा, लोकजीवन, राजकीय, आर्थिक प्रश्नांना प्रकाशात आणले. 'महाराष्ट्र मानव विज्ञान परिषदेने' हे नियतकालिक सुरु करताना हाकाराने नवोदित आदिवासी लेखक, कवी, कार्यकर्ते यांना आपल्या समाज, परंपरा, इतिहास लेखनाचे आवाहान केले. त्यामुळे आदिवासींच्या वेदना, दुःख, संस्कृती आणि साहित्याला हाकाराने आपल्या अंकात मध्यवर्ती स्थान दिले आहे. आदिवासी लेखकांच्या कविता, कथा, समीक्षात्मक लेखन हाकारात आले आहे. आदिवासी कवींची कविता अस्सल आदिमत्त्व प्रकट करते व ती विविध भाषिक सौंदर्याने नटलेली आहे. आदिवासी कविता ह्या राजकीय, सामाजिक, निसर्ग, स्त्री, संस्कृती या आशयसूत्रात मांडल्या आहेत. जागतिकीकरणाच्या कविता, स्त्रीजीवन, आंबेडकरी विचारप्रेरणा, आदिवासी ऐक्याची भूमिका, सामाजिक समस्या या घटकांचा परामर्श आदिवासी कवितेत घेता येतो. हाकारा अंकामधून आलेल्या कवितातून प्रस्थापित व्यवस्थेला जाब विचारण्याचे काम आदिवासी कविता करताना दिसते. आदिवासी कवितांमधून थोर पुरुष, समाजसेवक, देशभक्त, संस्कृती, इतिहास, समाज, निसर्ग, स्त्रियांचे गौरवीकरण करण्यात आले आहे. सीताराम सूर्या, बाबूराव हे. शेडमाके, राणी दुर्गावती, अनुताई वाघ यांच्या कार्याचा गौरव करण्यात आला आहे. 'विरसामुंडा' या आपल्या कवितेत वर्तमानात आदिम विरसाला पुन्हा आदिम मार्गाच्या कुशीत जन्म घेण्याचे आवाहन करते. इथे मृत्यू अन्यायाला पुन्हा जीव देणे आहे. प्रस्थापितांचे अत्याचार सहन होत नाही. त्यामुळे क्रांतीच्या नव्या ज्वाला पेटून पुन्हा आमच्यातला जोश जागवायला ये. दीपक्कपाती सहदेव सोहाच्या फुलासारखे हिरवे जगाचा आदिवासी जीवनाची नवीन पहाट होऊन ये असा आशावाद, यातना कवयित्री करते आहे. उषाकिरण आत्राम म्हणतात की,

अरे विरसा तू पुन्हा एकदा ये रे बाबा
आमचा आदिम मार्गाच्या कुशीत जन्मायला
पुन्हा एकदा होवू दे 'उलगुलान'!'

आदिवासी भारत (१९८४) : आदिवासी भारत या नियतकालिकाची सुरुवात १९८४ मध्ये वर्धा, वसतमाळ येथून राजाभाऊ राजगडकर यांनी केली. वैचारिक लेखनात 'प्राणहिताचा लिंक शहीदवीर बाबूराव शेडमाके', 'आपण बंडखोरांने वारसदार होऊ या', 'आदीच या देशाचे मूलनिवासी का?' कवितालेखनात 'आक्रोश', 'क्रोध', 'भीती', यांसारख्या विद्रोही कविता 'विषमतेच्या चक्रव्यूही' हा तुलसाय विशायक आणि 'आक्रोश' ही उषाकिरण आत्राम कविता प्रसिद्ध झाली.

महाराष्ट्र आदिवासी दर्शन (१९८५) : १ मे १९८५ रोजी किसन साबळे यांनी पुणे धनकवडी येथून पहिला अंक प्रसिद्ध केला. 'आदिवासी संस्कृती आणि शिक्षण', 'आदिवासी एक निराळा विचार', 'आदिवासींचे फलित', 'रानातील विस्मृतीतला रानमेवा', 'आदिवासी गीते' प्रसिद्ध करून सर्वांचविचारवंतांना वैचारिक व्यासपीठ निर्माण दिले. आदिवासी समाजाला जागृत करण्याचे कार्य या नियतकालिकाने केले.

जव्हार वार्ताहर(१९९६) : १३ मे १९९६ मध्ये चित्रांगण घोलपने जव्हार येथून प्रसिद्ध केले. कथा साहित्य मोठ्या प्रमाणावर प्रसिद्ध केले. त्यामध्ये 'गोरी', 'कळतनकळत', 'कर्तव्य', 'कसबंदीची जाळी', 'निर्णय'यांसारखे सामाजिक कथालेखन प्रसिद्ध केले.

ढोल (१९९७) : आदिवासींच्या विविध बोलींचा संशोधनात्मक अभ्यास करून त्याविषयी लिहिले जावे म्हणून डॉ. गणेश देवी यांनी वडोदरा येथून १९९७ मध्ये सुरु केले. अहिराणी, देहवाली, पावरी भिली, राठवी भिली, कुकणा डांगी, डुंगरी भिली, पंचमहाली भिली आणि भांतु अशा एकूण आठ बोलींमध्ये ढोल प्रसिध्द करण्यात येते. पुढे १९९९-२००० ला ते मराठीतून प्रसिद्ध होऊ लागले. 'ढोल' नावाचं

एकमेव विशिष्ट वाद्य संपूर्ण भारतभर सर्वत्र प्रचलित आहे. या साधारण त्रिमितकालिकाचे नाव 'ढोल' देण्यात आले. प्रत्येक अंकातून लोकसंस्कृती, लोकपरंपरा, लोकजीवन, आदिवासी जीवन जाणिवा, आदिवासी बोलीभाषा, लोकभाषा, लोककला- आदिवासी कला, लोकवाङ्मय, लोकदैवते, लोकश्रध्दा, आदिवासी चित्र- शिल्प, लोकशिक्षण आदींना प्राधान्य देत. प्रत्येक अंकात अशा विशिष्ट गोष्टींवर लक्ष केंद्रित करून भर देण्यात आला. या बरोबरच आदिवासी लोकजीवन, आदिवासी कथा, व्यथा, आदिवासी संस्कृती, आदिवासींनी जमीन, त्यांचे मालकीपण, आदिवासींचं शिक्षण आणि आदिवासींसाठीचे कायदे यांचाही विचार अंकात मांडण्यात आला. 'ढोल'चे स्वरूप जाणीवपूर्वक कायम सांस्कृतिक, धार्मिक, सामाजिक, शैक्षणिक आणि लोकशिक्षण घडवणारं असंच होतं.

वैचारिक लेखनातून आदिवासी जमातीचा इतिहास मांडला आहे. जसे. 'सातपुड्यातील भिल्ल'. त्याचबरोबर कणसरीची कथा, पिठोऱ्याची कथा, बैलाची कथा, ढोल जन्माची कथा, दाभचे राजे, घुडान कहाणी, तवर(दारू) काढायचे दिस ह्या कथा आल्या आहेत. कवितेमध्ये होळी गीत, ढोल गीत, लग्न प्रसंगाची गीते, नमन गीते, भातलावणी, खुरपणी, कापणीप्रसंगी गायली जाणारी श्रमगीते प्रसिद्ध झाली आहेत. आदिवासी साहित्याचे अभ्यासक, कवी भुजंग मेश्राम म्हणतात की, ''आदिवासी साहित्याच्या संदर्भात लघुपत्रिका आंदोलनाची भूमिका काय होती याबाबत कुठलेही अनुमान काढता येणार नाही वा तर्कही लावता येणार नाही. मात्र 'पहलफ' 'युद्धरत आम आदमीफ किंवा 'अभिव्यक्ती' यांसारख्या नियतकालिकांनी आदिवासी साहित्याला न्याय देण्याचा प्रयत्न अवश्य केला आहे हे नमूद करणे गरजेचे आहे. 'सापेक्ष', 'समझ', 'अभिव्यक्ती', 'वसुधा', 'वर्तमान साहित्य', 'दायित्व-बोध' यांसारख्या मोजक्या नियतकालिकांनी या दिशेने प्रयत्न नक्कीच केलेले आहेत...महाराष्ट्रातदेखील 'जांगोरायतड', 'आदिवासी भारतफ अशी लघुनियतकालिके होती. पुढे ती बंद पडली. आज आम्हाला 'ढोल'हे नियतकालिक खूप चांगल्या पद्धतीने पाहायला मिळते आहे. मला आशा वाटते की, 'ढोल'सारखी अजून नियतकालिके निघावी आणि त्यातून या मानवसमूहांचे प्रतिनिधित्व व्हावे.''[५]

आदिरंग (१९९९) : डॉ. यु.म. पठाण व गोविंद गारे यांनी १९९९ मध्ये नंदुरबार येथून 'आदिरंग' नियतकालिक सुरु केले. काव्यलेखनात 'वनांतर', 'लेणी', 'आदिमाये', 'एकलव्य', 'मोर नाचले', 'संस्कृती' , 'आदिवासी नक्की कोण आहेत', 'गवतभारा', 'भग्नप्रेम', 'तुझ्या आठवणीत चूर आहे' या शीर्षकांतर्गत काव्यलेखन आले आहे. कथालेखनात 'बुलूम', 'भूक', 'शबरी', 'नागपान', 'घोटूल', 'मोर एक उपकार' या वैचारिक लेखनात 'हुंदाकळी एक घातक प्रथा', 'आदिवासी आरक्षण', 'काही बाबू' आणि 'आदिवासी आत्मसन्मानाच्या चळवळीला खिंडी' असे लेख प्रसिद्ध झाले आहेत.

तारपा (२००१): मुंबई येथून शंकर वळी यांनी २००१ मध्ये सुरु केले. आदिवासी समाज आणि आदिवासी एकता परिषद यांचे तारपा मुखपत्र आहे. त्यामध्ये वैचारिक लेखनात आदिवासींची होणारी कुचंबना, शोर व्यक्तींचा, आदिम संस्कृतीचा परिचय, समस्या-उपाय असे वैचारिक लेखन केले आहे. साहित्य चळवळीत जन्म झालेल्या कवितेत 'नर्मदा मेधा आणि आदिवासी', 'कर्म कहाणी', 'अपयश', 'दारूची नशा', 'छोटे जवान' अशा विविध विषयावर कविता प्रसिद्ध झाल्या आहेत. आदिवासी शोर विभूती या सदरात 'भगवान बिरसा मुंडा', 'काळूराम धोंदडे', 'अलकारी' या व्यक्तिरेखांचा परामर्श घेतला आहे. साहित्याबरोबरच बोगस आदिवासींचा शोध घेण्यासाठी जनजागृती केली आहे.

शब्दमशाल (२०००) : शरद पाटील यांनी २००० साली वाडा, जिल्हा ठाणे येथून शब्दमशाल सुरु केले. शहापूरविषयीची इत्यंभूत माहिती संकलित करून 'शहापूर विशेषांक' प्रसिद्ध केला. 'अशी घडली शहापूर नगरी', 'नाट्य क्षेत्रातील उगवता तारा', 'गोर गरीबांचा कैवारी', 'भूतांच्या वाटेवर भूतांचे सन्मान्य', 'चेटकिणीचा फेरा', 'आम्हाला कंगाल बनवून काय साधेल?' यांसारखे वैचारिक लेख प्रसिद्ध केले आहेत.

फडकी(२००७) : आदिवासी साहित्य चळवळीला तोंड फुटले ते उपेक्षेतून, दुर्लक्षातून आणि घुसमटीतून. आदिवासी कार्यकर्ते आपले लेखन वेगवेगळ्या माध्यमांकडे पाठवत असू. पण त्याला दाद मिळत नसे. शेवटी स्वत:चा मंच असावा म्हणून 'फडकी' हे मासिक डिसेंबर २००७ मध्ये प्रसिद्ध केले. आदिवासी साहित्य, संस्कृती आणि अस्मिता जपणारे ते मासिक निरगुडेवाडी (ता. अकोले, जि. अहमदनगर) या सुमारे नव्वद लोकसंख्या असलेल्या आदिवासी, दुर्गम वाडीतून डॉ. संजय लोहकरे यांनी सुरू झाले. आदिवासी साहित्याचा प्रवाह समृद्ध व्हावा, नवनव्या लेखकांना प्रेरणा मिळावी, इतर साहित्य प्रवाहांहून आदिवासी साहित्य प्रवाह निराळा आहे याची जाणीव समग्र साहित्यविश्वाला व्हावी या हेतूने 'फडकी'तून विचारमंथन होते. फडकी आदिवासींच्या समस्या येथील प्रस्थापितांपुढे आणि शासनापुढे मांडत आहे.

मासिकाच्या वतीने डॉ. गोविंद गारे व्याख्यानमाला सुरू केली, त्यासही दहा वर्षे झाली. मासिकातून नवोदितांचे साहित्य प्रकाशित होत असतेच. पुस्तक प्रकाशन हे 'फडकी' मासिकाचे

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स्वाभाविक अंग आहे. बत्तीस नवोदित साहित्यिकांच्या साहित्यकृती मासिकाच्या सहकार्याने प्रकाशित झाल्या आहेत. समीक्षात्मक लेखनामध्ये बाबाराव मडावी यांचे 'आकांत' आत्मकथन, टाहो कादंबरी, कवितासंग्रहापैकी 'गोधड', 'वळीव' 'म्होरकी', 'रानपाखरांची गाणी' यांचे समीक्षात्मक लेखन केले आहे. आदिवासी कवितांमध्ये 'कसा जगू मी ?', 'देस', 'हरितक्रांती', 'आदिवासी झेंडा', 'आयुष्य डोंगरावरचं', 'हायकू आजीफ सारख्या कविता समाजाचे वास्तवचित्रण आले आहे. वैचारिक लेखनात धनगर आरक्षण, बोगस आदिवासी तसेच आदिवासी संस्कृती, सण-उत्सव, आदिवासी लोकगीतांविषयी लिहिले आहे. फडकीसाठी वाहरू सोनवणे, बाबाराव मडावी, तुकाराम धांडे, डॉ. तुकाराम रोंगटे, उषाकिरण आत्राम, भुजंग मेश्राम, विनायक तुमराम यांनी भरपूर लेखन केले आहे.

समारोप :

आदिवासी साहित्य प्रस्थापितांपर्यंत पोहोचविणे, नागर समाजाला नव्याने आदिवासी संस्कृतीची ओळख करून देण्याची महत्त्वपूर्ण भूमिका आदिवासी नियतकालिकांनी बजावली. आदिवासी ललित साहित्याचे स्वरूप हे आदिवासी जीवन, आरोग्य, समस्या, संस्कृती, पर्यावरण, कला या घटकांशी निगडीत आहे. आदिवासी नियतकालिकात त्यांची संस्कृती, परंपरा, जल-जंगल-जमीन, जगण्याच्या तऱ्हा, वैद्यकशास्त्र, यातुविद्या, अरण्यज्ञान, कलांभोवतालचे जीवन चित्रित झाले आहे. आदिवासी नियतकालिकांनी आदिवासी नवलेखकांना व्यासपीठ निर्माण करून दिले. या नियतकालिकांनी आदिवासी सामाजिक व राजकीय चळवळ उभी करून तिला योग्य दिशा देण्याचे काम केले. आदिवासी समाजाला जागृत करण्याचे सामाजिक कार्य नियतकालिकांनी केले. आदिवासी लोकसाहित्याची प्रेरणा घेऊन नवलेखकांनी कविता, कथा, कादंबरी तसेच वैचारिक लेखन केले आहे. त्यामुळे आदिवासी नियतकालिकांनी आदिवासी वाङ्मयीन संकृतीला संपन्न केले आहे असे म्हणता येईल. आदिवासी नियतकालिकाचे मराठी साहित्यात मोलाचे योगदान आहे. उज्ज्वल भविष्यकाळ लाभलेल्या आदिवासी साहित्यप्रवाहाने मराठी साहित्यात मोलाची भर घातली आहे.

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प्रस्तावना :

तेराव्या शतकात प्राचीन महाराष्ट्रात यादव राजे वैदिक संस्कृतीचे कट्टर अभिमानी आणि विद्या, कलांचे पुरस्कर्ते होते. तत्कालीन लोकजीवन धर्मसंबद्ध असल्याने साहजिकच सर्वसामान्य जनतेत संभ्रमाचे वारे होते. सामान्यांना त्यांच्याच भाषेत मोक्षमार्ग सुलभ करून सांगणारे, तळागाळातील लोकांना आकर्षित करणारे जैन, नाथ, लिंगायत धर्मसंप्रदायांनी आपापली पारमार्थिक विचारधारा जनमानसात मांडायला सुरुवात केली होती. त्यांनी सनातन धर्मातील चातुर्वण्य व्यवस्थेलाच आव्हान दिले. पारंपरिकता व कर्मकांडात यादवकालीन सामाजिक परिप्रेक्ष्यात संत ज्ञानेश्वर व कर्नाटकात म. बसवेश्वरांनी सर्वात प्रथम विद्रोह केलेला दिसतो. महानुभाव पंथाने परिवर्तनवादी विद्रोही रूप रेखाटले, जातीव्यवस्था नाकारणारा, विद्रोही विचार महानुभावांच्या विचारधारेत दिसून येतो. आवतारवाद, द्वैतीवाद, अहिंसावाद, एकेश्वर, भक्ती मार्गात भेदाभेद न मानणारा, सामाजिक विषमता नाकारणारा महानुभाव संप्रदाय लोकांना आपला वाटू लागला यात नवल नव्हते.

यादवकालीन महाराष्ट्रातील समाजजीवन :

इ. स. ११९४ ते १२८२ हा महाराष्ट्रातील ऐश्वर्याचा आणि समृद्धीचा कालखंड समजला जातो. देवगिरीच्या यादवांची कारकीर्द यावेळी महाराष्ट्रात होती. धार्मिक पगडा म्हणून उच्चवर्गात व्रतवैकल्ये, तीर्थयात्रा, उपवासाचे पेव फुटले होते. वेदशास्त्र, धर्मशास्त्र, ज्योतिष, पंचांग, कर्मकांड, देवदेवता, ग्रंथनिर्मिती याबाबत राजदरबारी हेमाडपंत या महापंडिताचा दबदबा होता. संस्कृत भाषेचा पर्यायाने पंडिती विचारधारेचा पगडा होता. मोक्षप्राप्तीचे दरवाजे संस्कृत भाषेत बंदिस्त झाल्याने सर्वसामान्यांना त्यापासून

वंचित राहावे लागत होते. "तत्कालीन महाराष्ट्रात देवतांचे व तत्तीर्थांचे चालू असलेल्या तीर्थक्षेत्रव्रतदानादिकांचे स्तोम केवढे माजले होते, याची कल्पना हेमाद्रीपंडितांच्या चतुर्वर्गचिंतामणीतील व्रतखंड दानखंड या भागांवरून येण्यासारखी आहे. त्यात हेमाद्रींनी ३६५ दिवसांची एकंदर २००० व्रते नि तत्तीर्त्यथ ब्राह्मणभोजने व दानधर्म इत्यादी आचार सांगितले आहेत. 'स्थानपोथी'त तत्कालीन महाराष्ट्रातील सुमारे १५३ देवतांचा उल्लेख आलेला आहे. त्यांत प्रमुख अशा वैष्णव व शैव देवतांव्यतिरिक्त काळीका, कोळाए, सुराए, डोबाए, जखीण यांसारख्या शुद्र देवतांचाही अंतर्भाव झाला आहे. यावरून शुद्र देवताभक्तीने महाराष्ट्राचे धार्मिक जीवन कसे गजबजून गेले होते हे दिसून येते."[1] अशाप्रकारे राजाश्रयाच्याजोरावर धर्ममार्तंडांनी धर्माच्या नावाखाली जातीभेद व वर्णभेदाला जास्त प्राधान्य दिले. त्याचवेळी बहुजनांना आपलेसे वाटावे असे धर्माचे रहस्य आपल्या बोलीभाषेत सांगणाऱ्या बौद्ध, जैन, लिंगायत, नाथ इत्यादी संप्रदायांनी जनभाषेत आपले तत्त्वज्ञान सांगण्याचा प्रयत्न केला. चक्रधर आणि पुढे ज्ञानदेव यांनी केलेला लोकभाषेचा पुरस्कार हे या काळातील एक मोठे सांस्कृतिक कार्य होते.

समाजात चातुर्वर्ण्याची मिरासदारी वाढलेली असण्याच्या काळात चक्रधरांनी आपल्या द्वैती तत्त्वज्ञानाचा प्रसार केला आणि सामान्य देवतांचे प्रस्थ कमी केले. देवतांच्या पूजेचा निषेध केला आणि चातुर्वर्ण्यांवर हल्ला चढविला. आपल्या पंथात त्यांनी स्त्रिया, शूद्र, ब्राह्मण, क्षत्रिय अशा सर्वांनाच संन्यास घेण्याची सोय ठेवली. संपूर्ण अहिंसा आणि कडकडीत वैराग्य यांचे पालन आपल्या संप्रदायात अपरिहार्य मानले. "सांसारिक दुःखाच्या झळांनी होरपळून निघालेल्या जीवांना श्रीचक्रधरस्वामींनी अपरंपार मायेने जवळ करून त्यांच्या अंगांवर आपल्या जीवनदर्शनाचे जे पांघरून घातले ते पांघरून ज्या धाग्यांनी विणलेले आहे त्यात जळजळीत विरक्ती, कडकडीत संसारनिवृत्ती आणि अव्यभिचारी स्वरुपाची अनन्य ईश्वरभक्ती हे धागे प्रामुख्याने गुंफलेले आहेत."[2]

महानुभाव संप्रदायाचा उदय : महानुभाव पंथ हा हिंदू धर्मातील एक संप्रदाय आहे. या पंथाची स्थापना चक्रधरस्वामींनी १२व्या शतकात केली. महानुभाव पंथाचे प्रवर्तक चक्रधर हे होते. सर्वसामान्य समाजापासून धर्म व धर्मविचार हरवत चालला होता. त्यावेळी श्रीचक्रधरांनी अशा

समाजाला नवा मार्ग दाखविण्यासाठी महानुभाव पंथाची स्थापना केली. 'शब्द रत्नाकर' कोशानुसार महानुभाव म्हणजे उदार, श्रेष्ठ, महात्मा, कृष्ण-उपासकांचा एक विशिष्ट पंथ असा शब्दार्थ सांगितला आहे. महानुभाव पंथाचे मूल पुरुष गोविंदप्रभू ऊर्फ गुंडम राऊळ हे असले तरीही या पंथाचे प्रणेते मात्र श्रीचक्रधर आहेत.गेली सहाशे वर्षे ह्या पंथाचे अनुयायी महाराष्ट्र, मध्य प्रदेश व पंजाबमध्ये अस्तित्वात आहेत.या पंथाचा अनुयायी वर्ग सर्वसाधारण जीवन जगणारा शूद्रातिशूद्र मानला जातीतून प्रामुख्याने आढळतो. ज्ञान आणि भक्तिला प्राधान्य देणारा पंथ 'महानुभाव' या नावाने जरी आज ओळखला जात असला, तरी त्याची 'महात्मा', 'अच्युत', 'जगकृष्णी' अशी अन्य नावेही आहेत. संशोधक वि.भि.कोलते यांच्या मतानुसार, 'भटमार्ग', 'परमार्ग' ही दोन नावे सार्थ ठरतात. महानुभावीयांची कृष्णाची मंदिरे, सत गुंबई, दिल्ली व अमृतसर, कर्नाटक, आंध्रप्रदेश ते पेशावरपर्यंत पसरलेली आहेत.

महाराष्ट्रात 'महानुभाव पंथ', गुजरातेत 'अच्युत पंथ' व पंजाबात 'जगकृष्णी पंथ' ही नावे लोकप्रिय आहेत. सोळाव्या शतकात महानुभाव पंथाचा प्रसार पंजाबमध्ये झाला. कृष्णराज नावाच्या पंजाबी व्यापाऱ्याने हा धर्मपंथ तिकडे नेला., ते पुढे कृष्णमुनी म्हणून प्रसिद्धीस आले. त्यांचा हा संप्रदाय जयकृष्ण पंथ म्हणून पंजाबमध्ये प्रसिद्ध आहे. जीव-जगत-देवता यापासून वेगळा असणारा, केवळ परमेश्वर भक्तितून ज्ञान प्राप्त करणे हेच या पंथाचे ध्येय आहे. परमेश्वर जीवांच्या उद्धारासाठी अवतार घेत असतो या कल्पनेवर आधारलेला असल्याने साहजिकच महानुभाव पंथ परमेश्वराचे पाच प्रमुख अवतार मानतो. १. श्रीकृष्ण २. श्री दत्तात्रय ३. श्री चांगदेव ४. श्री गोविंदप्रभू ५. श्री चक्रधर या पाच अवतारांनाच 'पंचकृष्ण' म्हणतात. यातील पंचकृष्ण म्हणजे श्रीकृष्ण हा मूळ पुरुष होय. महानुभावाचे संपूर्ण वाङ्मय हे याच पंचकृष्णाभोवती निर्माण झाले आहे. महानुभावांनी पंथीय प्रसार व प्रचाराला महत्त्व देत साहित्यनिर्मिती केली आहे. या पंचकृष्णांचा संबंध आलेली माहूर, फलटण, रिद्धिपूर, पैठण, डोमेग्राम, सालबर्डी ही महाराष्ट्रातील तीर्थस्थळे वंदनीय व पूजनीय मानली जातात. पंचकृष्णांना प्रत्यक्ष परमब्रह्म परमेश्वरावतार मानून त्यांची उपासना करावी असे या पंथाची शिकवण आहे.

महानुभाव संप्रदायाचे तत्त्वज्ञान : 'सूत्रपाठ' या ग्रंथास महानुभावांचा वेद असे संबोधले जाते. त्यातून महानुभावांचे सारे तत्त्वज्ञान विशद झाले आहे. महानुभाव जीव, देवता, प्रपंच व परमेश्वर या चार वस्तू मुख्य व नित्य अशा मानतात. त्यांच्या मते, या चार वस्तू स्वतंत्र, नित्य, अनादि व अनंत आहेत. जीव, देवता, प्रपंच व परमेश्वर यांचे परस्परांशी किंवा सर्वांशी कधीच ऐक्य साधले जात नाही, असे हा पंथ मानतो. म्हणूनच त्यास 'द्वैती पंथ' म्हणतात. 'देवता या नित्यबद्ध आहेत, जीव बद्धमुक्त आहेत, परमेश्वर नित्यमुक्त आहे व प्रपंच अनित्य आहे' असे या तत्त्वज्ञानाचे सूत्र आहे. एक सामाजिक गरज म्हणून चातुर्वर्ण्यावर महानुभावांचा विश्वास आहे. मात्र तत्त्व म्हणून ते जातिभेद, स्त्री-पुरुष भेद मानीत नाहीत. ते कृष्णभक्त आहेत आणि कृष्णाचे पाच अवतार झाले असे मानतात. ते भक्तिमार्गी असून पंथियांच्या मनावर नियंत्रण म्हणून काही नियम पाळतात. त्यातील प्रमुख चार नियम म्हणजे शणागती, प्रसाद सेवा, मूर्तिध्यान वा मूर्तिज्ञान आणि नामस्मरण हे होत.

स्त्रियांना मठांत संन्यासिनी म्हणून जगण्याचा अधिकार आहे. मात्र विधवांना हा हक्क नाही. ते अहिंसक, शाकाहारी असून साधे राहणीमान, भिक्षा मागणे व देशभ्रमण या गोष्टी काटेकोरपणे पाळतात. चक्रधरोक्त सिद्धान्तसूत्रपाठ, गीता हे या पंथाचे प्रमुख धर्मग्रंथ असून श्रीकृष्णलीलावर्णन करणारे भागवत ते प्रमाण मानतात. जीव, देवता, प्रपंच आणि परमेश्वर ही अनादि व अनंत मूळ चार तत्त्वे असून परमेश्वर नेहमी मनुष्यरूप धारण करून अवतार घेतो. मनुष्यरूपानेच प्राणिमात्रांचे उद्धरण परमेश्वरास करता येईल, अशी त्यांची श्रद्धा आहे. प्रपंच हा अनित्य असून अनादि अविद्यायुक्त जीव बद्धमुक्त आहे, जीव अनंत असून परमेश्वराचे अवतारही अनंत आहेत. हा पंथ द्वैती असून आत्मा आणि परमात्मा वेगळे मानणारा आहे. अविद्येपासून मुक्त होऊन ईश्वरस्वरूपाचा आनंद भोगण्याची पात्रता जीवाच्या ठिकाणी असल्याने महानुभवांनी जीवास 'बद्धमुक्त' मानले आहे. देवतांचे मुख्य कार्य सृष्टीतील जीवांना त्यांच्या कर्मांची सुखदुःखात्मक फळे देणे हे आहे, तो अनादि, नित्य, स्वयंप्रकाशी, ज्ञानमय, आनंदमय, सर्वसाक्षी व सर्वव्यापी आहे अशी त्यांची धारणा असते. जीवाच्या उद्धारासाठी परमेश्वर मनुष्यदेह धारण करून अवतार घेतो.

महानुभाव तत्त्वज्ञानानुसार परमेश्वराचे अवतरदृश्यावतार, परदृश्यावतार, उभयदृश्यावतार असे तीन प्रकारचे अवतार आहेत. ईश्वराचे स्वरूप ज्ञानामुळे ओळखता येते. ज्ञानमार्ग आणि भक्तिमार्ग ही मोक्षप्राप्तीची दोन साधने आहेत. महानुभावांचे उपदेशी आणि संन्यासी असे दोन वर्ग असून उपदेशी वर्ग लौकिक जीवनात चातुर्वर्ण्य पाळतो. संन्यासदीक्षेनंतर मात्र जातीनिर्बंध पाळण्याची आवश्यकता नाही. व्यक्तीचे श्रेष्ठत्व जन्माने नव्हे, तर त्याच्यातील तत्त्वज्ञानातून ठरते, असे सांगणारा महानुभाव हा एकच पंथ असून, येथे सर्व माणसे समान आहेत, असे काही विद्वान मानतात. या समतावादी विचारधारेला तत्कालीन समाजव्यवस्थेने साहजिकच विरोध केला. ''सनातन भागवत धर्म हा भक्तिमार्गी आहे. तसाच चक्रधरांचा नवपरिणत भक्तीमार्ग हा परमेश्वराची अनन्य भक्ती शिकविणारा आहे. हा मार्ग धर्माच्या नावावर होणारी हिंसा निषिद्ध मानतो. मग ते हिंसा वैदिक कर्मकांडातील याज्ञिक हिंसा असो की बहुजनांच्या शुद्रफलदात्या, देवतांच्या भक्तीपायी करण्यात येणारी प्राण्यांची बळीप्रथा असो, बहिरमच्या शिखरावर देण्यात येणाऱ्या बळींची संख्या असो. आणि तुळजापूरच्या नवभवानीसमोर कापल्या जाणाऱ्या बोकडांची हिंसा अमान्य करणारा श्रीचक्रधरांचा भक्तिमार्ग होता. त्यामुळे स्वामींचा हा नवा धर्म वैदिक याज्ञिकांना आणि भवानीच्या हिंसक भक्तांना आवडणारा नव्हता. म्हणून स्वामींच्या भक्तिमार्गाचा दोन्हीपक्षी विरोध होणे स्वाभाविक होते. हिंसक पूजापद्धतीच्या विरुद्धचे ते बंड होते. परंतु ते देव देवतांभक्तीच्या मात्र विरुद्ध नव्हते. उलट स्वामी देवतांचे सनातन अस्तित्त्व मान्य करीत होते. अद्वैती विविध देवतांचे अस्तित्त्व तत्त्वतः नाकारतात. स्वामींनी देवता हा स्वतंत्र पदार्थ मान्य करून, त्यांच्या सामर्थ्यालाही मान्य केले आहे. अद्वैतात एकमेव 'ब्रह्म' मानले आहे, त्यामुळे तेही तेहतीस कोटी देवता या पौराणिक काळातील कल्पित मानतात. तसे स्वामींनी मानले नाही. तरीही स्वामींना देवता विरोधक मानून तत्कालीन कर्मठ धार्मिकांनी स्वामींचा विरोध करणे सुरु केले होते.''[३]

त्या त्या युगातील देहधारी जीव साकार परमेश्वराच्या सन्निधानाने आपला उद्धार करून घेतात.मुक्तीनंतरही जीवाचे अस्तित्व टिकून राहते. ईश्वराकडून शब्दज्ञान झाले, तरी मोक्षमार्गाने जाण्यासाठी अनुसरणाच्या मार्गाचा अवलंब करून वयाच्या छप्पन्नाव्या वर्षापूर्वी सर्वेंद्रिये कार्यक्षम

असताना संन्यास घेणे आवश्यक आहे. त्यांच्या मते दंभ निर्माण होतात तेव्हा धर्मात अपप्रवृत्ती येतात. प्रत्यक्ष असणे व दिसणे यातील भेद संपतो, तेव्हा दंभ संपतो. त्याचवेळी समाजात परिवर्तन घडू शकते. महानुभाव पंथ हा सर्वांना सामावून घेणारा पंथ आहे. येथे सर्व समान आहेत. त्यामुळे सर्व जाती-धर्माचे लोक येथे दिसतात. येथे जातिभेद नाही, तर केवळ तत्त्वज्ञान आहे. धर्मासाठी आम्ही नाही, तर धर्म आमच्यासाठी आहे. तो साध्य नाही, तर साधन आहे. हीच पंथाची शिकवण आहे. इ.स. १२व्या शतकात मानवतेला लागलेला भेदाभेदांचा कलंक दूर करण्याचा प्रयत्न चक्रधर स्वामींनी महानुभाव पंथाच्या माध्यमातून केला

महानुभाव संप्रदायातील पंचकृष्ण: पंथाचे वाङ्मय मराठी भाषेतून या पंचकृष्णांच्या भोवती निर्माण झाले असल्याने त्यांचा पंचकृष्णविचार जाणून घेणे आवश्यक आहे. जीवांना ज्ञान देणे हे परमेश्वराचे अवतरण्याचे कारण आहे. जेव्हा धर्मावर संकट येईल तेव्हा परमेश्वर अवतार घेत असतो. ''महाराष्ट्र देश आणि मराठी भाषा या संबंधीचे महानुभवांना विलक्षण प्रेम होते. महाराष्ट्र देशातच राहावे, आणि मराठी भाषेतच बोलावे, लिहावे, अशी चक्रधरांची, म्हणजे महानुभावपंथाच्या संस्थापकांची कडक आज्ञा होती. 'महाराष्ट्री वसावे', हे त्यांचे सूत्र प्रसिद्ध आहे. तसेच ''नको गा केशवदेवा: माझिया स्वामीचा सामान्य परिवारु नागवैल की : मणौनि संस्कृत सूत्रबद्ध प्रकरण न करी कीं:'' आणि ''पंडित केशदेया: तुमचा अस्मात्? कस्मात्? मी नेणे गा: मज श्रीचक्रधरे निरुपिली मऱ्हाटी तियाच पुसा:'' ही नागदेवाचार्यांची, महानुभावांच्या पहिल्या आचार्यांची शिस्त होती.''[४] महानुभाव चार युगांचे चार अवतार मानतात. कृतयुगात हंसावतार, त्रेतायुगात दत्तावतार, द्वापारयुगात कृष्णावतार आणि कलियुगात चक्रधरावतार असे हे अवतार होत. महानुभावांनी फक्त पाचच मूर्ती मानून त्यांची पूजा केली आहे. हे पाच अवतार हेच त्यांचे पंचकृष्ण होत. महानुभाव पंथाचे मूळ पुरुष गोविंदप्रभू उर्फ गुंडम राऊळ असून पंथाचे प्रणेते मात्र चक्रधर आहेत. गुरूवर प्रीती करावी पण त्याला परमेश्वर समजू नये असे महानुभाव मानतात. हा पंथ वेदांबद्दल आदर बाळगणारा असला तरी वेदांना प्रमाण मानणारा नाही. महानुभाव संप्रदायाचा दत्त हा एकमुखी आहे. द्वारकाधीश कृष्ण, दत्तात्रय, द्वारावतीचे चांगदेव राऊळ, ऋद्धिपूरचे गोविंदप्रभू आणि

प्रतिष्ठानचे चक्रधर असे कृष्णाचे पाच अवतार ते मानतात. त्यांपैकी श्रीकृष्ण, दत्तात्रय,चक्रधर हे उभयदृश्य पूर्णावतार होत. महानुभावांचा पवित्र ग्रंथ सूत्रपाठात तत्त्व ज्ञानाचे स्वतंत्र प्रकरण आले आहे त्याप्रमाणे,

जैसे द्वापरी श्रीकृष्णचक्रवर्ती ।।१।।
जैसे सह्याद्री श्री दत्तात्रय प्रभु।।२।।
जैसे द्वारावतीय श्री चांगदेव राऊळ ।।३।।
जैसे रिद्धिपुरी श्रीगुंडम राऊळ ।।४।।
जैसे प्रतिष्ठानीश्रीचांगदेवो राऊळ ।।५।।

असे पंचकृष्ण अवतार मानले गेले आहेत. महानुभाव पंथात गुरूपरंपरेनुसार श्री दत्तात्रय प्रभूपासून श्री चक्रपाणि, श्री चक्रपाणिपासून गोविंद प्रभूंना, श्री गोविंदप्रभूपासून श्री चक्रधरांना ज्ञानप्राप्ती झाली आहे. श्रीकृष्ण हे मूळ दैवत मानले गेले आहे.

श्रीकृष्ण: महानुभाव पंथात श्रीकृष्णचक्रवर्तीचा अवतार म्हणजे द्वापारयुगात पिता वासुदेव व माता देवकीच्या पोटी जन्मलेला अवतार. 'देवकी देवीसि प्रसूती जाली: सवेचि परमेश्वरे गर्भाशी बिजे केले' हा अवतार गर्भीचा अवतार म्हणून ओळखला जातो. या पंथानुसार श्रीकृष्ण हा विष्णूचा अवतार नसून ते त्याला परब्रह्म परमेश्वरावतार व संपूर्ण उभयदृश्यावतार मानतात. ते श्रीकृष्णाला मनुष्यवेषधारीच समजतात. महानुभाव जीवनाप्रमाणे हा जीवोद्धारक अवतार होय. विरोधीमुक्ती म्हणजेच श्रीकृष्णांनी वैर केलेले असताना एखाद्याला मुक्ती देणे हा या अवताराचा विशेष आहे. श्रीकृष्णांनी राजधर्म स्वीकारला असल्याने अर्जुनाच्या रथाचे सारथ्य केले. त्याच्या करवी संहार करण्याची आज्ञा करून त्याला उपदेश म्हणून भागवतगीतेचे अपूर्व मार्गदर्शन केले. महानुभावांना गीता हा प्रमाण ग्रंथ म्हणून पूर्ण मान्य आहे. महानुभाव पंथी श्रीकृष्ण अवतार पुराणवाद्यांपेक्षा वेगळा मानतात. श्रीकृष्णाच्या अंगी अनेक शक्ती होत्या त्यापैकी विज्ञान व ज्ञानशक्ती होय. गोकुळात आपल्या बालवयातच विज्ञानी शक्तीचा वापर करून गोकुळात अनअघटित कृत्ये करून दाखवली आहेत. श्रीकृष्णाची नोंद लीळाचरित्रात आलेली आहे. श्रीकृष्णाने सांगितलेल्या भागवतगीतेचे महत्त्व विषद करताना चक्रधर म्हणतात,'बाई :गीता श्रीकृष्णोक्ति : एर अवघी व्यासोक्ति:'

श्री दत्तात्रय : श्री दत्तात्रेय हां दुसरा अवतार. तेत्रायुगात अत्री ऋषींपासून व माता अनूसया यांचा गर्भीचा हा अवतार. महानुभावांचा हा पौराणिक अवतार आहे. पौराणिक मतानुसार ब्रह्म-विष्णू-महेश हा अवतार मानला जातो महानुभावांचा दत्त एकमुखी आहे. महानुभावांचा दत्तावतार हा एक देवतावतार नसून तों प्रत्यक्ष परमेश्वराचा अवतार आहे. महानुभाव पंथाच्या पंचकृष्णात श्रीदत्तात्रेयचा समावेश केव्हा आणि कसा झाला असावा यांविषयी संशोधकांना कुतूहल आहे.''चांगदेव राउळांचा संबंध पाशुपत संप्रदायी नागनाथप्रवर्तित राउळ परंपरेशी आला होता... अफगाणिस्तान, पंजाब, राजस्थान व गुजरात भागात राउळांचा प्रभाव होता. रावळ हे पाशुपत असल्याने राऊळ हेही शैव पाशुपत ठरतात, व चांगदेव राउळही प्रारंभी शैवपाशुपत असावा असे दिसते.''[५] चक्रधरांना शिवोपासना मान्य नव्हती. लीळाचरित्रात दत्तावतराच्या काही लीळा दिसून येतात. ते जीवोद्धारक अवतार आहेत. परमेश्वराची भेट दुर्मिळ आहे. 'ते अमोघ की गा :' कृपाप्रसादाने दर्शन झालेच तर ते फलप्राप्ती नक्कीच साधता येते. या अवताराबाबत सर्व भक्तगणात एकवाक्यता दिसून येते.

चांगदेव राउळ : श्री चांगदेव राउळ पुण्याजवळील फलटण या गावचे रहिवासी. वेदाध्ययन करणारे घराणे कऱ्हाडे ब्राह्मण जातीचे. त्यांचे वडील व्यापारी होते. चांगदेव व चक्रपाणिच्या आशीर्वादाने त्यांना पुत्रप्राप्ती झाली. चांगदेव व चक्रपाणी ही दोन नावे रूढ झाली. व्रतबंध, विद्याभ्यास, विवाह व वडिलांच्या व्यापारात मदत करणे हे त्यांचे पूर्वायुष्य. त्यांच्या आयुष्यात अलौकिकत्व सहजपणे प्रकटू लागले. फलटणमध्ये ३२ वर्षे वास्तव्यास होते. वडिलांनी आपल्या शेतातील भाताचे काढणी केल्यानंतर त्यांना धान घरी पोहचवायला सांगितले असता, जेवढी गाडीभरून वाहतूक केली तेवढे पुन्हा शेतभर उभे पिक पुन्हा जसेच्या तसे उभे, एकदा आई-वडील वाराणशीला गेले असता घराची राखण्याची जबाबदारी चांगदेवावर टाकतात. ते दोन्हीकडे राखण करतात. अलौकिकत्व प्राप्त झालेल्या चांगदेवांनी आपला कमळाईसाबरोबरचा सुखी संसार त्यागून ते फलटणहून माहूरला प्रयाण करतात. तिथे त्यांना देवदेवेश्वरयेथे व्याघ्ररुपात श्री दत्तात्रय प्रभूंचे दर्शन घडते. त्यांच्या शक्ती स्वीकारून पुढे ते द्वारावतीला जातात. गोमती

नदीच्या तीरी एका पाताळ गुहेमध्ये ते ६५ वर्षे राहिले. तिथे ते बावन्न पुरुषांना विद्यादान देतात. डोक्यावर सूप ठेवून पाठीवर खराटा मारणे अशी विद्यादानाची पद्धती आहे. उदास वृत्तीने राहून ते जीवांचा उद्धार करण्याचे कार्य करीत होते. आंधळ्याला नेत्र देणे, पांगळ्याला पाय देणे, मुक्याला वाचा देणे, वांझला पुत्र देणे, दुःखीतांचे दुःख दूर करणे, मनाच्या इच्छा पूर्ण करणे अशाप्रकारे पूर्ण फलटण नगरीत जीवोद्धाराचे काम केले. वर्णधर्माची बंधने न मानता त्यांनी शुद्राच्याही घरी जेवण केले. ते सिद्धनाथ होते, असे रा.चिं.ढेरे यांनी आपल्या 'श्री गुरुगोरक्षनाथ' या ग्रंथात म्हंटले आहे. चांगदेवांच्या दैवी सामर्थ्याची महती ऐकून काउरली येथी कामाख्या हटयोगिनी त्यांच्या सौदार्यावर भाळते व रतीसुखाची मागणी करते. सिद्धपुरुष राउळाच्या गुहेच्या द्वारापाशी सात दिवस हटून बसते. तिचा निर्धार पाहून चांगदेव आपल्या योगसामार्थ्याच्या बळावर स्वतःचा देह त्यागून आपला अवतार संपवितात. मात्र त्याचवेळी भडोच येथे स्मशानात आणलेल्या मृत हरपाळदेवाच्या शरीरात प्रवेश करून नवीन अवतार धारण करतात. हा अवतार म्हणजेच महानुभाव पंथाचे संस्थापक श्रीचक्रधर होत. पुढे आपल्या आयुष्यातील उर्वरित कार्य ते चक्रधरांच्या रूपाने पूर्ण करतात.

गोविंदप्रभू : श्रीकृष्ण अवतारातील चौथा अवतार. श्री गोविंद प्रभु महाराज अथवा गुंडम राउळ यांचा अवतार, भाद्रपद शुक्ल १३ ला रात्री १० वाजता काटसुरा जिल्हा अमरावती येथे एका ब्राह्मण कुटूंबात झाला. त्यांच्या पित्याचे नांव अनंतनायक व आईचे नांव नेमाइसा असे होते. या दांपत्यांची संतती जगत नसल्यामुळे त्यांनी परमेश्वराची भक्तिभावाने प्रार्थना केली. फलप्राप्ती म्हणून नेमाइसाच्या पोटी जो जीव आला, त्याला दवडून श्री गोविंदप्रभूंनी अवतार धारण केला. त्यांचे नाव गुंडो असे ठेवण्यात आले. जन्मानंतर मात्र श्रीप्रभूंना आई वडीलांचे सुख प्राप्त झाले नाही. ब्राह्मण असूनही त्यांनी जातिभेद केला नाही. स्त्री आणि शूद्र यांनाही समाजातील अन्य घटकांप्रमाणेच भक्ती व उपासना करून आपला उद्धार करून घेण्याचा अधिकार आहे, हे त्यांनी आपल्या कार्यातून समाजाला पटवून दिले. गोविंदप्रभूंच्या लीळा म्हाइंमभटाने एकत्र गुंफल्या आहेत. हा लीळासंग्रह 'रिद्धिपूर चरित्र' या नावाने प्रसिद्ध आहे. देहाने ते वेडापिसा वाटायचे मात्र अलौकिकत्व प्राप्त केल्याने लोकमनात केंद्रस्थानी होते. 'हा

ईश्वरु अवतारु होईल' अशी लोकमानसाची श्रद्धा झाली. विशुद्ध, नि:स्वार्थ भावामुळे त्याच्या ठायी मातृप्रेम दिसून येते. 'राउळ वेडे:राउळ पिसें' अशी असणारी समजूत पुढे त्यांच्या स्त्री - शिष्यांना''श्री प्रभू राऊळ माझे राऊळ बापु''असे वाटू लागले. या लीळांमध्ये त्यांच्या कार्याविषयी अनेक प्रसंगांचे वर्णन आले आहे. जसे. एका निराधार गर्भवती स्त्रीच्या घरी जाऊन ते, ती स्त्री मोकळी होईपर्यंत तिची सेवा करतात.

ते रिद्धिपूरचे सर्वसत्ताधीश होते. त्यांची सत्ता प्रेमाची सत्ता होती. ते कलेचे जाणते होते. एकदा कलावंतीणीचे नृत्य व ठेका चुकल्याचे सांगतात. गायकाचा राग आळवताना सूर आणि वाद्याचा ठेका चुकल्याचे 'मर तू बोडी मोरासी' म्हणत नापसंती व्यक्त करतात. त्यांच्या सेवेत समतेची दृष्टी होती. सामान्य स्त्रियांचे अन्न खातांना ते संकोचत नाहीत. वेश्येने दिलेले खोजे खातात. पाणी भरायला गेलेल्या बाईचे ते लेकरू सांभाळतात. मुलाला न्हाऊ घालायला गरम पाण्यात 'वीसान'घालतात. ज्यांना कुणीच नाहीत त्या सासुरवाशीणीचे ते माहेरघर बनतात. मातंगाच्या घरचे अन्नही ते आवडीने खातात. शिंपी, तेली,माळी, गवळणीआणि समाजाच्या सर्व स्थरांतीलव्यक्ती त्यांना एकसारख्याच समान वाटतात. त्यांच्याबरोबर राहणे- वागणे, हसणे-बोलणे, खाणे-पिणे विषयी त्यांना कोणताच विधिनिषेध वाटत नाही. एका गावावर हल्ला होतो, तेव्हा ते दोन्ही सैन्यांमध्ये उभे राहून दोन्ही गावांत समेट घडवितात.बौद्ध, मातंग, महाजन या सर्वांच्या घरात जाऊन ते जेवण करीत.''मातंगा विनवणी स्वीकारू यासारख्या लीळेत ते स्पृश्यास्पृश्य भेद कसा पाळीत नाहीत, याचे वर्णन आले आहे. महाजनांनी मातंगांना पाणी भरण्यास बंद केले तेंव्हा, ''आम्ही पाणीयेवीण मरत असो'', अशी काकुळती ते लोक करतात, तेव्हा श्री गोविंद प्रभू त्यांच्यासाठी विहीर खोदायला लावतात, तिला भरपूर पाणी लागते. अशाप्रकारे आपल्या अलौकिकत्वाने त्यांनी समाजाची सेवा केली पुढे हरपाळदेवाला अवतारी पुरुष बनविले. चक्रधराच्यारूपाने एका पंथ संस्थापकाचे बीज पेरणारा व साधुत्व अंगी बाणलेला हा सत्पुरुष पंचकृष्णातील महत्त्वाचा अवतार मानला जातो. प्राचीन साहित्याचे अभ्यासक डॉ. अ.ना.देशपांडे म्हणतात की, ''आधुनिक महाराष्ट्राला महानुभाव पंथ व त्यांचे पारमार्थिक व वाङ्मयीन कर्तृत्व यांचा परिचय होऊन अर्धशतक

लोटले आहे. त्यामुळे आता तरी ही अनास्था मावळावी आणि गोविंदप्रभूसारख्या महानुभावी संतश्रेष्ठांना महाराष्ट्राच्या नित्यस्मरणीय संतनामावलीत स्थान मिळावे अशी अपेक्षा आहे. याशिवाय, श्री गोविंदप्रभूंची विद्वानांनी वेडापिसा म्हणून विल्हेवाट लावू नये.''[६]

चक्रधर : श्री चक्रधर हा पंचकृष्णावतारातील पाचवा अवतार होय. चक्रधरांचे व्यक्तिमत्त्व अतिशय तेजस्वी होते. त्यांच्या चरित्राची सुरुवात विलक्षण घटनेने होते. भरवस (भडोच) येथील हरपाळ नावाचा प्रधानपुत्र ऐन पंचविशीत मरण पावतो. त्याच्याच मृत शरीरात चक्रधर परकायाप्रवेशविद्येच्या बळावर प्रवेश करतात. या अलौकिक घटनेला आणखी एक दुवा आहे तो म्हणजे कामाख्येच्या हट्टाग्रहापुढे अगतिक होऊन श्री चांगदेव राउळ आपल्या शरीराचा त्याग करतात व स्मशानात आणलेल्या हरपाळदेवाच्या मृत शरीरात प्रवेश करतात. हरपाळदेव जिवंत होतो. 'अवधेयाही हरीखु जाला: कमरू जीयाला: कमरू जीयाला' या अवलौकिक घटनेने त्याचा देह ईश्वरावताराचा वाहक बनला. हरपाळाचा पुढे श्रीचक्रधर बनतो. म्हणजेच चांगदेवांचा अवतार म्हणजेच श्रीचक्रधर होय. चक्रधरांचा कालखंड (इ. स. ११९४ ते १२८२) हा महाराष्ट्रातील ऐश्वर्याचा आणि समृद्धीचा कालखंड समजला जातो. देवगिरीच्या यादवांची कारकीर्द यावेळी महाराष्ट्रात होती. चक्रधरांनी देवतांच्या पूजेचा निषेध केला आणि चातुर्वर्ण्यावर हल्ला चढविला. आपल्या पंथात त्यांनी स्त्रिया, शूद्र, ब्राह्मण, क्षत्रिय अशा सर्वांनाच संन्यास घेण्याची सोय ठेवली. संपूर्ण अहिंसा आणि कडकडीत वैराग्य यांचे पालन आपल्या संप्रदायात अपरिहार्य मानले. धर्माचे रहस्य आपल्या बोलीभाषेत सांगणाऱ्या जैन, लिंगायत, नाथ इत्यादी संप्रदायांप्रमाणे जनभाषेत आपले तत्त्वज्ञान सांगण्याचा प्रयत्न केला.

ऋद्धिपूरच्या गोविंदप्रभू या परमेश्वरावताराचे ते शिष्य. त्यांचे मूळचे नाव हरपाळदेव असून त्यांच्या मृत शरीरात चांगदेव राऊळ यांनी प्रवेश करून नवीन अवतार धारण केला अशी कल्पना आहे. हरिपाळाचे वैवाहिक जीवन कमळाईसाबरोबर सुखात सुरु झाले. पुढे ३२ व्या वर्षी हरीपाळाचा द्यूतामध्ये पुंजी गमावल्यानंतर कमळाईसाकडे दागिन्यांची मागणी केली. तिने नकार देताच आपल्यापेक्षा धर्मपत्नीला दागिने प्रेमळ वाटू

लागतात या भावनेतून ते निराश होतात. संसाराचा उबग आल्याने ते घराबाहेर पडतात रामटेक, रिद्धिपूरला येऊन ते गोविंदप्रभूंकडून संन्यासदीक्षा स्वीकार करतात. गोविंदप्रभूंनी हरपाळाला चक्रधर म्हणून संबोधले. अशाप्रकारे हरिपाळाचा चक्रधर झाले. भाद्रपद शुद्ध द्वितीया हा दिवस अवतार दिवस 'चक्रधर जयंती' म्हणून महानुभावपंथीय लोक साजरा करतात. चक्रधरांनी समाजातील कर्मठपणा, अंधश्रद्धेची जळमटे पुसून टाकीन ज्ञानाचा मार्ग सर्वांसाठी खुला केला. स्त्री, शुद्र, पंडितांना एकाच मांडीत गुंफले. भक्तिमार्गाचा नवीन पायंडा पाडून लोकोद्धार, धर्म, तत्त्वज्ञानाची बीजे जनसमुदायात पेरली. "सर्वज्ञ श्री चक्रधरांनी दिलेली शिकवण सर्व पंथीयांना शिरोधार्य आहे. सर्वस्वाचा त्याग करून परमेश्वराला शरण जाण्याचा संदेश देणारे सर्वज्ञ स्वातंत्र्य हा मोक्षाचा महामंत्र व या मार्गासी श्री दत्तात्रेय प्रभू असे आदिकारण म्हणतात. सत्य, अहिंसा, समानता, समव्यसनांचा त्याग, प्राणिमात्रावर प्रेम, सदाचार या तत्वांचा अवलंब करावा अशी त्यांची शिकवण आहे. परब्रह्म परमेश्वराचे नामस्मरण करावे. परमेश्वर प्राप्तीसाठी ज्ञानयुक्त भक्तिमार्गाचा स्वीकार करावा असे त्यांचे सांगणे आहे."[७]

समारोप : महानुभाव पंथाचे स्वरूप वैविध्यपूर्ण आहे. महानुभाव पंथीयांच्या विचारात, आचारात व प्रत्यक्ष कृतीतून समाजिक सुधारणेची भूमिका प्रत्ययास येते. परमेश्वर नेहमी मनुष्यरूप धारण करून अवतार घेतो अशी पंथाची धारणा आहे. पंचकृष्णांनाच साक्षात परब्रह्माचा अवतार मानून उपासना करावी असे महानुभाव पंथ मानतो. महानुभाव पंथाने पुरुषांच्या बरोबरीने स्त्रियांना समान धार्मिक, सामाजिक अधिकार दिला आहे. महानुभावाचे तत्त्वज्ञान द्वैती स्वरूपाचे असून त्याला भगवतगीतेचा आधार आहे. त्यामुळे महानुभावांचा सन्यास हा परमेश्वराची प्राप्ती करून देणारा कर्मप्रधान सन्यास आहे. मराठी भाषेवर महानुभावांचे फार मोठे उपकार आहेत. चक्रधरांनी आपल्या भक्तिमार्गाचे तत्त्वज्ञान सांगण्यासाठी मराठीला ज्ञानभाषा, धर्मभाषा बनवून ज्ञानाचे भांडार सर्वांसाठी खुले केले. महानुभाव पंथाचे संपूर्ण वाङ्मय पंचकृष्णांभोवती निर्माण झाले आहे. श्रीचक्रधरांनी आपल्या कृतीतून भक्तांना स्पृश्यास्पृश्यता पाळू नये असा संदेश दिला आहे. देवतांच्या पूजेचा निषेध व चातुर्वर्ण्यावर हल्ला चढविल्याने अनेक अनुयायी पंथाला येऊन मिळाले.

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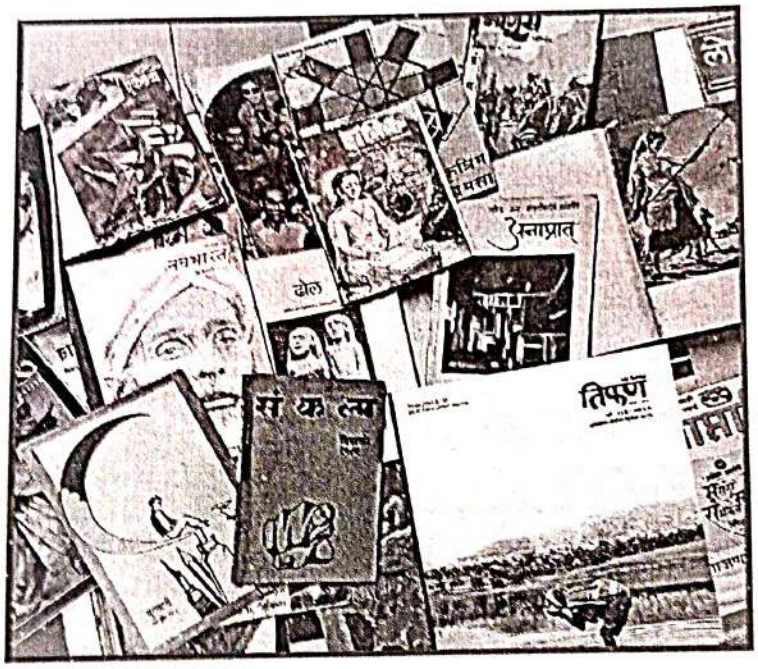

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(या अंकातील लेखकांच्या मताशी संपादक सहमत असतीलच असे नाही.)

या नियतकालिकास महाराष्ट्र राज्य साहित्य आणि संस्कृती मंडळाकडून अनुदान प्राप्त झाले आहे; परंतु या नियतकालिकात प्रसिद्ध झालेली मते मंडळास मान्य असतीलच असे नाही.

१७	वाङ्मयीन अभिरुची जडणघडणीत नियतकालिकांचे योगदान	डॉ. विद्या नावडकर	१०५
१८	'ज्ञानोदय' नियतकालिकातील शेतीविषयक विचारांचा परामर्श (१८४२ ते १८५०)	मधू गुमाडे डॉ. संजय गवळी	१११
१९	सत्सार: विद्रोही अनियतकालिक	प्रा. प्रमोद शेटे	११८
२०	'ज्ञानमोचक' नियतकालिकाचे स्वरूप व भूमिका	दत्तात्रय बाळासाहेब सोनवणे	१२२
२१	स्त्रीमुक्तीची तळी उचलणारे मासिक 'मिळून साऱ्याजणी'	डॉ. शिवराज कोचे	१२६
२२	वाचनवृद्धीसाठी 'मिळून साऱ्याजणी' चे योगदान	प्रा. सुप्रिया नवले	१३२
२३	नियतकालिकांतील स्त्रियांचे कथालेखन व अनुभवविश्व (१९८० नंतर)	प्रा. तुकाराम भवर	१३५
२४	१९७५ पासूनची मराठीतील स्त्रियांच्यासाठी वाहिलेली नियतकालिके आणि स्त्री संघटनांची मुखपत्रे	प्रा. विजया ठाकूर	१४०
२५	मराठीतील स्त्रीवादी नियतकालिकांची वाटचाल	डॉ. उज्ज्वला सामंत	१४५
२६	स्त्रीयांसाठी वाहिलेल्या नियतकालिकांची वाटचाल	अभिता निकम डॉ. पद्माकर तामगाडगे	१५४
२७	मराठीतील स्त्रीवादी नियतकालिकांचा परामर्श	डॉ. संदीप चपटे	१५९
२८	आदिवासी नियतकालिकांचे वाङ्मयीन आणि सामाजिक कार्य	डॉ. संजय मेस्त्री डॉ. तुकाराम रोंगटे	१६४
२९	'हाकारा' नियतकालिकातील आलेल्या आदिवासी कवितांची आशयसूत्रे	डॉ. विकास बहुले	१७०
३०	साप्ताहिक 'साधना'चे महाराष्ट्रातील सार्वजनिक आणि सामाजिक योगदान	डॉ. संतोष पवार	१८०
३१	मराठी नियतकालिकांची वाटचाल आणि 'तिफण'ची वाङ्मयीन कामगिरी	डॉ. ताहेर एच.पठाण	१८४
३२	'फडकी' नियतकालिकाचे वाङ्मयीन स्वरूप	प्रा. चिंतामण धिंदळे	१९१
३३	'तिफण'चा समकालीन कथा व व्यावहारिक मराठी विशेषांक	डॉ. भास्कर शेळके	१९६
३४	कैलास दौंड साहित्य विशेषांक	डॉ. रंजना कदम	२०१
३५	'तिफण'चा लोककला विशेषांक	सुनील घनकुटे	२१
३६	वाङ्मयीन नियतकालिकांसमोरील आव्हाने	डॉ. शिवाजी हुसे	२२
३७	'तिफण'चा मराठी बोलीभाषा विशेषांक	डॉ. प्रेमला मुखेडकर	२३

'हाकारा' नियतकालिकात आलेल्या आदिवासी कवितांची आशयसूत्रे

डॉ. विकास बहुले

वाङ्मयीन नियतकालिके विशेषांक

प्रस्तावना

१६ व्या शतकात मुद्रणक्रांती झाल्यामुळेच जगातील प्रबोधनाला वेगळी गती आणि दिशा मिळाली. लोकशाही शासनव्यवस्था असलेल्या देशांमध्ये वृत्तपत्रे, नियतकालिके ही समाजाची गरज बनू लागली. इंग्रजी राजवटीबरोबर भारतात ज्या कित्येक गोष्टी आल्या त्यात नियतकालिकेही आली. मुद्रणकला ही नियतकालिक सुरु होण्याचे एक साधक कारण बनली. शिक्षणाचा प्रसार, वाचन लेखनाची आवड, छापखाने या सर्व घटकांचा प्रभाव म्हणून नियतकालिकाच्या उदयाला व प्रसाराला उत्तेजन मिळाले. ख्रिस्ती मिशनरी, सनातन विरुद्ध सुधारक या संघर्षात नवविचार तसेच हिंदूविरोधी मत प्रचाराचे खंडन करण्यासाठी नियतकालिकांचा उदय झाला. लोकशिक्षणाबरोबरच समाजात वैचारिक क्रांती घडवून आणण्याचे कार्य नियतकालिकांनी पार पाडले. मराठीत नवी विचारधारा, नवे लेखक, नवे लेखन उदयास आले. स्वातंत्र्योत्तरकाळात दलित, आदिवासी, भटक्यांच्या समस्यांना न्याय देण्यासाठी आदिवासी, दलित नियतकालिके सुरु झाली. 'मधुबन', 'गोंडवाना', 'आदिवासी टाईम्स', 'फडकी', 'ढोल', 'हाकारा', 'आदिवासी संशोधनपत्रिका' यांसारखी नियतकालिके सुरु झाली. पुणे येथून १९८० मध्ये सुरु झालेल्या 'हाकारा' त्रैमासिकाने आदिवासींचे सामाजिक, राजकीय, आर्थिक प्रश्न, दुःख मांडण्याचा प्रयत्न केला. त्यामुळे 'हाकारा'नियतकालिकाचे योगदान मोलाचे

मराठी नियतकालिकांची परंपरा व प्रकार

'नियमित प्रकाशित होते ते नियतकालिक' असे सर्वसाधारणपणे म्हणता येईल. मराठी भाषेत नियतकालिकांची परंपरा मोठी आहे. १९ व्या शतकात इंग्रजी राजवटीत मराठी भाषिकांना इंग्रजी भाषेचा आणि त्यातील विचार, संस्कृती, जीवनमूल्यांचा जवळून परिचय झाला. त्याचा परिणाम म्हणून महाराष्ट्रात प्रबोधनाला सुरुवात झाली. सर्वांत प्रथम या अभिजनांनी अभिव्यक्त होण्यासाठी वृत्तपत्रे व नियतकालिकांचा वापर सुरु केला. प्रारंभीच्या काळात ज्ञानप्रसार हीच भारतीय नियतकालिकांची प्रेरणा होती. दर्पणकार बाळशास्त्री जांभेकरांनी 'दिग्दर्शन' (१८४०) नावाच्या मासिकाचा पहिला अंक काढून मराठी नियतकालिक युगाचा प्रारंभ केला. पुढे लोकहितवादींची शतपत्रे त्यामध्ये प्रसिद्ध झालेले 'प्रभाकर' (१८४१), ज्ञानोदय (१८४२), ज्ञानप्रकाश (१८४९), ज्ञानविस्तार (१८६०), मनोरंजन, सत्यकथा, अभिरुची याच परंपरेतील असंख्य नियतकालिके निघाली. शिक्षण, व्यापार, शेती, आरोग्य, क्रीडा, पर्यटन, विज्ञान, चित्रपट, रंगभूमी अशा कितीतरी दैनंदिन विषयांवर नियतकालिके प्रसिद्ध होऊ लागली. "मनोरंजन, चित्रा, मौज, सत्यकथा, धनुर्धारी, मराठा वैभव, केरळ कोकीळ, रत्नाकर, किर्लोस्कर, स्त्री, मनोहर, वसंत, हंस, वाङ्मयशोभा, सह्यादी, समाजस्वास्थ अशी नियतकालिके निघाली. त्यातील 'किर्लोस्कर' मासिकांनी फार महत्त्वाची कामगिरी केली आहे. सामाजिक, धार्मिक, आर्थिक, औद्योगिक सर्व क्षेत्रातील अत्यंत पुरोगामी लेख छापावयाचे, असा त्याचा बाणा होता. डॉ. केतकर, सावरकर, फडके अशा थोर लेखकांचे लेख अनेक वर्षे किर्लोस्करांनी छापले. स्त्रीजीवनसुधारणेविषयी त्यांचा कटाक्ष होता. अजूनही 'किर्लोस्कर' व 'स्त्री' या मासिकांनी आपली कीर्ती टिकवून धरली आहे."[१] मराठी साहित्याच्या इतिहासात अजरामर झालेल्या साहित्यकृती ह्या नियतकालिकातूच प्रसिद्ध झाल्याचे दिसून येते. स्वातंत्र्योत्तर काळात प्रसिद्धीच्या कालावधीनुसार साप्ताहिके, पाक्षिके, मासिके, त्रैमासिकांच्या संख्येत भर पडली आहे. मासिकापेक्षा जास्त कालावधीत प्रसिद्ध होणारी नियतकालिके ही वैचारिक प्रणालीशी निगडीत असतात. नव्या कल्पना, संशोधन, सामाजिक, राजकीय, शैक्षणिक समस्या याविषयीची क्षमता असलेले लेखक व वाचक इथे कार्यरत असतात. नियतकालिकांच्या स्वरूपावरून जसे, साप्ताहिक, पाक्षिक, मासिक, त्रैमासिक असे तर विषयावरून साहित्य, संशोधन, समीक्षेला वाहिलेली नियतकालिके असे प्रकार पडतात. नियतकालिकांच्या उद्दिष्टांवरून त्यांच्या कार्याचे स्वरूप लक्षात येते.

'हाकारा'चे प्रयोजन व कार्य

१९८० साली 'हाकारा' या त्रैमासिक नियतकालिकाची सुरुवात झाली. या नियतकालिकाने सर्वप्रथम आदिवासी कला, संस्कृती, परंपरा, लोकजीवन, राजकीय, आर्थिक प्रश्नांना प्रकाशात आणले. 'महाराष्ट्र मानव विज्ञान परिषदेने' हे नियतकालिक सुरु करताना हाकाराने नवोदित आदिवासी लेखक, कवी, कार्यकर्ते यांना आपल्या समाज, परंपरा, इतिहास लेखनाचे आवाहान केले. त्यामुळे आदिवासींच्या वेदना, दुःखाला हाकाराने आपल्या अंकात मध्यवर्ती स्थान दिले. हाकाराचे पहिले कार्यकारी संपादक जगदीश गोडबोले यांनी हाकाराच्या हेतूविषयी दुसऱ्या अंकातील संपादकीय विचारात लिहिले आहे की, "दलित आदिवासींच्या समस्यांबद्दल डोळस जाणीव निर्माण व्हावी, त्या क्षेत्रात काम करणाऱ्यांचा आपसात आणि इतरांशी संवाद घडावा यासाठी आम्ही हा हाकारा घातला होता. आमचा हाकारा रानावनात-गावकुसाच्या आत-बाहेर, हस्तीदंती मनोऱ्याच्या आरपार पोहोचतो की नाही याची आम्हाला उत्सुकता होती. थोडी धागधुगही होती; परंतु प्रत्यक्ष क्षेत्रात काम करणारे कार्यकर्ते, या प्रश्नांबद्दल आस्था

असणारे असंख्य लोक, वृत्तपत्रे-मासिके यांनी आमच्या हाकाऱ्याला जो उत्स्फूर्त प्रतिसाद दिला, त्यांनी आम्हाला दिलासा मिळाला."[२] प्रस्थापित वर्गाला गावकोसापासून अतिदूर असलेल्या दुर्गम भागातील आदिवासींच्या संस्कृती, परंपरा, राहणीमान, नृत्ये, कला यांची नव्याने ओळख होऊ लागली. म्हणजेच हाकाराचे आदिवासी संस्कृती, कला, समस्यांची माहिती, ओळख ही नागरी समाजाला करून देणे हेच मुख्य प्रयोजन होते असे म्हणता येईल. त्यानुसार १९८० पासून आजतागायत हे कार्य अविरतपणे चालू आहे. आदिवासी लेखकांच्या कविता, कथा, समीक्षात्मक लेखन हाकारात आले आहे. या ललित साहित्याचे स्वरूप हे आदिवासी, आरोग्य, समस्या, संस्कृती, पर्यावरण, कला या घटकांशी निगडीत आहे. नियतकालिकांचे महत्त्व सांगताना सु. रा. चुनेकर म्हणतात की, "अभिरुची उत्पन्न करणे व त्या अभिरुचीला सातत्याने खाद्य पुरविणे हे नियतकालिकांचे कार्य असते."[३]

'हाकारा'त आलेल्या आदिवासी कविता आणि त्यांची आशयसूत्रे

'हाकारा' नियतकालिकाने १९८० पासून कविता या सदराची सुरुवात करून नवोदित आदिवासी कवींना व्यासपीठ निर्माण करून दिले. आदिवासी साहित्याची सुरुवात ही कविता या वाङ्मयप्रकाराने झाली असल्याने उत्स्फूर्तपणे आलेल्या वेदना, संवेदना, समस्या कवितेत सहजपणे उतरतात. आदिवासी कवितेचे दालन समृद्ध आहे. प्रारंभीची आदिवासी कविता ही मासिके, अनियतकालिकातून प्रसिद्ध झालेली दिसते. आदिवासी कवींच्या पहिल्या पिढीत भुजंग मेश्राम, विनायक तुमराम, गोविंद गारे, वाहरू सोनवणे, पहिल्या कवयित्री उषाकिरण आत्राम यांनी उत्स्फूर्तपणे काव्यलेखन केले. अर्वाचीन कवितेत आदिवासी कविता तुरळक प्रमाणात दिसते. कवितांमधून त्यांच्या अत्याचाराला शह दिला गेला आहे. नव्या पिढीमध्ये गंगाधर कुरसुंगे, संयजामेश्राम, प्रभू राजगडकर, वामनदादा गवळी, सुखदेव ढाईक, माधव सुरकुंडे, विठ्ठलराव वरखंडे, [illegible] मडावी, बाबाराव मडावी, वसंत कुरसुंगे, कृष्णकुमार चांदेकर या सर्व प्रतिभावंत कवींनी आदिवासी समाजजीवन आपल्या कवितेत मांडले आहे. कोणत्याही साहित्यप्रकारात लेखक, वाचक, समीक्षक म्हणजेच सर्जन, अभिरुची आणि समीक्षा यांचा परस्परसंबंध दडलेला असतो. प्रा. चिंतामण धिंदळे म्हणतात की, "आदिवासींच्या समस्या कवितेतून मांडण्यामागील प्रेरणा ह्या चळवळीच्याच असल्याचे लक्षात येते. म्हणूनच कवितेतून आदिवासी कुपोषण, दारिद्र्य, आरक्षण, स्त्रियांवरील अन्याय, अत्याचाराचे चित्रण कवींनी केल्याचे पहावयास मिळते. आदिवासी कविता हा आदिवासी जीवनाचा आरसाच आहे. कवितेतून आदिवासी कवींनी सूचकपणे यथार्थवादी दृष्टिकोनातून आदिम भावना मांडून नवआदिवासी कवींनी एक दिशा व प्रेरणा देण्याचे काम केले आहे. आदिवासी कवींची कविता अस्सल आदिमत्त्व प्रकट करते व ती विविध भाषिक सौंदर्याने नटलेली आहे."[४] निसर्गदत्त प्रतिभा ही स्वशोध, आत्मचिंतन आणि संस्कृतीचे स्थान निर्माण करणारे रूप धारण करते. आशयसूत्रांच्या केंद्रस्थानी मूल्यात्मक संस्कारांचा प्रभाव पडलेला असतो. हे संस्कार मानसिक पातळीवर प्रतिबिंबित होत असल्याने त्यामध्ये लवचिकता येते. प्रसिद्ध ग्रीक विचारवंत ॲरिस्टॉटल यांच्या मते आशयसूत्र हे लेखककेंद्री असते. थोडक्यात असे म्हणता येईल की कोणत्याही साहित्यकृतीचा मध्यवर्ती अनुभव आणि आशय म्हणजे आशयसूत्र होय. आशयसूत्र हे संहितेच्या बाहेरील समाज वास्तवाशी, सांस्कृतिक विचारप्रणालीशी संबंधित असते. आदिवासी कविता ह्या राजकीय, सामाजिक, निसर्ग, स्त्री, संस्कृती या आशयसूत्रात मांडल्या आहेत. जागतिकीकरणाच्या कविता, स्त्रीजीवन, आंबेडकरी विचारप्रेरणा, आदिवासी ऐक्याची भूमिका, सामाजिक

समस्या या घटकांचा परामर्श आदिवासी कवितेत घेता येतो.

राजकीय कविता

आदिवासी हा सर्वदूर जंगलात कसलीही शासकीय सुविधा न घेता जीवन जगतो. त्याला कधी राजकीय पुढारी तर कधी सरकारी अधिकाऱ्याशी आपल्या हक्कांसाठी लढावे लागते. घटनेने दिलेल्या हक्कांमुळे जागृत होऊन तो आवाज उठवू लागला आहे. हाकारा अंकामधून आलेल्या कवितातून प्रस्थापित व्यवस्थेला जाब विचारण्याचे काम आदिवासी कविता करताना दिसते. कवी वाहरू सोनवणे यांच्या खालील कवितेत राजकीय नेत्याचे चित्रण आले आहे.

सत्तेच्या हिरव्या पानाखाली
झोपा घेणारे बगळे
झोपेशी भांडत आहेत
आणि त्यांच्या पाठिंब्यावर
लचके तोडणाऱ्यांना
धडकी भरली आहे (हाकारा, १९८० पृ.३५)

वरील कवितेत आदिवासी नेत्यांचा खोटारडेपणा दिसून येतो. त्यांची आश्वासने खोटी असून झोपा घेणाऱ्या बगळ्यासारखी ढोंगी आहेत. या पुढाऱ्यांच्या जोरावर अनेक अन्याय अत्याचार आदिवासींवर केले जातात. त्याबद्दल आपले विद्रोही मत कवी सदर कवितेत मांडतो.

डाकूच्या पुराव्यांनी सुटतात खुनी
बहिष्कार घालणारे सुटतात निर्दोष
पुराव्याच्या विक्री सुलभेपुढे
परंतु एखाद्या गोंडावर
एखाद्या कोलामावर
अतीक्रण केल्यावर गुन्हेगार केले जाते
तेव्हा त्याला प्रथम द्यावा लागतो
माणूस असल्याबद्दलचा पुरावा
(हाकारा अंक १९८८,पृ.६४)

विस्थापित आदिवासींचे पुनर्वसन होत नसल्याने कुठेतरी मोकळ्या जागेवर आपला निवारा तयार करतात. अशावेळी तात्पुरता निवारा अतिक्रमण ठरते व आदिवासी गुन्हेगार ठरतो. खोट्या पुराव्याच्या आधारावर प्रत्यक्षात खऱ्या गुन्हेगारांना सरकार निर्दोष सोडते. आदिवासी समाजाला आपण माणूस म्हणून पुरावा द्यावा लागतो ही शोकांतिका कवीने इथे मांडली आहे. सरकार आणि पुढारी, कोर्ट, भ्रष्टाचारी लोक संगनमत करून गुन्हेगाराला मुक्त करतात.आपल्या न्याय्य हक्कासाठी लढणारा आदिवासी मात्र कोर्टाच्या चकरा मारतो. कवीची शंका योग्य वाटते. 'लीडर' या कवितेत कवी कृष्णकुमार चांदेकर म्हणतात की,

आमचे लीडर आम्हालाच 'राम-राम' करतात
आणि आमचीच संस्कृति सांगतात
प्यारे पोटभर आमचं खातात
आणि नावं त्यांचे घेतात (हाकारा १९९१ पृ. ८१)

या राजकारणात असंख्य आदिवासी म्होरके आपली राजकीय पोळी भाजण्यासाठी आपल्याच माणसांना फसवत असतात. आदिवासींचे खाऊन गुणगान मात्र परक्यांचे करतात. ज्या लोकांनी अन्याय केलाय, भाकरी हिसकावली आहे त्यांच्याकडे भिक मागतात. याचना करतात. प्रस्थापिथांशी कराव्या लागणाऱ्या लढाईत रक्त आमचेच जाते. नाव मात्र या पुढाऱ्यांचे होते अशी भावना कवी व्यक्त करतो. तसेच नैतिक अधःपतन झालेल्या राजकीय पुढाऱ्यांच्या बदलत्या भूमिकेचे चित्रण कवीने केले आहे. कवीने लोकशाही राज्यात असलेल्या पक्षपातीपणा व्यक्त करताना,

त्या दिवशी आमचे मतदान
नाकारले होते यासाठी की
लोक अन्न खावून गु हागत होते
आणि आम्ही झाडपत्ती खावून शेण
हागत होतो म्हणून (हाकारा १९९९ पृ.७४)

लोकशाहीमध्ये प्रत्येक नागरिकाला समान मताधिकार प्राप्त झालेला आहे. आदिवासींना जेव्हा वेगळी वागणूक दिली जाते तेव्हा कवी पेटून उठतो. मनात चीड निर्माण होऊन तो आवाज उठवतो. आदिवासी समाजाचा हा राजकीय अधिकार हिरावून सरकारी यंत्रणा त्यांच्यावर अन्याय करते. अतिशय शिवराळ भाषेत, प्रतीकांचा वापर करून आपल्या भावना व्यक्त केल्या आहेत.

सामाजिक कविता

अन्न-वस्त्र-निवारा या गरजा भागवताना सरकारी नावाने आलेल्या विविध योजनांच्या नावाखाली आदिवासींचे होणारे शोषण, विस्थापन, भ्रष्टाचार तसेच आरोग्याच्या समस्यांचे निराकरण वर्षोनुवर्षे तसेच चालत आलेले आहे. हे कोणीतरी समाजापुढे मांडायला हवे म्हणून सर्वप्रथम ते आदिवासी कवींनीच मांडले आहे.

पोट भरून खा बरं
अश्रु? अश्रुंचे काय
हे तर रोजच वाहत राहतात,
तुम्हीं जेवा पोट भरून...
आणि कुशितून
पोरगा कटाक्ष मारला
माझ्या पहिल्या घासावर (हाकारा-१९८५ पृ.३५)

आदिवासी समाजातील वास्तव चित्रण करणारी 'कटाक्ष' ही वाहरू सोनवणे यांची कविता आहे. अतिशय हळुवारपणे आदिवासींचे दुःख, दारिद्र्य मांडले आहे. रोजच्या दुःखाला कुरुवाळत जगणे त्यापेक्षा येणाऱ्या संकटाशी दोन हात करण्याची आदिवासी स्त्रियांची वृत्ती इथे दिसून येते. हा विद्रोह पोटापाण्यासाठी आलेला आहे.

भुजंग मेश्राम या आदिवासी कवीने आदिवासीला शिक्षण नाही त्यामुळे रोजगार नाही म्हणून वाट्याला आलेले दुःख, दिशाहीन जगणे या कवितेत चित्रित केले आहे. समाजामध्ये वाट्याला आलेली माणसांची नावे ही कशाचाही आधार न घेता ठेवली जातात. भावनात्मक आपलेपण, प्रेम, उत्साहाच्या भरात जो शब्द उत्स्फूर्तपणे येईल तोच त्याचे नाव बनून जाते. मग ते प्राणी, पक्षी, दैवते, वार, संस्कृती, धर्म, इतिहास या कोणत्याही एका निकषाचे पालन करणारे असले पाहिजे. कवी म्हणतो,

नाव काय ठेवू नाव
नावात जसं काही नसते
पर बुडाला बरंच असते
दगडधोंड्यात जलमला मनून दगड्या
अंधारात मनून काळ्या
गुरुवारी जनमला म्हणून बस्तऱ्या
हे झालं बक्कळ (हाकारा अंक १९९४ पृ.४७)

आदिवासी समाजाला दिली जाणारी सापत्न वागणूकीचे चित्रण कृष्णकुमार चांदेकर 'विषमता' या कवितेत व्यक्त करतात. आदिवासी समाजाला दिली जाणारी वागणूक येथे दिसून येते. कवी प्रस्थापितांना प्रश्न करतो,

गर्व करणाऱ्या संस्कृतीत
आम्ही जगत आहोत
त्यांच्याच मर्जीने मरत आहोत
परंतु जोशीबाईची मांडी दिसली
तर ती अब्रू ठरते आणि
मडावी बाईची मांडी दिसली तर
ती संस्कृती ठरते
असे का? (हाकारा अंक १९९१, पृ.६)

आदिवासी समाजाला दिली जाणारी विषमते वागणूक इथे व्यक्त झाली आहे. दोन संस्कृतीत असलेला दृष्टिकोन कसा वेगळा असून चीड निम करणारा आहे. एकीकडे उदात्तीकरण तर दुसरी अधोगती असा परस्पर भेद सांगितला आहे. आदिवास जे जगणं आहे ते निसर्गाच्या सानिध्यात आपसू आहे.

निसर्गपर कविता

आदिवासी साहित्यनिर्मितीची निसर्ग ही प्रथम प्रेरणा आहे. आदिवासी आणि निसर्गाचेनाते अतूट आहे. आदिवासी स्थानिक पर्यावरणाशी तादात्म्य पावलेले असतात. आदिवासींचेनिसर्गाशीनिगडीतजीवननिसर्ग आदिवासी कवितेत आले आहे.आदिवासी हा निसर्गाचा भोक्ता आणि त्राता या दोन्ही भूमिकेत वावरताना दिसतो. तो निसर्गपूजक असून निसर्गातील झाडे, डोंगर, नद्या, पशु, पक्षी, चंद्र, सूर्य, तारे यांना दैवत मानतो. हाकारामध्ये आलेल्या आदिवासी कवितांमध्ये अभिव्यक्तीसाठी आदिवासी संस्कृती, दैवते, जल-जंगल-पाणी यासारख्या प्रतिमा व प्रतीकांचा मोठ्या प्रमाणात वापर झालेला आहे. निसर्गावरील अतिक्रमणाचा विचार करताना कवी ...म्हणतो की,

होत आहे जंगलांचा नाश
विविध वनस्पतीच्या जातींचा विनाश
नाही घातला आवर तर एक दिवस
होईल साऱ्या मानव जातीचा ऱ्हास
एकत्र मिळून सारे आपण
करू वृक्ष वनस्पतींचे संरक्षण
अन् संवर्धन संगोपन
वाढवू या जंगलधन (हाकारा १९९५ पृ.१४)

आदिवासी निसर्गावर मनापासून प्रेम करतो म्हणून त्याची चिंता साहजिकच आहे. त्याचे निसर्गमय मन नेहमी त्याच्या सहवासात रममाण असते. कवी म्हणतो,

वाटते मजला होऊन फुल गुलाबाचे
मने लोकांची करावी आकर्षित
पसरावा सुगंध सगळीकडे
रहावे डौलाने तरुणीच्या केसांत
(हाकारा १९९३ पृ.५५)

निसर्गातील गुलाब होऊन लोकांना आपल्याकडे आकर्षित करून घ्यावे, सुगंध दरवळून पहावा, तरुणीच्या केसांमध्ये माळून स्वच्छंदीपणे फुलपाखरांसारखे बागडावे असे कवीला वाटते. जंगलजिव्हारातील पुनरापणे जागण्याने कल्पनाविलास चित्र रंगवले आहे.

अन्न शिजविण्यासाठी लाकूडफाटा मिळविणे अशक्य आहे. वनरक्षकाचा चक्रकाळा चावून हतबल झालेल्या आदिवासींची तगमग व्यक्त करताना कवी म्हणतो की,

आणण्यासाठी मोळीभर लाकूडफाटा
करावा लागतो जीवाचा आटापिटा
देईल का कोणी आमच्याकडे लक्ष
सुटेल का हा इंधनाचा प्रश्न (अंक १९९५ पृ.२२)

निसर्ग सहवासात जगत असताना फळे, कंदमुळे, शिकार, मासेमारी करून तो आपली उपजीविका भागवतो. आधुनिकीकरणामुळे नवनवीन संसाधने आली. आदिवासी मात्र पारंपारिक इंधन लाकूड जळणासाठी वापरतो. मात्र अलीकडे लाकूडफाटा सहजासहजी मिळत नाही. जबरदस्तीने मिळवावा तर तो गुन्हा ठरतो. आदिवासींना आपल्या प्राथमिक गरजाही पूर्ण करता येत नाहीत. सरकारचेही त्याच्याकडे दुर्लक्ष आहे असे कवी सांगतो.

स्त्री संघर्षाच्या कविता

आदिवासी स्त्रियांना अहोरात्र कष्ट करावे लागतात. आदिवासी समाजात स्त्री पुरुष समानता असते. आर्थिक दृष्टीने ती संपूर्ण कुटुंबाचा कणा असते. तिला आदिवासी समाजाने पूर्ण स्वातंत्र्य दिले आहे. स्त्रियांविषयी आदर व मातृसत्ताक कुटुंबपद्धती ही आदिवासी समाजात दिसून येते. आदिवासी स्त्री कणखर, शोषिक, निर्भय, स्वच्छंदी जीवन जगते. स्वातंत्र्योत्तरकाळात मात्र नागर समाजाच्या संपर्कात आल्याने तिचे मानसिक, आर्थिक, लैंगिक शोषण होताना दिसते. आदिवासी स्त्रियांच्या वेदना आदिवासी कवितेतून सर्वप्रथम शब्दबद्ध होताना दिसतात. उषाकिरण आत्राम यांनी आदिवासी स्त्रियांच्या संघर्षाच्या अनेक कविता हाकारा नियतकालिकातून मांडल्या आहेत. त्यांच्या काव्याची भाषा विद्रोहाची, क्रांतीची आहे. आपल्या समाजाची म्होरकी बनून त्या

एकप्रकारे सामाजिक स्त्रियांना सतर्कतेचा इशारा देतात. आपल्या आईला गोंड कन्या मनाला वाटते 'मी ही कोणाची'

सांग माय मी ही कोणाची ?
बापाची-भावाची ?
नवऱ्याची-सावकार-रेंजर-पाटील-
जमीनदाराची-शिंप्याची-सोनाराची-की आणखी
सांग मी कोणाची ? (हाकारा १९९१, पृ-८९)

येथे सामुदायिक गोंड कन्येची विवंचना लक्षात येते. समाजात तिच्या भोवती असलेला प्रत्येक पुरुष तिच्यावर अधिकार गाजवू पाहतो. आपल्या कामपूर्तीचे साधन मानतात. अशावेळी ती पेटून उठते. पुरुषप्रधान संस्कृतीच्या परिप्रेक्ष्यात स्त्रीच्या जगण्याला कवडीचीही किंमत नसल्याचे वास्तव चित्रण कवयित्री उषाकिरण आत्राम यांनी मांडले आहे. 'चिंबोरी' ही भुजंग मेश्राम यांची कविता लेडीज हॉस्टेलचा अनागोंदी कारभार प्रकट करते. वसतिगृहातील मुलींना अब्रूरक्षणासाठी करावा लागणारा संघर्ष प्रतीकांचा वापर करून मांडला आहे.

मला बी लय वाटतं
चिंबोरीगत जपावी नांगी
ठेवाव सुरक्षित मनात
अचानक ऑर्डर ओरडते
पाहुण्याना पसंत चिंबोरीपेक्षा नांगी
आता ग बाई? (हाकारा १९९८ पृ-३८)

प्रत्येक मुलीच्या मनाची ही व्यथा आहे. आलेल्या पाहुण्याचा पाहुणचार करताना या मुलींचे होणारे शोषण सदर कवितेत मांडलेले आहे. हे भयानक समाजवास्तव चिंबोरीची प्रतिमा, प्रतीकांचा वापर करून मांडले आहे. ती वाचकाला सुन्न करून सोडते.

उषाकिरण आत्राम यांच्या 'आश्रमशाळा' या कवितेतही हाच विषय आलेला आहे. शिक्षणव्यवस्थेतही आलेला भ्रष्टाचार, अनागोंदीपणाचा इथे उल्लेख केला आहे. घरदार सोडून वसतिगृहात राहायला आलेल्या पोरीला तेथील वातावरण पाहून आपल्या आईला सांगावेसे वाटते की,

खरंच सांगते ग आई काही खरे नाही
आश्रमशाळा आता सुरक्षित नाही
गुरुजनांवर आता आमचा विश्वास नाही
ज्ञानदानाऐवजी प्रेम लैंगिकता शिकवतात बाई
(हाकारा २००३,पृ-१४)

'शृंगार' या कवितेत उषाकिरण आत्राम आदिवासींच्या म्होरक्यांना उजागर करतात. आदिवासी स्त्रिया भोळ्या आहेत. ढोलाच्या थाप्यावर फसतात, नाच म्हंटले की नाचतात, शृंगार केल्याने अनेक तरुण भाळतात म्हणून कवयित्री या नवतरुणींना इशारा देतात की,अंगभर कपडे घाल. अवतीभवती असलेल्या पुरुषांचा खोटेपणावर भाळू नकोस. स्वतःला सांभाळ आणि तयार हो लढायला. त्या आपल्या कवितेत म्हणतात की,

गोंदून निळी-होवू नगं काळी !
रानफुलासारखी डवर
हो! सूर्यासाठी !
हो! सूर्यफूल
हो! तांबडी पळसाची लाल अंगार
तरच उठून दिसंल-
ह्या बाजार फुकयाले तुहा-'शिणगार'
(हाकारा १९९१, पृ.९१)

आदिवासी समस्याचित्रण: आदिवासी कवितेत अनेकसामाजिकप्रश्नांचीदखलघेतलीआहे. आदिवासींचाअज्ञानवआरोग्याचाप्रश्न, शिक्षणाचाप्रश्न,कुटुंबसंस्था, शेती, आर्थिकशोषणाचाप्रश्न, विस्थापणाचाप्रश्न, नक्षलवादाचाप्रश्न, जंगल-जमिनीचाप्रश्नअशाअनेकसमस्यांतूनआदिवासीपरिवर्तनालासुरुवातझालीआहे. नर्मदा सरोवर प्रकल्पादरम्यान भिल्ल आदिवासींना गावोगावी जाऊन हाकारा(हाक) देताना मेधा पाटकर म्हणतात की,

[illegible] आवश्यक आहे. आर्थिकदृष्ट्या, हा प्रश्न नेटाने [illegible] सोडवण्याची आर्थिकदृष्ट्या, विकासाच्या [illegible] विस्थापन साहत असताना, या प्रश्नाच्या [illegible] आर्थिकदृष्ट्या, तंत्रज्ञ व समाज-संघटक यांच्या [illegible] आर्थिकदृष्ट्या, शुल्लक मानापमानाच्या [illegible] पल्याशी याच आर्थिकदृष्ट्या [illegible] एका धरणाशी संबंधित पुनर्वसनाच्या [illegible] राष्ट्रीय पुनर्वसन धोरणाकडे, व विस्थापनाची [illegible] घेऊन इतर विकासांच्या बाबतीने यातूनही [illegible] प्रकल्पांच्याच पर्यायांकडे नेता येईल."[५] [illegible] जीवनात आधुनिकीकरणामुळे नव्यानेच [illegible] विस्थापनाच्या समस्येने त्यांचे [illegible] प्रभावित होत आहे. अनेक आदिवासी कवींनी [illegible] लक्ष वेधून घेतले आहे. 'धरण आणि मरण' या [illegible] चामुलाल राऊत म्हणतात की,

जेथे आदिवासी तेथेच धरण
तेच आदिवासींचे मरण
जेथे आदिवासी तेथेच खाण
साऱ्या आदिम जीवनाची घाण
जेथे आदिवासी तेथेच प्रकल्प
तोही त्यांना मारण्याचाच संकल्प
(हाकारा अंक १९९३ पृ.६०)

धरणासाठी हजारो आदिवासी पाडे खाली केले [illegible]. या विस्थापितांचे पुनर्वसन करण्याचे कुणीही [illegible] घेत नाही. या प्रकल्पामुळे आदिवासी संस्कृती, [illegible], जंगल-जमीन पाण्याखाली जाते. इतरांचा जो [illegible] होतो, विकास होतो त्यामुळे आदिवासींच्या [illegible] मात्र मरणच येते. याची खंत ते व्यक्त करतात. आदिवासी भागात जंगल नष्ट करून खोदल्या जाणाऱ्या [illegible] म्हणजे आदिवासी जीवन घाण करण्याचाच संकल्प. इतरांच्या सुखासाठी आदिवासींचा बळी का असा सवाल कवी प्रस्थापित व्यवस्थेला विचारतो. कुपोषण ही आदिवासी समाजाची महत्त्वाची समस्या म्हणता येईल. निरक्षर, निसर्गनिर्भर, दैववादी प्रवृत्तीमुळे शासकीय योजनांकडे काणाडोळा केला जातो. लहान मुले, मातांसाठी योग्य पौष्टिक आहाराची कमतरता, कष्ट, आर्थिक अस्थिरता यामुळे आदिवासी कुटुंबे आरोग्याच्या दृष्टीने कुपोषित होण्याचे प्रमाण वाढले आहे. शासकीय योजना कागदावर रंगविल्या जातात. मंत्र्यांचे दौरे हे फक्त दिखावा असतो. गरीबीचे जीवन जगताना आंबील पेज खावून दिवस काढतो. कवी पुरुषोत्तम आगाशे आपल्या 'कुपोषण' या कवितीत म्हणतात,

आदिवासी भागात होता कुपोषण
सरकारला येते आठवण
मंत्र्यांना येते जाग
दौरा होतो लगोलग
होते खेड्यांची पहाणी
विमाने आणि मोटारगाड्यांनी
केल्या जातात घोषणा
जाहीर होतात योजना (हाकारा १९९५ पृ.२२)

'घर' या कवितेत सोपान सुरकुले म्हणतात, सूर्य मावळल्यावर गुराखी गुरे घरी आणतात, पक्षी आपल्या घरट्यात परततात परंतु अशी काही माणसे आहेत त्यांना निवाराच नाही, घर नाही त्यांनी कुठं जायचं असा सवाल कवीला पडला आहे.

कुठेतरी चुली पेटलेल्या असतात
इथे मात्र चुलीच नसतात
इतलं जगणं भयाण असतं
जणू काय दुसरे स्मशानच असते
वाटत काळोख कधीच येऊ नये
आल्यावर कधीच उजडू नये
(हाकारा १९९१, पृ.३२)

अनेक लोक भटकंती करतात मात्र संध्याकाळी त्यांच्या चुली पेटतात. रानोमाळ भटकंती करणारा,

निसर्गावर गुजराण करणारा आदिवासी मात्र रात्र होऊच नये म्हणून प्रार्थना करतोय. या रात्रीच्या काळोखात त्याच्या त्याच्या जगण्याची परवड होते म्हणून हा काळोख आला तर कायमचा यावा असे कवी म्हणतो. बेघर झालेल्या कुटुंबाची कहाणी, वास्तव कवीने मांडले आहे.

थोर पुरुषांच्या कविता

आदिवासी समाजाला हीन लेखण्यापलीकडे सुसंस्कृत समजल्या जाणाऱ्या समाजात आदिवासीला वेगळे स्थान नाही. आदिवासींमध्ये मात्र समतेची एक सार्वजनिक परंपरा आहे. आदिवासींचे लढे, बंडाला आत्मसन्मानाचीच प्रेरणा होती. आपल्या मनातील सल, चीड व्यक्त करण्यासाठी आदिवासी कविता बंड करून उठते. त्यातूनच स्व समाज, जंगल, पूर्वज, प्रदेश, इतिहास, क्रांतिकारकांचा, परंपरांचा अभिमान, ओळख, अस्मिता अभिव्यक्त होऊ लागली. साहजिकच आदिवासी कवितांमधून थोर पुरुष, समाजसेवक, देशभक्त, संस्कृती, इतिहास, समाज, निसर्ग, दैवतांचे गौरवीकरण करण्यात आले आहे. थोर पुरुषांमध्ये बिरसा मुंडा, बाबूरावजी शेडमाके, राणी दुर्गावती, अनुताई वाघ यांच्या कार्याचा गौरव करण्यात आला आहे. क्रांतिकारक बिरसा मुंडा यांच्या पराक्रमाचे वर्णन करताना कवी म्हणता की,

आदिवासी अस्मितेचा बिरसा तू शिल्पकार
जंगलात तू असा की पहाडात शुभ्र धार तू
जीवन तुला मिळाले वय वर्ष पंचविस
फितुरीने घात झाला तू दिपविले जगास
बिरसा धरम तुझा सन्मार्ग सत्य आहे
वाणी तुझी अशी की जी झरणापरिस वाहे
(हाकारा अंक २०१४, पृ.२९)

आदिवासी क्रांतिवीर बिरसाच्या कार्याचे गुणगान गाताना त्याच्या ठायी असलेला सन्मार्ग तसेच धैर्य, शौर्य, वाणीचा कवी गौरव करतो. बिरसाच्या उलगुलान म्हणजे एकाचवेळी केलेला उठाव हे आदिवासी मुक्तीचे सूत्र वाटते. कमी वयात त्याने आपल्या नेतृत्त्व, पराक्रमाने इंग्रजांना जेरीस आणले होते. आप्तस्वकीयांच्या फितुरीने अवघ्या पंचविस वर्षात बिरासाला फासावर लटकविले गेले. त्यामुळे कवीला बिरसा हा आदिवासी अस्मितेचा हुंकार वाटतो. 'बिरसामुंडा' या आपल्या कवितेत उषाकिरण आत्राम बिरसाला पुन्हा आदिम मायांच्या कुशीत जन्म घेण्याचे आवाहन करते. इथे तुझे उलगुलान पुन्हा शांत झाले आहे. प्रस्थापितांचे अत्याचार सहन होत नाही. त्यामुळे क्रांतीच्या नव्या ज्वाला घेऊन पुन्हा आमच्यातला जोश जागवायला ये. डोंगरकपारीत सडक्या मोहाच्या फुलासारखे जीवन जगणाऱ्या आदिवासी जीवनाची नवीन पहाट होऊन ये असा आशावाद, याचना कवयित्री करते आहे. उषाकिरण आत्राम म्हणतात की,

अरे बिरसा! तू पुन्हा एकदा ये रे बाबा
आम्हा आदिम मायांच्या कुशांत जन्मायला
पुन्हा एकदा होवू दे 'उलगुन'!
ही रानाची सय जळून राख झाली रे
इथल्या रानकुशीला महारोग जडला रे
इथल्या मायच्या कुशीलाच सुरुंग लागला रे
कच्चीबच्ची-तरणीसाठी...
(हाकारा अंक १९९२ पृ.६०)

आदिवासी अस्मितेचा विचार करताना एकलव्याचा विचार मध्यवर्ती मानला जातो. प्रस्थापित समाजाने आदिवासी समाजावर केलेला अत्याचार, अन्याय हा कवितेचा मुख्य विषय मानून अनेक कवींनी आपले लेखन केले आहे. आदिवासी कवी विनायक तुमराम म्हणतात की,

एकलव्या !
वनजीवनाच्या पोटी जन्मलेल्या
तुझ्या धनुर्धारी आयुष्याचा
क्रूर तेजोवध !

ठरला आहे माझ्यासाठी विद्रोहाचा कुळारंभ
तुझ्या स्वप्नाच्या सूर्यास्तासाठी
मी रक्ताळलेले क्षितिज होऊ शकलो नाही
(हाकारा अंक १९८०, पृ.३९)

कवी प्रथापितांनी निषधराजा पुत्र एकलव्यावर केलेल्या अत्याचाराचे वर्णन करतो. एक वनवासी म्हणून वाट्याला आलेले दुःख, धनुर्विद्या प्राप्त करण्यासाठी वर्णव्यवस्थेचा गुलाम ठरलेल्या एकलव्याचे जीवन कवीला प्रेरणादायी वाटते. द्रोणाचार्यांनी विद्यादान न करताही हाताचा उजवा अंगठा गुरुदक्षिणा म्हणून मागण्याचे ऐतिहासिक कपट कारस्थान म्हणजेच क्रूर तेजोवध वाटतो. आदिवासी अस्मितेचा विचार करताना हतबल झालेले कवीचे मन विद्रोह करून उठते.

समारोप

'हाकारा' नियतकालिकाने आदिवासी वाङ्मयीन संकृतीला संपन्न केले आहे. 'हाकारा'ने नवआदिवासी कवींना एक विचारपीठ मिळवून दिले. आदिवासी रूढी, परंपरांचे दर्शन तसेच संवर्धन हा 'हाकारा' नियतकालिकाचा मुख्य हेतू आहे. आदिवासी कवितेच्या आशयसूत्रांची मांडणी ही वास्तवाच्या जाणिवेतून झाली आहे. आदिवासी कवितेचे मूळ हे आदिवासी मानूस असल्याने त्याच्या समस्या, जीवनसंघर्ष, संस्कृतीविषयीचे चित्रण मोठ्या प्रमाणावर आलेले आहे. संवादात्मक काव्य हे आदिवासी कवितेचे वैशिष्ट्य आहे. स्त्रीसंघर्ष, निसर्ग प्रेरणा, आदिवासी ऐक्याची भूमिका, सामाजिक समस्या, राजकारण, समाजकारण, थोर पुरुषांचे स्मरण या आशयसूत्रांत विविध आदिवासी कविता गुंफल्या आहेत.

संदर्भ

१. महामहोपाध्याय दुर्गे पुरुषोत्तम गणेश, महाराष्ट्र संस्कृती, कॉन्टिनेंटल प्रकाशन, पुणे, तृतीयावृत्ती २००३, पृ.७८१
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•••

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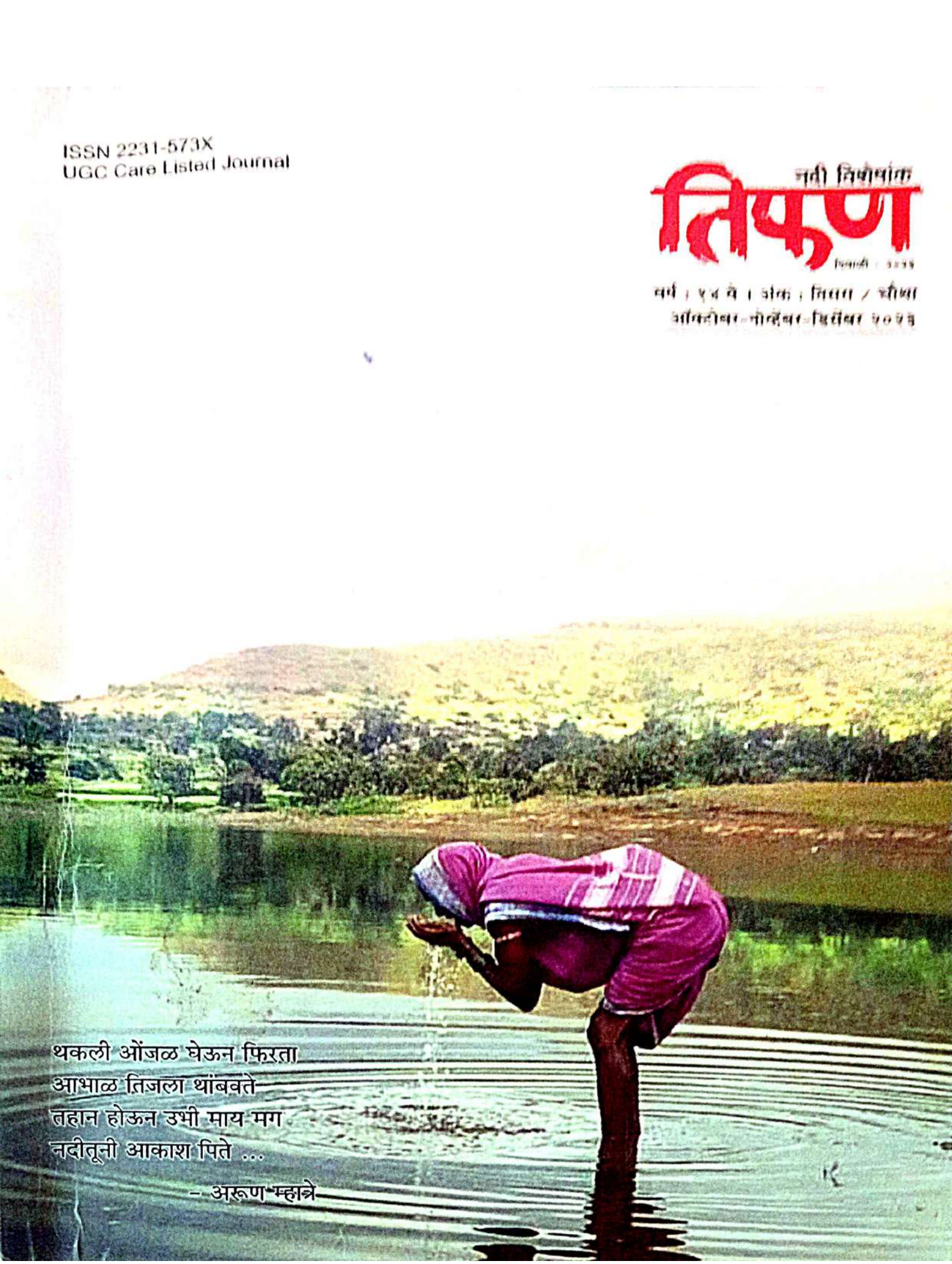

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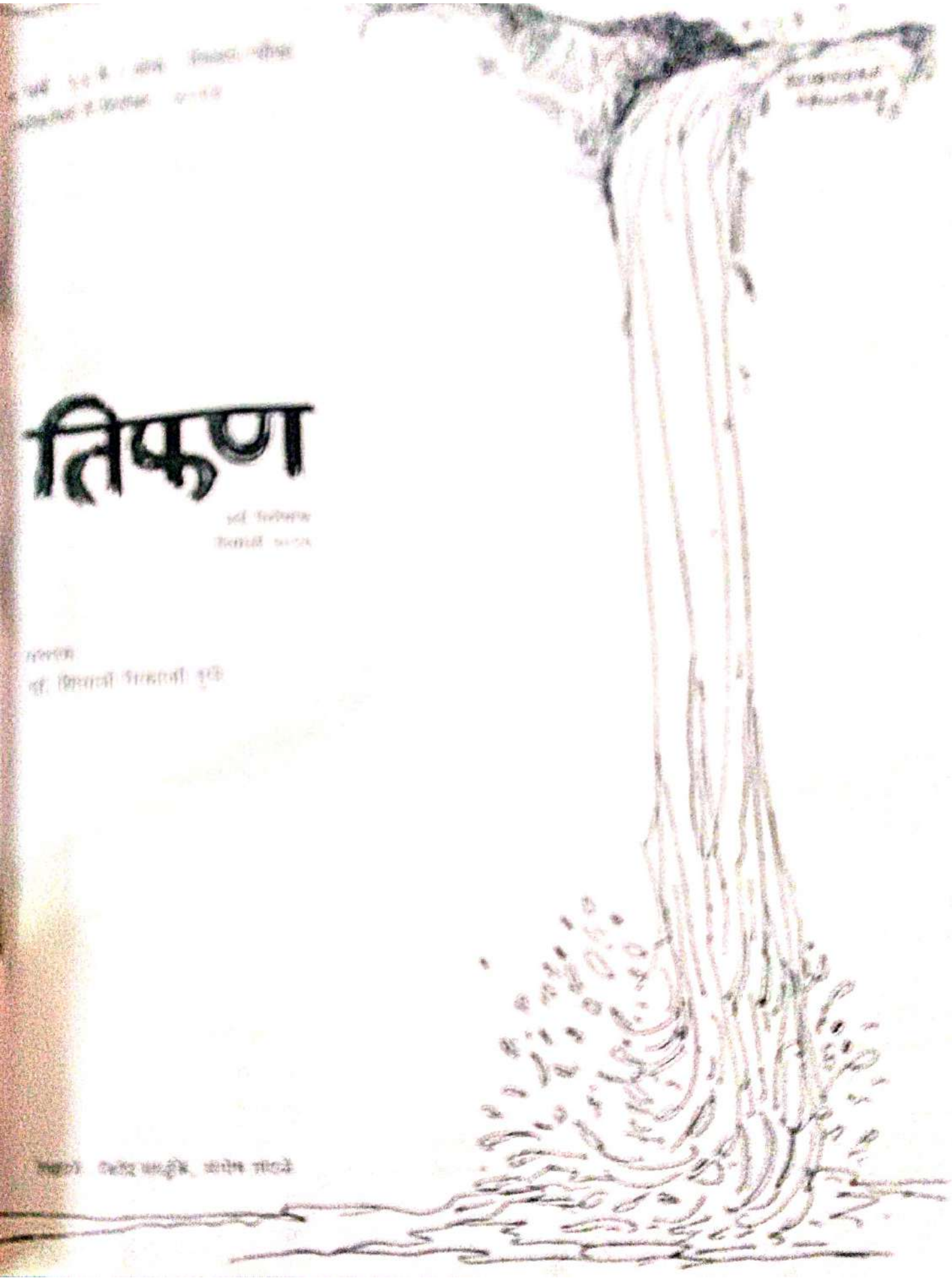

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डॉ. विकास बहुले, पुणे
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प्राचीनकाळापासून एक नदी प्रत्यक्ष वा अप्रत्यक्षपणे तिच्या आजूबाजूला राहणाऱ्या लोकांना असंख्य सेवा पुरवत असते. आपले जीवन नदीवरच अबलंबून आहे या जाणिवेतून तिच्याप्रती कृतज्ञतेची भावना लोकांमध्ये आपोआपच निर्माण होते. भारताची धार्मिक प्रतिमा समृद्ध आहे. भारतात कोणत्याही धार्मिक क्रियाकर्माला पाणी हे लागतेच. पाणी हे पंच महाभूतापैकी एक अंग आहे. दुसरी कोणतीही गोष्ट पाण्याला पर्याय होऊ शकत नाही हे माहीत असल्यानेच आपल्या पूर्वजांनी पाण्याला ईश्वराइतकेच अनन्यसाधारण महत्त्व दिले आहे.

नद्या : भारतीय संस्कृतीच्या पाउलखुणा

प्रस्तावना

पृथ्वीवरील जलावरण हा वातावरण आणि पर्यावरणाचा पाया आहे. सतत पाण्याच्या संपर्कात राहिल्याने आपल्याला आपल्या विचारांची परिपक्वता जाणून घेण्यास मदत होते आणि आपल्यातील सर्जनशील शक्तीचा शोधही घेता येतो. पाणी हे वसाहतीचे मध्यबिंदू समजले जाते. नदी ही पर्जन्य व परिसरातील जलावरणाचे अपत्य होय. त्यामुळेच नदी आणि मानवी संस्कृती या दोघांचाही प्रवास परस्परपूरक राहिला आहे. मानवी आरोग्य हे पूर्णतः नद्यांशी जोडले गेलेले

हे. भारतीय संस्कृती ही नद्यांच्या किनारीच उदयास ली आणि बहरली. नदीशिवाय संस्कृती नाही आणि कृतीशिवाय संस्कार नाही, अशी मानवी जीवनाची दरीत वाटचाल सुरु आहे. नदी ही संस्कृतीची निर्माती, क आणि संवर्धक आहे. प्रगती आणि विकासाची रक आहे. ऋग्वेदामध्ये सिंधू, सरस्वती यांसारख्या यांना देवता मानून त्यांचे स्तवन केलेले आपल्याला ाढळते. आर्यांच्या संस्कृतीचा विकास गंगा व सिंधू द्यांशी तर द्रविड संस्कृतीचा विकास दक्षिणेकडील र्मदा, गोदावरी, कृष्णा या दक्षिणेकडील नद्यांशी गडित आहे. मानवी संस्कृतीचा अभ्यास करायचा सेल तर या नद्यांचा, त्याकाठी वसलेल्या वसाहतींचा, स्कृतीचा, परंपरा आणि लोककथा, लोकसमज या टकांचा अभ्यास करणे महत्त्वाचे ठरते.

प्राचीनकाळापासून एक नदी प्रत्यक्ष वा अप्रत्यक्षपणे तिच्या आजूबाजूला राहणाऱ्या लोकांना असंख्य सेवा रवत असते. आपले जीवन नदीवरच अबलंबून आहे या जाणिवेतून तिच्याप्रती कृतज्ञतेची भावना लोकांमध्ये आपोआपच निर्माण होते. भारताची धार्मिक प्रतिमा समृद्ध आहे. भारतात कोणत्याही धार्मिक क्रियाकर्माला पाणी हे लागतेच. पाणी हे पंच महाभूतापैकी एक अंग आहे. दुसरी कोणतीही गोष्ट पाण्याला पर्याय होऊ शकत नाही हे माहीत असल्यानेच आपल्या पूर्वजांनी पाण्याला ईश्वराइतकेच अनन्यसाधारण महत्त्व दिले आहे. पाण्याची विध्वंसकता आणि महती दोन्हीचे ज्ञान असल्याने तलाव,कुंड, विहिरी खोदण्यावर त्यांनी भर दिला. अर्थतज्ञ ॲडम स्मिथ म्हणतात, 'पाणी ही नैसर्गिक संपदा आहे. तिचे मोल पैशांत करण्याची पद्धत असली तरी पाणी अमूल्य आहे.' आज आधुनिकीकरणाच्या रेट्यामध्ये आपण आपली संस्कृतीच मातीमोल ठरवू पाहतो आहोत. महाराष्ट्रातील दोन तृतीयांश नद्यांची अवस्था शुष्क, कोरडीठाक झाली आहे. ओढे आणि नाले अतिक्रमणांच्या विळख्याने गुदमरत आहेत. अशा या नद्यांचा श्वास मोकळा करून त्यांना पुनरुज्जीवित करण्याचा निर्धार प्रत्येक नागरिकाने करणे काळाची गरज बनली आहे.

नद्या आणि भारतीय संस्कृती: भारताबद्दल सांगायचे तर आपली संस्कृती नदीमातृक अर्थात जलकेंद्रीत आहे. नदी म्हणजे केवळ नुसता पाण्याचा ओघ नसून ती एक चैतन्यशाली, जिवंत शक्ती आहे. अथर्ववेदात नदी म्हणजे असे जल की जे मेघांना तोडून पृथ्वीवर वाहताना नाद करते ते जल म्हणजे नदी. भारतीय संस्कृतीच्या पाऊलखुणा म्हणून आपण ज्यांच्याकडे पाहतो, ते रितीरिवाज, रूढी-परंपरा, जगण्याच्या पद्धती एका पिढीकडून पुढच्या पिढीकडे आपोआप सरकत जातात आणि संस्कृती हळूहळू नदीपात्रासारखी सर्वत्र पसरते देशोदेशीची संस्कृती भिन्न असली, तरी त्यात एक समानतेचा धागा असतो ; तो म्हणजे दुसऱ्याकडे जे चांगले आहे, त्याचा सन्मान राखण्याचा. जे भव्य-दिव्य आहे, त्यासमोर नतमस्तक होणे, हा संस्कृतीचा स्थायीभाव असतो. आजवर विकसित झालेल्या सर्व मानवी संस्कृती नद्यांच्या काठावर विकसित झाल्या आहेत. या विकसित झालेल्या संस्कृतींनी पाणी व्यवस्थापन अतिशय कल्पकतेने केलेले दिसते. सामान्यतः समकालीन मेसोपोटेमिया (टायग्रिस-युफ्रेटीस), इजिप्त (नाईल), भारतातील सिंधू (सिंधू) हे प्रदेश त्यांच्या सभ्यतेच्या शिखरावर पोहोचल्या आहेत. या सर्व संस्कृतींमध्ये एक गोष्ट समान होती की त्या सर्व नदी खोऱ्यात वाढल्या. त्यामुळे नद्या हा आपल्या जीवनाचा आधार आहेत असेच म्हणावे लागेल. नदी आजारी असल्यास संस्कृती आजारी पडते.

प्राचीन भारतीय संस्कृतीमध्ये 'आपोदेवतांनी आमचे कल्याण करावे आणि आम्हाला पुनित करावे,' अशी ऋग्वेदात प्रार्थना आहे. 'जलदेवता' म्हणजेच नद्या या पवित्र असून जो त्यांच्या जलात स्नान करील, त्याला पावन करणाऱ्या असतात, ही भावना ऋग्वेदकाळापासून प्रचलित आहे. देशात पूर्वी नद्यांना आईचा दर्जा होता.

त्यांचे सर्वत्र पूजन केले जात होते. "वेदकाळी राजस्थान हा फार समृद्ध प्रदेश होता व सरस्वती ही समुद्रास मिळणारी वेदातील सर्वप्रथम नदी होती. ती प्रभास क्षेत्राजवळ समुद्रास मिळत होती. येथे हे स्पष्ट केले पाहिजे की, आर्य पश्चिमेच्या आखातातून जलमार्गाने सर्वप्रथम सरस्वतीच्या तीरावर आले व तेथे, सिंधू शहरापासून जवळच, वेगळ्या ठिकाणी, त्यांनी आपली वस्ती केली. राजस्थानच्या वाळवंटात सरस्वतीच्या तीरावर सिंधू शहरे उत्खनित झाली आहेत. ऋचांत सरस्वतीचे महत्त्व सर्वांत जास्त आहे. कारण आर्यांनी प्रथम तिच्या काठी वस्ती केली होती आणि आपले सर्वप्रथम राज्य ब्रह्मावर्त (Land of Vedic Prayers) सरस्वती आणि दृषद्वती या नद्यांच्या मध्यभागी स्थापले. पुढील काळात मनुस्मृतीत या प्रदेशाला 'देवनिर्मित देश' व सरस्वती आणि दृषद्वती या नद्यांना 'देवनद्या' म्हंटले गेले आहे."[१]

यावरून आपल्या लक्षात येते की, 'सरस्वती' ही वैदिक काळात आर्यांची आदरणीय नदी होती. त्यांनी तिला 'अंबितमा' (श्रेष्ठ माता), 'नदीतमा' (श्रेष्ठ नदी), 'देवितमा' (श्रेष्ठ देवी), अशा शब्दांनी गौरवले आहे. महर्षी व्यासमुनींनी नद्यांना 'विश्वस्य मातरः' म्हणजेच विश्वाची माता असे संबोधून तिचा गौरव केल्याचा उल्लेख आढळतो. भारतीय संस्कृतीत नदीस्नान हे पवित्र मानले आहे. सोमवती अमावस्या, चंद्र-सूर्यग्रहण, संक्रांती, शिवरात्री, अर्धोदय इ. दिवशी नदीवर जाऊन स्नान करावे असे धर्मशास्त्रात सांगितले आहे. कार्तिकस्नान, माघस्नान, वैशाखस्नान ही स्नानेही नदीच्या पाण्यातच करावी, असं शास्त्रवचन आहे. जिथे दोन नद्यांचा संगम होतो, त्या जागेला 'प्रयाग' म्हणतात. प्रयागात स्नान हे अत्यंत पुण्यप्रद मानले जाते.

नदीला सवाष्ण मानतात. नदीला हळदी - कुंकू, बांगड्या, साडी - चोळी वाहण्याची आणि खणा - नारळाने तिची ओटी वाहण्याची प्रथा रामायणकाळापासून चालत आली आहे, ग्रामीण भागातील काही लोक नदीत नागदेवतांचे वास्तव्य असते म्हणून वा भूताखेतांमुळे नदीला पूर येतो, या समजुतींनी नदीची पूजा करतात. गंगा नदी ही अत्यंत पवित्र मानलेली असल्यामुळे लोक आपल्या मृत पूर्वजांच्या अस्थि गंगेत नेऊन विसर्जित करतात. स्त्रिया आषाढ महिन्यात नदीला पूर येतो तेव्हा 'नदीत्रिरात्रव्रत'. चैत्रात 'नदीव्रत' करतात. नदीचे पाणी हे परंपरेमध्ये पापविमोचक मानले जाते. वेगवेगळ्या नदीमहात्म्यांमध्ये ही संकल्पना आहे. वैधव्य हे पापग्रस्त मानले जाते, संबंधित स्त्रीच्या पापाचे फळ म्हणून तिला ते लाभले, असे मानले जाते. मनुष्याची सर्व पातके त्यांच्या केसांच्या मुळाशी असतात अशा अर्थाच्या शास्त्रवचनाच्या आधारावरूनच गंगा किनारी वपन करुन आलेल्या विधवा स्त्रियांना गंगा भागीरथी म्हणण्याची चाल पडली असावी.

भारतातील नदीमातृक संस्कृतीचा विचार करता नदी ही प्रत्येक समूहाची माता असते. तिला लोकमातेचे व्यापक स्वरूप येते. समाजाची जीवनशैली, उपजीविकेची साधने, सामाजिक व्यवहार नदीच्या भोवती एकरूप झालेला असतो. या वसाहतीला तीर्थक्षेत्राचे स्वरूप प्राप्त होऊन दंतकथा, लोककथेचे वलय त्याला प्राप्त होते. आर्थिक व तात्त्विक विचारांची उलाढाल होते. भारतात गंगेप्रमाणेच सिंधू, सरस्वती, कृष्णा, कावेरी, गोदावरी या नद्यांनाही पवित्र मानले जाते. मानवी संस्कृतीचा उदय नदीच्या सानिध्यातच झाला. नातेसंबंध, कुटुंबसंस्था, ग्रामसंस्था, सहजीवन, धर्म, पर्यावरणसंस्था या घटकांचा विकास झाला. गंगा-यमुनेच्या दुआब प्रदेशात यज्ञसंस्कृती विस्तारली आहे. प्राचीन काळी चोळ आणि पल्लवांची

ल्ये, तसेच द्रविड संस्कृती कावेरीच्या तीरावर उदयाला आली. तुंगभद्रा नदीच्या काठी वैदिक संस्कृतीचा सर्वोच्च अभिमान बाळगणारं विजयानगरचं साम्राज्य उदयाला आलं. भारतीय वनसंस्कृती नर्मदा नदीच्या किनारी फुलली. गोदावरीच्याच तीरी महाराष्ट्र संतांच्या भक्तीसाहित्याची गंगा दुथडी भरून वाहिली. कृष्णा नदी ही महाराष्ट्राची आराध्यदेवता. महाराष्ट्राचं साधुत्व आणि वीरत्व, स्वतंत्रता आणि उदारता, सारे काही कृष्णेच्या वत्सल कुटुंबात वाढले आहे. अशाप्रकारे भारतीय संस्कृतीत नद्यांचे स्थान केंद्रस्थानी मानले जाते. पूर्वजांना पाण्याचे महत्त्व माहीत होते. मानवाचा इतिहास हे दाखवतो की, जगातील सर्वोत्कृष्ट संस्कृती ह्या नदीकाठी असलेल्या मानवी वसाहतीत झाल्या आहेत. उदा, नाईल नदीच्या काठची इजिप्त संस्कृती, सिंधू नदीकाठची हडप्पा संस्कृती, होल्गा नदीकाठची रशियन संस्कृती.

पाणी हे जीवन आहे. त्याबद्दल पूर्वजांना आदर होता. "आपल्या भारतीय संस्कृतीमध्ये सर्व क्रियाकर्माला पाणी लागते. मग तो एखाद्याचा जन्म किंवा मृत्यू असू दे. कुठल्याही धार्मिक क्रियाकर्माला पाणी हे लागतेच. अशा तऱ्हेने पाण्याचे जीवनातील महत्त्व जागोजागी ध्यानात येते. स्त्री ही शक्ती व मानवी जीवनाची जनक असल्यामुळे आपल्या सर्व नद्यांना देवींची नावे दिली आहेत. उदा. सरस्वती, यमुना, गंगा, कावेरी, कृष्णा, कोयना इत्यादी. आपल्या संस्कृतीत स्त्रीला माता म्हणून संबोधले जाते. माता म्हणून तिचे महत्त्व आहे. अशी ही आपल्या संस्कृतीत पाण्याची महती. पाणी हे पंचभूतांचे एक अंग आहे."[२]

नद्यांचे उगम आणि लोकसमज : प्राचीन भारतीय संस्कृतीच्या इतिहासात मूळ पेशा शेती हाच असल्याने कृषी अथवा मानवी जीवनात पाणी या घटकाला मध्यवर्ती स्थान प्राप्त झाले होते. "नद्यांची निर्मिती, त्यांची नावे यांच्या संदर्भात अद्भुत वाटतील अशा कथांची निर्मिती हे भारतीय संस्कृतीचे वैशिष्ट्ये आहे. त्यातील काही कथांमध्ये शास्त्रीय वास्तव आहे. तर काही कपोलकल्पित आहेत, संस्कृतीनुसार नद्यांना नावे आढळतात. नद्यांच्या काही नावांत देवदेवता, पुराणकालीन, रामायणकालीन, ऋषी-मुनींची नावे, महाभारतकालीन, आकाशस्थ ग्रह-ताऱ्यांची नावे, जनावरे, पक्षी, वृक्ष, फुले, फळे, आद्यवस्तु, रंग इ.चाही समावेश होतो. पारमार्थिक विषयांतील नावे तीर्थक्षेत्रांना आढळतात. तसेच नदीपात्राच्या त्यातील प्रवाहाच्या किंवा परिसराच्या एखाद्या वैशिष्ट्याचा संबंधही नदीच्या नावाशी आढळतो."[३] नदी अनेक दऱ्या, गावे आणि शहरांमधून वाहते आणि तिच्या मार्गात येणाऱ्या प्रत्येक वनस्पती आणि प्राण्यांची तहान भागवते. नद्या उगम पावतात व त्या अखंड प्रवास करीत आजूबाजूला हिरवळ निर्माण करण्याच्या प्रयत्नात प्रचंड वनराई जंगलांना पोसतात आणि ती जंगले पावसाचे पाणी जमिनीच्या पोटात मोठ्या प्रमाणात साठवून ठेवतात व त्यामुळे झऱ्यांची निर्मिती होते व असे असंख्य झरे छोटे छोटे झरे एकत्रित होवून नदीच्या प्रवाहाची सुरूवात होते. आपल्या पुराणांमध्ये बहुतेक सर्व नद्यांचे उगम दैवी मानण्यात आले आहेत. ऋषीचे कुळ आणि नदीचे मूळ विचारु नये अशी आपल्याकडे म्हंटले जाते. नदीचा जन्म ही बाळाच्या जन्मासारखीच आनंददायी घटना आहे. भारतातील सर्व नद्यांना आपण देव मानतो त्यामुळे प्रत्येक नदीला पौराणिक नावे आहेत व त्यांच्या स्वतंत्र लोककथा आहेत. त्यांच्याबद्दल नाना कथा सांगितल्या जातात त्या किती खऱ्या किती खोट्या त्याचा विचार न करता केवळ मनोरंजनासाठी, पौराणिक ठेवा म्हणून लोकमानसाने जतन केल्या आहेत.

जगातील विविध संस्कृतीमध्ये स्त्रीजातीला वेगवेगळे स्थान दिले गेले आहे. काही संस्कृतीमध्ये स्त्रियांना देवी, कापोल्कालपोसमान आदराचे तसेच काही संस्कृतीत चेटकीण मानून तिचा छळही केलेला दिसतो. भारतीय संस्कृतीत नदीला दिलेला मातेचा दर्जा

हा प्रचलित समजातूनच दिला आहे. वास्तविक स्त्रीत्व, मातृत्त्व या सामाजिक संकल्पना आहेत. जीवनशैलीतील प्रमुख घटक म्हणून तिला चैतन्य बहाल करून लोकदेवता म्हणून तिचे उदात्तीकरणही केले आहे. जलसंस्कृतीचे अभ्यासक डॉ. मोरवंचीकर म्हणतात की, "नदीला लोकमाता तथा लोकसंस्कृतीची माता मानली जाते. या मधूनच नकळत रूपकाच्या माध्यमातून कधीकाळी होऊन गेलेल्या ऐतिहासिक घटनांचे जतन केले जाते. या घटना लोक इतिहासात म्हणजेच लोकमनात जशा रुतल्या आहेत, तशाच त्या जतन केल्या गेल्या आहेत. प्रादेशिकतेनुसार त्यामध्ये बरेच फेरफार केले जातात. कारण त्यांना वास्तवाशी फारसे देणे-घेणे नसते. असाच काहीसा प्रकार खोरेनिहाय सांगितल्या जाणाऱ्या नदीमातृक संस्कृतीच्या संदर्भात दिसून येतो. नदीकाठी अनादि कालापासून वसलेल्या मानवी पुंजक्यांची ही उस्फूर्त प्रतिक्रिया असते. यामध्ये एकीकडे नदी जलावरणाचे प्रादेशिक अपत्य असते, तर दुसरीकडे ती पर्यावरणाची माताही असते."*

भारतीय परिप्रेक्ष्याचा विचार करता नद्यांच्या उगमापासूनच्या निर्मितीच्या, प्रवासाच्या पाउलखुणा, प्रादेशिक आख्यायिका, लोककथा, धार्मिक विधी, नद्यांचे स्त्रीत्व, लोकसमज भारतीय संस्कृतीत प्रचलित आहेत. एकेक नदी म्हणजे एकेक संस्कृतीचा प्रवाहच आहे. लोकांचे जीवन नद्यांच्या प्रवाहात बांधले गेले आहे. त्याचा संबंध जमिनीच्या सुपीकतेशी आणि स्त्रियांशी आहे. भारतातील काही प्रमुख नद्यांच्या उगमाचा आणि लोकसमजाचा आढावा घेता येईल.

गंगा : गंगा नदी हिमालयात गंगोत्री येथे उगम पावते. पुराण आणि हिंदू धर्मग्रंथांमध्ये गंगा हिला पातालमध्ये भागीरथी आणि स्वर्गात मंदाकिनी म्हणून संबोधले जाते. जगातील एकमेव नदी ज्याला आई म्हणून संबोधले जाते ती म्हणजे गंगा. तिला स्वर्गीय नदी मानले जाते. भागीरथी व अलकनंदा यांच्या देवप्रयाग येथील संगमातून अधिकृत गंगा अवतीर्ण होते. वाल्मिकी रामायणानुसार राजा हिमावत व राणी मेनका यांची कन्या. विष्णूपुराणात ती विष्णूच्या पायांच्या घामाने निर्माण झाल्याचे सांगितले आहे. वामन पुराणानुसार वामनाच्या रूपात भगवान विष्णूंनी आपला एक पाय आकाशाकडे उंचावला, तेव्हा ब्रह्माजींनी भगवान विष्णूंचे पाय धुतले आणि त्यांच्या कमंडलमध्ये पाणी भरले. या पाण्याच्या तेजाने ब्रह्माजींच्या कमंडलमध्ये गंगेचा जन्म झाला. ब्रह्माजींनी गंगा हिमालयाच्या स्वाधीन केली, अशा प्रकारे देवी पार्वती आणि गंगा या दोघी बहिणी झाल्या. गंगा नदीच्या वेगवेगळ्या व्युत्पत्ती हिंदू जीवनात भारतभर पवित्र मानल्या आहेत. गंगेला भारतीय संस्कृतीचा आत्माच मानले जाते. गंगा नदीत स्नान करणे म्हणजे सर्व पापांची शुद्धी करणे, मोक्ष प्राप्त होणे असे समजतात. गंगा दशहरा, दशमी किंवा दहाव्या दिवशी हजारो लोक गंगेच्या तीरावर स्नान करण्यासाठी गंगोत्री, हरिद्वार किंवा वाराणसी तीर्थक्षेत्रांमध्ये गर्दी करतात. गंगेत स्नान केल्याशिवाय जीवन अपूर्ण असल्याचे बहुतेक हिंदू कुटुंबांमध्ये, प्रत्येक घरात गंगेच्या पाण्याची एक कुपी ठेवली जाते. घरात पवित्र गंगेचे पाणी असणे शुभ आहे, तसेच जर एखाद्याचा मृत्यू होत असेल तर ते पाणी पिल्यास एखाद्या व्यक्तीचा आत्मा मागील सर्व पापांपासून शुद्ध करू शकते आणि ते आजारदेखील बरे करू शकते.

सरस्वती : सरस्वती ही एक पौराणिक नदी आहे. जिचा वेदांमध्येही उल्लेख आहे. त्याला प्लाक्षवती, वेदस्मृती, वेदवती असेही म्हणतात. ही नदी हिमाचलमधील सिरमोर राज्याच्या पर्वतीय भागातून उगम पाऊन अंबाला व कुरुक्षेत्र, कैथल मार्गे पटियाला राज्यात प्रवेश करून सिरसा जिल्ह्यातील द्रिष्द्वती (कांगार) नदीला जाऊन मिळते असे म्हणतात. सरस्वती नदी भौतिक स्वरूपात अस्तित्वात नसेल पण आजही तिचे अनेक अर्थ आहेत. सरस्वती नदी आजही वारसा म्हणून

स्तित्वात आहे. सरस्वती ही विद्येची देवी म्हणून पूज्य
ाहे आणि ज्ञानाचा सर्वात जुना लिखित पुरावा वैदिक
स्कृतीतच सापडतो सरस्वती ही विद्येची देवी म्हणून
ज्य आहे आणि ज्ञानाचा सर्वात जुना लिखित पुरावा
दिक संस्कृतीतच सापडतो. आपल्याला आपले पठन
र्ण करता यावे म्हणून व्यासांनी नदीला हळू वाहण्याची
वनंती केली. मात्र उन्मत्त सरस्वती नदीने त्यांचे ऐकले
ाही. ती वेगाने वाहत राहिली. तिच्या अशा वागण्यामुळे
चिडलेल्या श्रीगणेशाने 'तू एक दिवस नष्ट होशील' असा
शाप दिला. आणखी एका पौराणिक कथेनुसार ज्या देवाने
विश्व निर्माण केले त्या ब्रह्मदेवाच्या डोक्यातून सरस्वतीने
जन्म घेतला. ब्रह्मदेवाने पाहिलेली ती सर्वात सुंदर स्त्री
होती. तिच्या सौंदर्याची ब्रह्मदेवाला भुरळ पडली आणि
तिला साध्य करावी अशी इच्छा ब्रह्मदेवाच्या मनात
निर्माण झाली. आपली जी विशेष दखल घेतली जात
होती त्याबद्दल सरस्वती नाखूष होती. तिने तिथून पळून
जाण्याचा प्रयत्न केला. त्यामुळेच ही नदी जमिनीखालून
वाहते असेही म्हणतात.

कृष्णा : कृष्णा ही महाराष्ट्राची आराध्यदेवता आहे. कृष्णामाई महाबळेश्वर येथे उगम पावते, चार मैत्रिणी कोयना, सावित्री, गायत्री आणि वेण्णा. यातील कोयनाच काय ती कृष्णेला थोडी सोबत करते, गायत्री आणि वेण्णा लगेचच कृष्णेला मिळतात तर सावित्री थेट कोकणात उतरते. कोयना सगळ्यात दुर्दैवी. उगमापासून काही अंतरावरच तिच्यावर कोयना धरण बांधले गेले आहे जे कोयनेचे पाणी वळवून कोकणात, वशिष्ठी मध्ये ओतते. अशी कथा आहे की सावित्रीनेच त्रिमुर्तीला शाप देऊन त्यांना नदी बनविले. कृष्णा म्हणजे विष्णूच. कृष्णेचा उत्सव हे वाईचे वैभव आहे. स्कंदपुराणांतर्गत कृष्णामहात्म्यात वाईचा वैराजक्षेत्र असा उल्लेख आढळतो. पांडव आपल्या अज्ञातवासात इथेच काहीकाळ थांबले होते अशी समजूत आहे. महाराष्ट्र, कर्नाटक आणि आंध्रप्रदेश या राज्यांतून कृष्णा वाहते. कृष्णेचे थेंबभर पाणी पोटात गेले तरी पुण्य लाभते अशी समजूत आहे. इंद्रायणी, भीमा कृष्णेत विलीन होतात.

गोदावरी : गोदावरी ही दक्षिण भारतातील प्रमुख नदी आहे. द्वीपकल्पीय नद्यांच्या दुसऱ्या उपनद्यांपैकी ही सर्वात मोठी आहे. तिला दक्षिण गंगा असेही म्हणतात. त्याचा उगम पश्चिम घाटात सापडतो. तो महाराष्ट्रातील नाशिक जिल्ह्यातील आहे. पौराणिक कथेनुसार गौतम ऋषींनी गोहत्येचे प्रायश्चित म्हणून भगवान शंकराची तपस्चर्या केली. शंकरांनी प्रसन्न होऊन ब्रह्मगिरी पर्वतावर जटा आपटल्या आणि गोदावरी पृथ्वीवर अवतरली. गौतम ऋषींनी गोदावरीत स्नान करून गोहत्येचे पाप धुतले. त्यामुळे तिला गोदावरी हे नाव पडले. ऋषी गौतम यांच्याशी जोडल्यामुळे तिला गौतमी असेही म्हणतात. या नदीत स्नान केल्याने सर्व पापे धुऊन जातात, म्हणूनच तिला "जुनी गंगा" किंवा "प्राचीन गंगा" असेही म्हटले जाते. गोदावरीचे नाशिक "पंचवटी" म्हणून ओळखले जाते. रामजी पंचवटी आपल्या वनवासाच्या कालावधीत येथेच राहिले. लक्ष्मणाने येथे शूर्पाखाचे नाक कापले होते आणि सीतामैयाच्या रावणाचाही येथे पराभव झाला होता. राजमहेंद्रीवरम हे लपण्याचे ठिकाण त्याच्या धार्मिक आणि ऐतिहासिक महत्त्वासाठी प्रसिद्ध आहे. ती सात भागांत विभागलेली असल्यामुळे तिला वसलेली गोदावरी असेही म्हणतात. रामजीचे वडील राजा दशरथ वनवासात असताना रामजींनी आपल्या वडिलांचे देहदान गोदावरी किनाऱ्यावर केले होते. रामायणातील महत्त्वामुळे गोदावरी नदी जगातील एक पवित्र स्थान आहे.

नर्मदा : नर्मदा नदी ही एक पवित्र नदी आहे. नर्मदा नदीचा उगम हा मध्य प्रदेशातील अनूपपूर जिल्ह्यातील अमरकंटक पर्वतावरून झाला आहे. नर्मदा नदीला अनेक नावांनी संबोधले जाते. या नदीला रेवा देखील म्हटले जाते आणि पूर्वी नारबदा म्हणूनही ओळखले जाते किंवा नेरबुड्डा म्हणून ओळखले होते. पवित्र ग्रंथ

रामायण, महाभारत, वेद, पुराण अशा अनेक ग्रंथांमध्ये या नदीचा उल्लेख आहे. एका पौराणिक कथेनुसार गंगा नदी कमंडलूच्या रूपात धारण करते आणि नर्मदेवर स्नान करण्यासाठी आणि आपल्या पवित्र पाण्यात स्नान करण्यासाठी येते. या नदीला माता देखील म्हणतात आणि पूजा केली जाते. नर्मदा नदी मध्ये स्नान केल्याने पाप मुक्त होते असे मानले जाते. नर्मदा नदीच्या आजूबाजूला अनेक देवळ्या आहेत. त्यापैकी एकाच्या मते, एकदा शिवाचा नाश करणाऱ्या भगवान शिवाने इतके कठोर ध्यान केले की त्यांना घाम येऊ लागला. शिवाचा घाम जमिनीत जमा झाला आणि नर्मदेच्या रूपात वाहू लागला. आणखी एक आख्यायिका अशी आहे की शिवाचा निर्भीत भगवान ब्रह्मदेवाच्या डोळ्यांतून पडलेल्या अश्रूंच्या दोन थेंबांमुळे नर्मदा आणि ब्रह्मपुत्रा या दोन नद्या आल्या आणि यांचा उगम झाला. प्रवाहाविरुद्ध वाहणाऱ्या नर्मदा नदीमागे एक पौराणिक कथाही प्रचलित आहे. या पौराणिक कथेनुसार, नर्मदा नदीचं लग्न सोनभद्रासोबत ठरलं होतं, पण नर्मदेची मैत्रीण जोहिला हिच्यामुळे दोघांमध्ये दुरावा निर्माण झाला आणि याचा राग आल्याने नर्मदेने आयुष्यभर कुमारी राहण्याचा निर्णय घेतला आणि म्हणून नर्मदेने प्रवाहाविरुद्ध वाहून जाण्याचा निर्णय घेतला.

सिंधू : भारतीय संस्कृती आणि इतिहासात सिंधू नदीचे खूप महत्त्व आहे. या नदीच्या आसपासच्या प्रदेशात वास्तव्यास असलेल्या समाजास सिंधी समाज म्हटले जाते. तिथे राहणारे हिंदू आणि मुस्लिम दोघांना सिंधी म्हटले जाते. सिंध प्रांत भारताच्या वायव्येस येतो. भारतात बहुतांश परकीय आक्रमणे याच दिशेने झाली. सिंधी लोकांचा सिंधू नदीशी जवळचा संबंध होता. प्राचीन काळापासून ते जहाज गलबतांद्वारे प्रवास करून व्यापार करत होते. त्यामुळे त्यांच्यात जल देवता म्हणजेच वरुण देवाचे महत्व खुप होते. व्यापारी दौऱ्यावर गेले कि घरी त्यांच्या बायका जलदेवतेला त्यांना सुखरूप परत येता यावे म्हणुन प्रार्थना करत असत.

इंद्रायणी : लोणावळ्याजवळील कुरवंडे गावालगतच्या नागफणी डोंगरातून इंद्रायणी नदीचा उगम होतो. उगमाजवळ बांधलेल्या लोणावळा धरणाच्या भिंतीपासून खरी इंद्रायणी वाहू लागते. इंद्रायणी नदी ही पुर्वाश्रमाची कुबेरगंगा. ती इंद्रायणी कशी झाली यामागे एक कथा आहे. येथे भगवान शंकर आणि माता पार्वती क्रीडा करीत असताना, इंद्रही त्यांच्या मागोमाग गेला. पार्वतीच्या रुपाकडे पाहून तो मोहित झाला. आणि पार्वतीला त्याने विचारले, 'या सार्वांगाला भस्म फासणाऱ्या शंकराची सेवा करण्यात तुला कसला आनंद मिळतो ? त्याच्यात तुला कोणते त्याच्या या प्रश्नांचा रोख जाणून पार्वती अतिशय क्रोधीत झाली. तिने इंद्राला शाप दिला. 'तू येथून पुढे सर्व काळ जलरूपातच राहशील. तुला स्त्रीत्व प्राप्त होईल आणि जगात कोणीही तुला पूज्य मानणार नाही. 'या शापाने इंद्र भानावर आला. त्याला स्वतःच्या वर्तनाची लाज वाटली. भगवान शंकरांना प्रसन्न करून घेण्यासाठी त्याने घोर तप केले. तेव्हा शंकरांनी प्रसन्न होऊन त्याला सांगितले, 'तुझ्यापासून उत्पन्न झालेल्या नदीला इंद्रायणी नाव लाभेल. ती मला प्रिय होईल आणि पवित्र होईल. या ठिकाणी इंद्रायणी नदी एकटीच नाही, तर इंद्रायणी, भागीरथी, आणि मनकर्णिका अशा तीन नद्यांचा संगम असल्याचे मानले जाते. अशा या इंद्रायणीत स्नान करणे अत्यंत पवित्र मानले जाते. ही नदी आध्यात्मिक मानली जाते. इंद्रायणी काठी आळंदी येथे संत ज्ञानेश्वरांनी जीवनसमाधी घेतली आहे.

नद्या आणि सद्यस्थिती : पवित्रता एवढाच विशेष लक्षात न घेता, नदी ही आपल्या मानवी जीवनाचा एक महत्त्वाचा भाग आहे याचे सतत भान आणि त्याची काळजी घेणे आवश्यक आहे. लहरी हवामान, जागतिक तापमानात वाढ, पर्जन्याचा अभावामुळे पाण्याचा प्रश्न जगभर कठीण होत चालला आहे. पाणी हे नैसर्गिक देणगी आहे तसेच प्राणीमात्रांना स्वच्छ पाणी मिळावे

त्यांचा अधिकार आहे. नद्यांची आजची स्थिती काय आहे हे अहवाल, सर्वेक्षणे, त्यावर आधारित स्तके, माहितीपट यावरून कळू शकेल. ऐतिहासिक - सांस्कृतिक - राजकीय पार्श्वभूमी आणि जगावर राज्य रणाऱ्यांचे बदलत गेलेले तत्वज्ञान या गोष्टीही परंपरांना ष्ट करण्यास कारणीभूत ठरू पाहत आहेत. नद्यांची निर्मिती म्हणजे प्रादेशिक विकासाला चालना होती. आज ी नदीच लुप्त होत आहे. राजकीय इच्छाशक्तीचा, जल नियोजनाचा अभाव, लोकसंख्या वाढीचा भस्मासुर, साम्राज्यवादाचा पगडा, भौतिकवादाने दिलेली यांत्रिक जीवनप्रणाली यामुळे नद्यांचे अस्तित्त्व धोक्यात आले आहे. नदीवर ठिकठिकाणी बांधलेल्या धरणांमुळे मानव आणि नद्यांच्या सहजीवनाला पहिला तडाखा बसला.

देशाच्या विकासावर भूगोलाचा प्रभाव पडत असतो. भारतात मोसमी पावसाचा तसेच प्रादेशिक सांस्कृतिक बदलांचा त्यामध्ये कुलधर्म, कुलाचार, सण - समारंभ, आहार विहार, आचार-विचार, यावरही त्याचा प्रभाव पडला आहे. यामध्ये केवळ मानवी संस्कृती, जीवनाकडे न पाहता सर्व चराचर, चैतन्यमय सर्जीव सृष्टीचा विचार होणे आवश्यक आहे. हजारो वर्षे सांस्कृतिक जडणघडणीत मोलाचा वाटा उचलणाऱ्या नदीला भौतिकवादाने मरणासन्न अवस्थेला पोहचविले. चंगळवादी मनोवृत्तीने धार्मिक, आध्यात्मिक, सांस्कृतिक, जीवनवादी मानवी मूल्यांचा ऱ्हास केला. नदीचे नैसर्गिक देणं माणूस हळूहळू विसरत चालला आहे. भारतीय संस्कृतीची नाळ जलाशी जोडली आहे. "ज्याप्रमाणे नदीचे मंदिर केले जाते, तिच्या प्रतिमा किंवा शिल्पे केली जातात, त्याप्रमाणे वाचिक पूजाही केली जाते. ज्यामध्ये स्तवन, स्तोत्र, अष्टक, लहरी, कवच, आरती आणि पुराणांची निर्मिती केली जाते. या सर्व प्रकारच्या माध्यमातून रंजनवादाचा अतिरेक पहावयास मिळतो. रंजनवाद हाच वास्तववाद आहे अशी त्या समाजाची धारणा होती. यामधून नदीचे पावित्र्य जरूर जपले जाते. जलपूजनाचे समारोह मोठ्या प्रमाणावर साजरे केले जातात. नदी कोणत्याही संकटांतून निभावून नेईल अशी बळकट श्रद्धा निर्माण होते. गंगेच्या आणि नर्मदेच्या बाबतीत हे आजही १०० टक्के खरे असल्याचे जाणवते. गंगा आणि नर्मदा या नद्यांनी भारतीयांच्या मनावर असे काही गारुड निर्माण केले आहे, की त्यामुळे त्यांचे भौतिक अस्तित्व धोक्यात आले आहे."[५] साहजिकच या वास्तवातील लोकमातेचे स्वरूप धोक्यात आले आहे. पूर्वी नदीकाठी घर असणे संपन्नतेचे लक्षण मानले जायचे पण बदलणाऱ्या आधुनिक नगरांच्या संरचनेत नदीला स्थान नाही. नदीकाठी असणारी तीर्थक्षेत्रे आता अर्थ संकलनाच्या मक्तेदारीची, रोगराईची केंद्रे बनली आहेत.

मानव हा कोणत्याही प्रदूषणाचा मूलभूत कारण आहे. आपला देश प्राचीनकाळापासून नद्यांना पूजनीय आणि माता मानत आला आहे. पण ज्या देशात नद्यांना एवढा सर्वोच्च सन्मान दिला जात होता, त्याच देशात आज नद्यांची दुर्दशा होत आहे, हे खेदजनक आहे. विज्ञान - तंत्रज्ञानामुळे पाणी सहज उपलब्ध होवू लागले. परिणामी त्याच्याकडे पाहण्याचा दृष्टीकोन बदलला. जगभरातील नद्यांच्या समस्यांचे हेच प्रमुख कारण आहे. भारतातील भूपृष्ठीय जल, नद्या, सरोवरे, तलाव मानवी वसाहतीमुळे प्रदूषित होत आहे. औद्योगिक क्रांतीनंतर कच्च्या मालाची गरज वाढत असतांना त्यांनीही नद्यांचे शोषण करणे सुरूच ठेवले. धरणामुळे नदीचा प्रवाह अडवला जाऊन निम्न घट झाल्याने तिची पात्रे कोरडी पडतात. नागरी वसाहतीचे मैलापाणी, सांडपाणी, औद्योगिक व रासायनिक कारखान्यांचे सांडपाण्यामुळे मूळ स्त्रोत प्रदूषित होऊन प्राणवायूच्या अभावी वनस्पती, जलचर प्राण्यांचेही जीवन धोक्यात आले आहे. हजारो वर्षांपासून विविध धार्मिक विधी पार पाडल्यानंतर नदीत टाकण्यात येणारा कचरा हाही या समस्येचा एक भाग आहे. गंगा-यमुनेसारख्या काही नद्यांनी प्रदूषणातील जागतिक उच्चांक मोडले असल्याचे दिसते. आपल्या देशातील

सर्वांत पवित्र मानल्या जाणाऱ्या गंगा नदीची स्थिती आज अतिशय गंभीर आहे. गंगेबरोबरच यमुना, नर्मदा, कृष्णा, कावेरी, तापी, गोदावरी, महानदी आणि इतर नद्यांच्या लहान वहिणीही आपल्या असंवेदनशीलतेच्या बळी ठरत आहेत. नद्यांची शुद्धता महत्त्वाची आणि आवश्यक आहे.

नदीच्या काठी झाडे असावीत, जंगल तोडण्याचा अधिकार राजालाही नव्हता. विविध वृक्षांची धार्मिक विधींच्या अनुषंगाने पूजा केली जाई. पाणी प्रदूषणमुक्त राहावे म्हणून जलाशयाभोवती देवराई लावली जात असे. रोजच्या जगण्यातील वनस्पती आणि पाण्याचे महत्त्व भारताच्या इतिहासात अनेक आंदोलनातून पुढे आलेले आहे. चिपको आंदोलनात स्थानिक महिलांनी झाडालाच मिठी मारून म्हणजेच चिपकून राहिल्याने जंगलतोडीला विरोध केला आणि चिपको आंदोलन घडले हे सांगताना लेखक अतुल देऊळगावकर म्हणतात की, "निसर्गाशिवाय गरिबांजवळ गमावण्यासारखं दुसरं असतं तरी काय? ती मालमत्ता हडपली गेली की त्यांची दारिद्र्यातून सुटका होत नाही. निसर्ग नष्ट होणं म्हणजे भीषण दुष्टचक्राचा प्रवास याची जाणीव झाल्यामुळे साध्या माणसांनी चिपकोचे यशस्वी आंदोलन केलं."[५] तेथील देवराईने आदिवासी संस्कृतीत जंगलांना अनन्यसाधारण महत्त्व असल्याने जंगलतोडला विरोध करताना त्यांच्या मुखातून 'माँ का घर उजडने नही देंगे' अशी घोषणा दुमदुमली.

समारोप : नदी विषयी मानवाच्या मनात अनादी काळापासून प्रेम,आदराची भावना दिसून येते. भारतीय संस्कृती ही नद्यांच्या किनारीच उदयास आली आणि वहरली. नदी आणि मानवी संस्कृती या दोघांचाही प्रवास परस्परपूरक राहिला आहे. नदी संस्कृतीची पर्यायाने नदीमातेची पुनर्स्थापना करणे ही आजच्या काळाची प्राथमिक गरज आहे. नगरपालिका, औद्योगिक वसाहती, कारखान्यांचे रासायनिक पाणी प्रक्रिया करूनच नदीपात्रात सोडणे, आयटी टावर्स, शासकीय कार्यालयात पाण्याचा पुनर्वापर करणे, पर्जन्य जलसंवर्धन, समा वाटप, वृक्षतोडीवर बंदी, वृक्षलागवड व संवर्ध पाठिंबा, नदी पात्रातील वाळू उपसा बंदी, जल सा अभियान, जलनीती, जलसिंचन या राष्ट्रीय पातळी उपाययोजनांची लोकसहभागातून अमलबजावणी आवश्यक आहे. आपले नदीप्रती असलेले भावना सांस्कृतिक मुद्दे बाजूला ठेऊन आधुनिक जीव उंचावण्यासाठी शाश्वत विकासाला हातभार ल प्रत्येक नागरिकाचे प्रथम कर्तव्य आहे.

संदर्भ

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डोळे मोडीत राधा चाले कादंबरीतील समाज चिंतन

डॉ. सहदेव चव्हाण

प्रतिभेचे लेणं लाभलेल्या निरक्षर अण्णा भाऊ साठे यांनी अक्षर वाङ्मयाची निर्मिती केली. त्यांनी कथा-कादंबऱ्या, लोकनाट्य, प्रवासवर्णन, पोवाडे - लावण्या, पदे, छक्कड अशा अनेक प्रकारचे वाङ्मय लिहिले. त्यांनी आपल्या लेखनातून तळागाळातील सर्वसामान्य माणसांच्या जीवनातील जगण्याचा संघर्ष रेखाटताना सामान्य माणसाला नायक म्हणून उभे केले. त्यामुळे त्यांच्या साहित्यातील नायक हे ग्रामीण जीवनातील किंवा दलित, पीडित, शोषित, कामगार, श्रमिक अशा स्तरातील असलेले दिसतात. सामान्यांच्या जीवनातील विद्रोह आणि संघर्ष शब्दबद्ध करताना त्यांची लेखणी अधिक धारदार होते. त्यांनी लिहिलेल्या साहित्याला वैचारिक अधिष्ठान आहे. वास्तवातील आणि सभोवतालच्या वातावरणातील सत्य लेखनात आणताना ते कल्पनेचा पोकळ आधार घेत नाहीत. त्यामुळे त्यांच्या साहित्यातून कार्ल मार्क्स, जोतिराव फुले, डॉ. बाबासाहेब आंबेडकर यांचे विचार प्रसृत झालेले दिसतात.

अण्णा भाऊ साठे यांनी वारणेच्या खोऱ्यात, फकीरा, वारणेचा वाघ, वैजयंता, चित्रा, माकडीचा माळ, संघर्ष, आवडी यांसारख्या अनेक अप्रतिम कादंबऱ्यांचे लेखन केलेले आहे. तत्कालीन काही समीक्षकांनी त्यांच्या कादंबरी

लेखनाची दखल घेतली, तर काहींनी त्याकडे जाणीवपूर्वक दुर्लक्ष केले. लेखक म्हणून अण्णा भाऊंची सिद्धता त्यांच्या कादंबरीतील लेखनातून स्पष्टपणे दिसून येते. त्यांच्या अनेक कादंबऱ्या स्त्री प्रधान किंवा नायिका प्रधान आहेत. मध्यमवर्गीय जीवनातील स्त्री जाणिवांचे भलेबुरे चित्रण करणाऱ्या काळात अण्णा भाऊ साठे यांनी ग्रामीण, दलित जीवनातील नायिकांचे चित्रण कादंबऱ्यांतून केले. ते स्त्री- दास्य मुक्ती साठी लेखणी झिजवतानाच तिच्या स्वसंरक्षण, शीलरक्षण, स्वाभिमान या मूल्यांची जपणूक करतात. अण्णा भाऊ साठे यांच्या अनेक कादंबऱ्यांपैकी 'डोळे मोडीत राधा चाले' ही १९६३ मध्ये लिहिलेली स्त्री प्रधान कादंबरी आहे. ही कादंबरी समीक्षकांच्या आणि अभ्यासकांच्या नजरेतून सुटलेली आणि थोडीशी दुर्लक्षित राहिलेली आहे. काही अभ्यासक, संशोधक यांनी वाङ्मयीन अंगाने या कादंबरीचा विचार केलेला आहे परंतु समाजशास्त्रीय परिप्रेक्ष्यातून सखोल चिंतन झालेले नाही.

डोळे मोडीत राधा चाले या कादंबरीचे कथानक ज्या भौगोलिक परिसरात घडते तो प्रदेश लेखकाची जन्मभूमी आणि कर्मभूमीचा आहे. त्यामुळे लेखकाला परिसरातील भौगोलिक, सामाजिक, आर्थिक, राजकीय, ऐतिहासिक संदर्भ उत्तम पद्धतीने माहीत आहेत. महाराष्ट्रातील सांगली-मिरज परिसरात कादंबरीच्या कथानकाला सुरुवात होते. वारणा नदी काठावरील मालवाडी आणि खुजगाव या दोन गावातील मातब्बर घराण्यातील सोयरीक ही रितीरिवाजाप्रमाणे होते. राधा आणि शामराव यांच्या लग्नाच्या निमित्ताने दोन गावातील जमीनदार, प्रतिष्ठित एकत्र येतात आणि कथानक अनेक पात्रांच्या सहाय्याने रंगले जाते. बाबाजी माने यांची राधा आणि पिलाजी डिसले यांचा शामराव यांच्यातील नाते संबंधांमुळे दोन गावातील ग्रामसंस्कृती, गावगाडा, गावातील गुंडप्रवृत्ती, समाजातील रितीरिवाज, रूढी-परंपरा धार्मिक समजुती, अंधश्रद्धा, दैवभोळेपणा, बुवाबाजी, अध्यात्म, जातीयता, स्त्री जीवनातील सूक्ष्मातिसूक्ष्म अंतस्थ पदर, विकार आणि विचारातील विवेकशून्य मानसिकता, खलप्रवृत्ती, सतवर्तन, नैतिक मूल्ये आणि त्यांचा होत चाललेला ऱ्हास, परंपरा आणि आधुनिकता यांचा झालेला अनोखा मिलाफ ही समाजशास्त्रीय माहिती मिळते. 'डोळे मोडीत राधा चाले' या कादंबरीची नायिका राधा आहे. ती मालंवाडीतील बाबाजी माने यांची तरुण मुलगी असते. तिचा विवाह नदीच्या पलिकडील खुजगावातील पिलाजी डिसले यांच्या शामराव बरोबर होतो. डिसले यांचे घराणे श्रीमंत आणि मातंब्बर असते. गावात सामाजिक, आर्थिक दृष्टीने त्यांचा दबदबा असतो. सासरी आलेल्या राधाच्या तारुण्यांवर, रूपावर गावातील गुंडांची नियत फिरलेली असते. सायब्या, दत्या खोत, भुज्या हे राधासाठी झुरायला लागतात. परंतु याची कल्पना साध्या भोळ्या, सुस्वभावी, निरागस आणि डोळे मोडीत चालण्याची, बोलण्याची सवय असलेल्या राधाला नसते. पुतळाबाई राधाला गावगुंडांची

आणि त्यांच्या मनातील राधा विषयीच्या दुष्ट विचारांची कल्पना देते. सायब्या, दत्त्या, भुज्या कट करून शामरावचा खून करतात. त्यावेळी राधा एकाकी पडते. तारुण्याला आणि मनातील अग्निकुंडाला शांत करण्यासाठी नारु कासाराबरोबर पंढरीची वारी करते. विधुर नारू कासार राधाकडे आकर्षित होतो. त्याचा तिला मिळवण्याचा प्रयत्न असफल होतो. पंढरपूरमध्येच जगूबुवा महाराजांची राधा बरोबर ओळख होते. राधाला अध्यात्माचे वेड लागते. ती जगूबुवाचे किर्तन आपल्या गावात ठेवते. राधा बुवाच्या मनातील कामवासनेची बळी पडणार तोच राधा भानावर येते. अब्रू वाचवण्यासाठी ती बुवाला दूर करते. स्वतःचे चारित्र्य अबाधित ठेवून शील रक्षण करते. भावनेच्या आहारी जाऊन, मोहाला बळी पडून कर्तव्याकडे पाठ फिरवू पाहणारी राधा वेळीच सावध होते आणि डिसलेंच्या घराण्याची अब्रू स्वतःच्या निःश्वासात जपते. पश्चात्तापदग्ध बुवा राधाच्या पायावर डोकं ठेवतो व असं पाप पुन्हा करणार नाही म्हणून विनवतो. १

अण्णा भाऊ साठे राधाच्या माध्यमातून तोल जाऊ पाहणाऱ्या स्त्रीच्या स्वत्वाचा, तिच्या अब्रूचा आणि स्त्रीमुक्तीचा पुरस्कार करतात. त्यांनी त्यांच्या साहित्यातील स्त्रीचे सुंदर वर्णन केले आहे. पण स्त्रीला कुठेही विद्रूप केलेले नाही. त्यांची लेखणी स्त्री सन्मानाची कास धरते. डोळे मोडीत राधा चाले कादंबरीतील स्त्री शालीनता चारित्र्यसंपन्नता आणि स्वअस्तित्व या त्रिसूत्रीवर रेखाटलेली आहे.

लेखकाने कादंबरीत गावगाड्याचे सुस्पष्ट चित्रण केलेले आहे. ग्रामसंस्कृतीत गावगाड्याचे आणि गावगाड्यातील जातीय, वर्गीय, आर्थिक संबंध यांचे अनोखे बंध निर्माण झालेले असतात. वतनदारांच्या गावा संबंधांच्या परस्पर व्यवहाराला आणि वतनदारांच्या जगदव्यापी जाळ्यात गुरफटलेल्या गावाच्या सामूहिक अंतर्वाह्य व्यवहाराला गावगाडा म्हणतात. २ या कादंबरीत दोन गावातील पाटील, कुणबी, अलुतेदार बलुतेदार, वतनदार आणि त्यांच्यातील सामाजिक, आर्थिक, जातीय संबंध आलेले दिसतात. बाबाजी माने, पिलाजी डिसले, नारू कासार, दत्त्या खोत, भुज्या, गोंदा वडार, उस्मान आत्तार या पात्रांच्या निर्मितीतून त्यांच्या जात संबंधांचा तपशील कादंबरीत येतो. गावगाडा अशा अनेक जात संबंधांनी तयार होतो. केवळ गावगाड्याचे वर्णन जाणीवपूर्वक येत नाही, तर कथानकाच्या अनुषंगाने गरजेसाठी आलेले आहे. गावकी भावकीचे परस्पर व्यवहार आणि त्यातून निर्माण झालेले मानवी संबंध यांचे दर्शन कादंबरीत येते. गाव, शिवार, मळा, देऊळ, चावडी, बाजार, जत्रा, तमाशा, कुस्त्या, तालीम हे सर्व गावगाड्याचे घटक आहेत. कादंबरीत त्या सर्वांची माहिती आलेली आहे. कृषी संस्कृतीशी निगडित ग्रामीण बोलीभाषा नजरेत भरणारी आहे. पश्चिम महाराष्ट्रातील सांगली, सातारा, कोल्हापूर या परिसरातील ठसकेबाज, करारी बोलीभाषा संवादातून प्रकट होते.

अण्णा भाऊ साठे यांनी 'डोळे मोडीत राधा चाले' कादंबरीत गुंड प्रवृत्तीचे चित्रण केलेले आहे. गावातील पाटील आळीचा सायब्या, दत्या खोत, भुज्या या पात्रांच्या माध्यमातून गाव गुंड उभे केले आहेत. यातून गावातील उपद्रवमूल्य वाढविणारी मानसिकता दिसते. खलप्रवृत्तीच्या मानसिकतेतील विविध विकार समाज स्वास्थ्य नष्ट करतात. समाजातील अन्याय अत्याचाराला प्रोत्साहन देतात. अण्णा भाऊ साठे यांनी या खलप्रवृत्तीचा तिरस्कार केलेला आहे. समाजात अराजकता माजविणारी प्रवृत्ती नष्ट करून मंगलमय नवसमाज निर्मितीचा ध्यास त्यांच्या लेखणीने घेतलेला दिसतो. गावातील तरण्या बायांना भुरळ घालणारा सायब्या, गोंदा वडाराच्या बायकोची अब्रू लुटणारा दत्या खोत, जाती घडविणाऱ्या पाथरवट बाईवर भर दिवसा बलात्कार करणारा भुज्या, अध्यात्माच्या नावाखाली राधाला भुरळ घालणारा जगूबुवा या प्रवृत्तींना अण्णा भाऊ थारा देत नाहीत.

आर्थिक स्तर रचना आणि त्यावर आधारित वर्गीय आणि जातीय संबंध रेखाटणे हा अण्णा भाऊंच्या लेखनातील गाभा आहे. आर्थिक हितसंबंधातून वर्ग वर्चस्ववादी व्यवस्था निर्माण होते तर वर्ण संबंधातून जातीय व्यवस्था तयार होते. मार्क्सवादी विचारधारा वर्गीय व्यवस्था नाकारते. तर आंबेडकरवादी विचारधारा जातीय व्यवस्था मुळापासून उखडून टाकते. या दोन्ही विचारधारा अण्णा भाऊंनी स्वीकारलेल्या आहेत. 'डोळे मोडीत राधा चाले' कादंबरीत पिलाजी डिसले आणि बाबाजी माने यांची आर्थिक स्थिती मजबूत आहे. दोन्ही घराणी श्रीमंत आहेत. त्याच वेळी कादंबरीतील इतर पात्रांची आर्थिक परिस्थिती हालाखीची दिसते. उदा. नारू कासार हा रोज गावभर फिरून बांगड्या भरण्याचा व्यवसाय करतो. त्याचे उत्पन्न अत्यंत कमी आहे. त्याची म्हैस चोरीला गेली तरी तो व्याकूळ होतो. ही आर्थिक तफावत डोळ्यात ठसठशीतपणे भरणारी आहे. कादंबरीत जातीव्यवस्थेचे वर्णन थेटपणे येत नाही मात्र जातीयवादी मानसिकता चित्रित झालेली आहे. गोंदा वडाराच्या बायकोची अब्रू लुटणारा दत्या खोत, नारु कासाराची म्हैस चोरणारे गावगुंड, उस्मान अत्ताराला गृहीत धरून त्याच्या दुकानाच्या आधारे टगेगिरी करणारा सायब्या, पाथरवट बाईवर बलात्कार करणारा भुज्या ही पात्रे जातीय मानसिकतेची प्रतीके आहेत. अण्णा भाऊ पात्रांच्या माध्यमातून जातीय वास्तवाला भिडतात आणि शोषण करणारी व्यवस्था दाखवतात. पात्रांची भाषा ही देखील पात्रांची जात सूचित करते. त्यामुळे स्पष्टपणे जाती संघर्ष दिसत नसला तरी जातीय वास्तवाचे दर्शन कादंबरीच्या पार्श्वभूमीतून स्पष्ट दिसत असते. ३ हे किशोर जाधव यांचे फकिरा कादंबरी बाबतचे निरीक्षण या कादंबरीतील पात्रांबाबत देखील लागू पडते.

अध्यात्माचा बुरखा पांघरून बुवाबाजी करणाऱ्यांचा ढोंगीपणा आणि त्यांच्या वर्तनातील दांभिकता यांचे चित्रण 'डोळे मोडीत राधा चाले' कादंबरीत

अण्णा भाऊ साठे यांनी केलेले आहे. मनाची शांतता आणि आत्मोद्धार करण्यासाठी अध्यात्माशी संग केला जातो. समाजाचे स्वास्थ्य नियंत्रित आणि निरोगी राहण्यासाठी अध्यात्मिक वातावरणाची निर्मिती केली जाते. परंतु लोकांच्या द्वंद्वात्मक आणि भितीयुक्त मानसिकतेचा, त्यांच्या असहायतेचा फायदा घेऊन बुवाबाजी करणाऱ्या प्रवृत्तीचा वेगाने उदय होत आहे. अण्णा भाऊ अशा ढोंगी बुवांचा, महाराजांचा तीव्र शब्दात तिरस्कार करतात. बुवाबाजीविरुद्ध त्यांची लेखणी परखडपणे व्यक्त होते. 'डोळे मोडीत राधा चाले' कादंबरीतील जगन्नाथ महाराज (जगूबुवा) कीर्तनकार आहे. लोक त्यांना देवमुर्ती मानतात. दूरदूरचे टाळकरी, माळकरी, वारकरी त्यांची पूजा करतात. बुवांच्या अंगात दैवी शक्ती आहे असा लोकांचा समज आहे. बुवा हरी नामाचा तो जप करत गावोगावी फिरत असतो. तो संन्यास घेऊन किर्तन करत होता. परंतु राधासाठी वेडापिसा झाला होता. राधाला मिळविण्यासाठी तो तिला अध्यात्मिक शब्द जंजाळात गुंतवतो. राधाच्या गावात कीर्तनासाठी जातो त्यावेळी राधाला जवळ घेऊन तिचा उपभोग घेण्याचा प्रयत्न करतो. परंतु राधा आपला तोल संभाळते. बुवाचा शृंगारिक डाव ओळखते. बुवाचे हे वर्तन म्हणजे अध्यात्मिक नावाखाली केलेला व्यभिचार असतो. अण्णा भाऊंनी या अध्यात्मिक दुष्ट प्रवृत्तीला चित्रित केलेले आहे.

कादंबरीच्या उत्तरार्धात अनेक अभंग आलेले आहे. समाजमनातील संतवचने आलेली आहेत. कादंबरीत त्यामुळे अध्यात्मिक वातावरण तयार होते. लेखकाची सूक्ष्म निरीक्षण शक्ती आणि भक्तीभाव स्पष्टपणे दिसतो. लेखकाची संत साहित्यावरील निष्ठा, आपुलकी, प्रेम दिसून येते. कादंबरीतील प्रसंग आणि संतांचे अभंग यांची सांगड घातलेली आहे. त्यामध्ये कार्यकारणभाव जुळलेला दिसतो. उदा. जगूबुवाने पंढरपूरमध्ये कीर्तनाला सुरुवात करताना,

विठ्ठल विठ्ठला येणे छंदे । ब्रह्मानंद गर्जावे ।।
वाजे टाळ टाळ्या टाळी । हरी होळी विघ्नाची ।।
विठ्ठल आद्य भक्तांनी । विठ्ठल मनी भरावा ।।
तुका म्हणे विठ्ठलवाणी । वदा गाणी आईका ।। ४

अशी केलेली दिसते. त्यावरून तर लेखकाची तत्त्वनिष्ठा आणि भक्ती स्पष्टपणे दिसते.

कलाकृतीचा समाजशास्त्रीय अंगाने विचार करताना भाषेचा विचार अग्रक्रमाने करावा लागतो. कारण समाजाच्या निर्मितीमध्ये आणि वाटचालीमध्ये भाषेला अनन्यसाधारण महत्त्व असते. अण्णा भाऊ साठे यांनी डोळे मोडीत राधा चाले कादंबरीत कृषी संस्कृतीशी निगडीत ग्रामीण बोली भाषेचा वापर केलेला आहे.ती ग्रामीण बोलीभाषा नजरेत भरणारी आहे. पश्चिम महाराष्ट्रातील सांगली, सातारा, कोल्हापूर या परिसरातील ठसकेबाज, करारी बोलीभाषा

संवादातून प्रकट होते. गावगाड्यातील ग्रामनिष्ठ शब्द, म्हणी वाक्प्रचार यांचा प्राधान्याने वापर केलेला आहे. स्व-अनुभवावर आधारित भाषेचा वापर असल्यामुळे पात्रांचे, प्रसंगांचे, वातावरणाचे हुबेहूब चित्रच वाचकांच्या डोळ्यासमोर उभे राहते. एखादा प्रसंग जशाचा तसा केवळ शब्दांच्या आधारे डोळ्यासमोर उभा करणे यासाठी भाषेवर, शब्दांवर हुकूमत असावी लागते. शब्द सामर्थ्य अण्णा भाऊंची ताकत आहे. कादंबरीतील संवादात छोटी वाक्ये तर वर्णनात तुलनेने मोठी वाक्ये येतात. त्यामुळे कादंबरीतील कथानकात कुठेही अर्थदुर्बोधता किंवा क्लिष्टता न येता सहजता येते. उदा. मंग कसं वागायचं ते तरी सांगा. राधाने विचारलं नि पुतळा म्हणाली, 'ह्यो डिसल्यांचा वाडा हाय. इथं गाभणी गाय गाभ टाकती, पण तुमच्या या वागण्याने आज त्याच वाड्यात कोल्ही कुत्री शिरत्यात. आणि आब्रू कापराच्या वडीगत असती. ती भुर्रकन जळती नि तिच मागं काहीच राहत न्हाय. तवा तुम्ही कापरावाणी जळू नका.' ५ कादंबरीत ग्रामीण भाषेचा साज चढवून ठसकेबाजपणा आलेला दिसतो. अण्णा भाऊ साठे यांचे ग्रामीण जीवनाशी असलेले घनिष्ठ नाते त्यांच्या शब्द सामर्थ्य आणि भाषा प्रभुत्वाने लक्षात येते.

'डोळे मोडीत राधा चाले' कादंबरी नायिका प्रधान कादंबरी आहे. अण्णा भाऊ साठे यांनी राधा या नायिकेच्या माध्यमातून मानवी कल्याणासाठी नैतिक मूल्यांची प्रतिष्ठापना करण्याचा संदेश दिलेला आहे. ते स्त्रीच्या आयुष्याला मातीमोल न समजता तीला प्रतिष्ठा दिली पाहिजे हा विचार मांडतात. त्यांनी स्त्रीची शृंगारिक वर्णने केलेली आहेत, पण तिला कुठेही विद्रूप किंवा चारित्र्यहीन दाखवून मलिन केलेले नाही. त्यांनी ग्रामीण भागातील स्त्रीला नायकत्व बहाल करून तिच्या चारित्र्याचा सन्मान केलेला आहे. त्यामुळे ते राधेला अब्रू गमावू देत नाहीत. अण्णाभाऊंनी साकारलेली राधा मानवी मनाचा एक पैलू होय. मोहाला बळी पडू पाहणाऱ्या राधाचे हृदय परिवर्तन होते. ती कर्तव्याकडे वाटचाल करते. हे डॉ. ज्योती लांजेवार यांचे निरीक्षण योग्य वाटते.

अण्णा भाऊंनी समाजातील स्त्री-पुरुष गरीब-श्रीमंत, उच्च-नीच असा भेद न करता समानता प्रस्थापित होण्यासाठी आग्रह धरलेला दिसतो. या कादंबरीत देखील राधाची अब्रू घेण्यासाठी टपलेले सायब्या, दत्त्या, भुज्या यांचा बिमोड होतो. नारू कासार मनातील वाईट विचार सोडून देतो. जगू बुवा महाराज राधाला मिळविण्यात अपयशी होऊन पश्चात्ताप व्यक्त करतो. त्या सर्व संकटातून राधा अब्रू शाबूत ठेवून सुखरूप आपल्या कौटुंबिक जीवनात परत येते. अण्णा भाऊंच्या लेखनात मानवतेच्या सुखाचा हा दिव्य संदेश दिसतो. याबाबत, समाज सुखी, समृद्ध व्हावा. तो केवळ आर्थिक दृष्टयाच नव्हे तर नैतिकदृष्ट्या सुद्धा. पण तशी परिस्थिती समाजात व्हायला हवी. सामाजिक पापांची मुळेच उखडून टाकायला हवी, व्यभिचाराच बीज नष्ट करायला हवं. परंपरेने असत्प्रवृत्तीच्या

मुळ्या खोलवर पसरवलेल्या आहेत, त्याच नष्ट झाल्या पाहिजेत ही अण्णा भाऊंची तळमळ होती. ६ हे डॉ. सदा कऱ्हाडे यांचे मत चिंतनशील वाटते. कारण अण्णा भाऊंची मानवतावादी दृष्टी व्यापक आहे. या कादंबरीच्या रूपाने ही दृष्टी नव्याने लक्षात घेता येते.

'डोळे मोडीत राधा चाले' कादंबरीचे शीर्षक समर्पक आहे. संपूर्ण कादंबरी राधा या पात्राभोवती फिरते. राधाच्या विवाहापासून ते राधाच्या अध्यात्मिक जीवनातील घडामोडी यांचा पट कादंबरीतील चित्रित झालेला आहे. राधाच्या वैवाहिक जीवनातील चढ-उतारानुसार तिची मानसिक आंदोलने कादंबरीत उत्कंठा शिगेला पोहचवतात. राधाच्या व्यक्तिमत्त्वातील पत्नी, आई ही रूपे वाचकांच्या मनाला भावतात. तिचे साधे-भोळे राहणे आणि निष्पाप, निरागस जगणे वाचनीय बनते. तिचे डोळे मोडीत बोलणे, चालणे आणि त्यामुळे गावातील गुंडांच्या मनात तिच्याविषयी झालेला गैरसमज कादंबरीच्या कथानकाला गती प्राप्त देतो. तिची जगू महाराजांशी आध्यात्मामुळे जवळीक निर्माण होते. जगूबुवा आणि राधातील आपुलकी वाढवणारी गौळण

वारियाने कुंडल हाले
डोळे मोडीत राधा चाले!

कथानकाला शृंगारीक रसात आकंठ बुडून ठेवते. बुवाच्या स्वाधीन झालेली राधा आपली लाख-मोलाची अब्रू वाचविले. राधा बुवाला दूर करून कुटुंबाला, अब्रूला, घराण्याला आणि कर्तव्याला प्राधान्य देते हे राधाचे परिवर्तन कथानकाला नैतिकतेचे अधिष्ठान प्राप्त करून देते. त्यामुळे अण्णा भाऊंनी कादंबरीला 'डोळे मोडीत राधा चाले' हे दिलेले शीर्षक योग्य वाटते.

एकूणच, अण्णा भाऊ साठे यांनी ग्रामनिष्ठ जीवन जाणिवांनी ओतप्रोत भरलेला समाज 'डोळे मोडीत राधा चाले' कादंबरीत चित्रित केलेला आहे. गावगाड्यातील आर्थिक, जातीय, वर्गीय, अध्यात्मिक हितसंबंधांना अधोरेखित करतानाच ग्रामीण स्त्रीला नायिका म्हणून उभे केले आहे. गावात अध्यात्माच्या नावाखाली चालणारी बुवाबाजी आणि त्यातील दांभिकता दाखवून समाजातील सद्यस्थितीचे अवलोकन केलेले आहे. 'डोळे मोडीत राधा चाले' कादंबरीत समाजातील गुंड प्रवृत्तीचा नाश करून चारित्र्यसंपन्न स्त्रीचा सन्मान करणारा मूल्य विचार मांडलेला आहे तो यथार्थ वाटतो.

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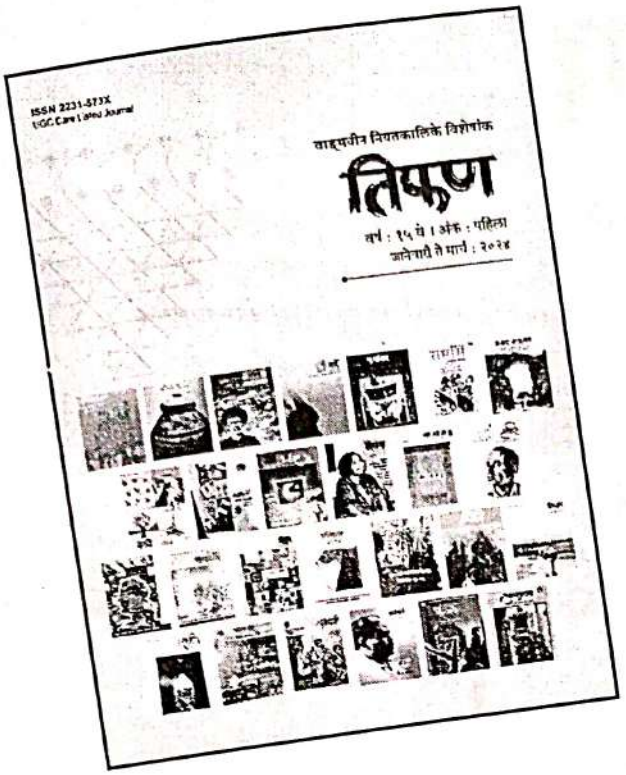

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या नियतकालिकास महाराष्ट्र राज्य साहित्य आणि संस्कृती मंडळाकडून अनुदान प्राप्त झाले आहे; परंतु या नियतकालिकात प्रसिद्ध झालेली मते मंडळास मान्य असतीलच असे नाही.

अनुक्रमणिका

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१०	समकालीन मराठी नियतकालीकांची वाटचाल	संगीता भगत	५८
११	मराठी साहित्य संस्थांच्या नियतकालिकांचा वाङ्मयीन आढावा	प्रा. प्रवीण गायकर	६६
१२	साठोत्तरी मराठी नियतकालिकांचा परामर्श (१९६०-१९७५)	डॉ. सोनू लांडे	७२
१३	भाषांतराला वाहिलेले मराठी नियतकालिक 'केल्याने भाषांतर'	डॉ. सहदेव चव्हाण	७७
१४	कोकणातील मराठी नियतकालिके (मर्यादा-रत्नागिरी जिल्हा)	प्रा. राजरत्न दवणे	८२
१५	डॉ.बाबासाहेब आंबेडकर यांच्या नियतकालिकांतील वैचारिकता	डॉ. सुनील परदेशी	९४
१६	१९३३-१९५६ या काळातील फुले-आंबेडकरी प्रेरणेच्या प्रारंभिक साहित्याची जडणघडण आणि 'जनता' या साप्ताहिकाची कामगिरी	डॉ. अश्विनी तोरणे	९८

भाषांतराला वाहिलेले मराठी नियतकालिक 'केल्याने भाषांतर'

डॉ. सहदेव शरद चव्हाण

वाङ्मयीन नियतकालिके विशेषांक

मराठी साहित्यविषयक नियतकालिकांनी सामाजिक, सांस्कृतिक बदलांना अधोरेखित करून वाङ्मयीन संस्कृतीचे संरक्षण, संक्रमण आणि संवर्धन करण्याचे महत्त्वपूर्ण कार्य केले आहे. लेखक, वाचक, समीक्षक यांच्या आस्वाद, आकलन, मूल्यमापनाचा परिप्रेक्ष्य रुंदावून वाङ्मयीन अभिरुची विकसित केलेली आहे. समाज प्रबोधन, ज्ञानप्रसार आणि सामाजिक सुधारणांच्या हेतूने सुरू केलेल्या 'दर्पण'पासून ते आजपर्यंतच्या जवळपास शतकभराच्या वाटचालीत जे नावीन्यपूर्ण सामाजिक बदल झाले, त्यांना नियतकालिकांनी शब्दरूप दिले. मराठी नियतकालिकांनी संस्कृतीचे जतन करण्याबरोबर त्याला प्रवाहित्व प्राप्त करून दिले. संस्कृतीला आणि वाचकाभिरुचीला नवे आयाम देण्याची महत्त्वाची कामगिरी नियतकालिकांनी केली. कला, वाङ्मयीन अभिरुची त्याचबरोबर वैचारिक प्रगल्भता यांना संपन्न करणारे अनेकविध प्रकारचे साहित्य नियतकालिकातून प्रकाशित झाले. त्यासाठी अनेक वाङ्मय प्रकारांतील साहित्य, समीक्षा, संशोधन, विचारप्रवाह, साहित्यप्रवाह,ललित गद्य, भाषांतर यांना वाहिलेली नियतकालिके प्रसिद्ध होऊ लागली. १९७५ नंतर ललित साहित्य, समीक्षा यांना प्रसिद्धी देणारी आणि साहित्य संस्थांनी सुरू केलेली नियतकालिके विपुल प्रमाणात निर्माण झालेली दिसतात. १९९० नंतर समाजात जागतिकीकरण, खाजगीकरण, यांत्रिकीकरण, इंटरनेटक्रांती, माध्यमक्रांती, मोबाईलक्रांती, कॉर्पोरेट भांडवलीशाही, आर्थिक उदारमतवाद, पश्चिमीकरण,

टेलिकम्युनिकेशन, डिजिटलायझेशन, ऑडिओ-व्हिडिओलायझेशन आणि विज्ञान तंत्रज्ञानामुळे माहितीचा झालेला विस्फोट यामुळे देशोदेशीच्या सरहद्दी कमी झाल्या. जग एकमेकांच्या जवळ आले. विचारांची व साहित्याची देवाण-घेवाण वाढली. परकीय भाषातील साहित्य स्वभाषेत आणण्यासाठी पूर्वीपेक्षा अधिक सुलभता येऊ लागली. त्यामुळे साहित्याच्या भाषांतराला नव्याने चालना मिळाली. परभाषेतील लालीत्यपूर्ण साहित्यानुभव प्रादेशिक भाषेत अनुवादित करण्यासाठी नियतकालिके निर्माण झाली. त्यामध्ये प्रामुख्याने 'केल्याने भाषांतर'चा उल्लेख करावा लागेल. परकीय भाषेतील साहित्याचे थेट मराठीत भाषांतर करण्याचा प्रामाणिक आणि स्तुत्य प्रयत्न केल्याने भाषांतर केला. 'केल्याने भाषांतर' हे त्रैमासिक आहे. ते पुणे येथील कलासक्त चॅरिटेबल ट्रस्टच्या वतीने प्रकाशित केले जाते. १ जानेवारी १९९९ पासून अविरतपणे या त्रैमासिकाचे अंक प्रकाशित होतात. एका कार्यशाळेच्या निमित्ताने एकत्र आलेल्या भाषांतरकारांच्या अनौपचारिक गप्पांमधून 'केल्याने भाषांतर' हे त्रैमासिक सुरू करण्याची कल्पना सूचली. त्या भाषांतरकारांमध्ये विद्यासागर महाजन, सुनंदा महाजन, चेतन ठकार, अनघा भट यांचा समावेश होता. १ जानेवारी १९९० रोजी प्रयोग म्हणून एक त्रैमासिक तयार करून त्याच्या झेरॉक्स प्रती वितरित करण्यात आल्या. विद्यासागर महाजन हे संस्थापक - संपादक होते, तर विवेकानंद फडके व्यवस्थापक म्हणून काम करत होते. दुसऱ्या अंकापासून रीतसर छपाई करून प्रकाशन सुरू झाले.परकीय भाषांच्या अध्यापनाच्या क्षेत्रात काम करणाऱ्या जिज्ञासू प्राध्यापकांनी चालविलेल्या 'केल्याने भाषांतर' मध्ये जर्मन, स्पॅनिश, रशियन, फ्रेंच, जपानी, पोलीश, इटालियन, कॅरेबियन, चिनी या भाषेतील ललित साहित्याचे भाषांतर इंग्रजी अनुवादाच्या आधाराशिवाय थेट मराठीत आणण्याचे एकमेवाद्वितीय काम केले आहे. 'केल्याने भाषांतर' हे ६४ पानांचे त्रैमासिक आहे. एका वर्षात चार अंक प्रकाशित होतात. आत्तापर्यंत ९४ अंक प्रकाशित झालेले आहेत. कोरोना महामारीच्या काळातही ऑनलाईन स्वरूपात अंक निघाल्यामुळे यामध्ये खंड पडला नाही. 'केल्याने भाषांतर'चे स्वरूप इतर कोणत्याही नियतकालिकापेक्षा भिन्न स्वरूपाचे आहे. 'इंग्रजी, रशियन, जर्मन, फ्रेंच, स्पॅनिश इत्यादी भाषांतील साहित्य अनुवादित स्वरूपात प्रसिद्ध करताना संपादकांनी व्यापक भूमिका ठेवली आहे. कथा, कविता, एकांकिका तसेच वैचारिक साहित्य, निबंध, स्फुटे, समीक्षा, पुस्तक परिचय असे विविध प्रकारचे अनुवादित साहित्य यातून प्रसिद्ध होते. मूळ लेखकाचा परिचय, साहित्यकृतीची माहिती व महत्त्व स्पष्ट करणारे टिपणही देण्यात येते.'१ त्याचबरोबर परकीय भाषेतील सांस्कृतिक महत्त्व प्राप्त झालेले साहित्य, ऐतिहासिक, धार्मिक, राजकीय, वैचारिकदृष्ट्या गाजलेल्या कलाकृती, मान्यताप्राप्त लेखकांचे आणि वाचकांच्या पसंतीस उतरलेले अभिजात वाङ्मय निवडून त्यांचे थेट मराठीत भाषांतर करण्याचा आग्रह धरलेला आहे.कविता, कथा, लघुकादंबरी, एकांकिका यांच्या अनुवादाबरोबरच वैशिष्ट्यपूर्ण सदरे देखील लक्ष वेधून घेतात. या सदरांतील मजकूर आशयघन, विचारप्रवर्तक व उत्कंठावर्धक असतो. 'शिंपल्यातील मोती'आणि 'माती आणि आकाश'या सदरामुळे अंक अधिक वाचनीय झाले आहेत. 'शिंपल्यातील मोती'सदरातील 'रीत जगण्याची न्यारी' (वोल्तेअर), 'राजहंस' (सिरगेय इसिनीन), 'युध्द' (येक्गनी येफ्नुश्येन्का), 'जाक् प्रेव्हेरच्या काही कथा', 'बिनसलेलं बिऱ्हाड' (बर्टोल्ट ब्रेष्ट), 'ओढा आणि नदी' ही सदरे अतिशय नावीन्यपूर्ण आणि आकर्षक आहेत. 'माती आणि आकाश'या सदरातील जर्मनीतील 'सोनेरी ऑटम'(गेओर्ग ट्रावल),'बुल फाईट' यांसारख्या लेखांचा विशेष उल्लेख केला पाहिजे.प्रत्येक वर्षाच्या शेवटचा म्हणजे चौथा अंक एका विषयाला धरून म्हणजे एक विशिष्ट असे सूत्र घेऊन केलेली भाषांतरे प्रकाशित करण्यासाठी एक अनोखी पद्धत 'केल्याने भाषांतर'ने निर्माण केली. 'प्रारंभ','शैशव''भवताल', 'प्रवास','रंगभूमी','पत्रव्यवहार','प्रेम'. अशा विविध आशयसूत्रांनी व्यापलेले परकीय साहित्यातील बंध भाषांतरित

केले. यावावत 'केल्याने भाषांतर'च्या संपादकांचे म्हणणे, 'गेली काही वर्षे वर्षातील शेवटच्या म्हणजे चौथ्या अंकात एक आशयसूत्र घेऊन केल्याने भाषांतर त्याच आधीच्या अंकांमध्ये प्रसिद्ध झालेल्या भाषांतरित कथा आम्ही संकलित स्वरूपात सादर करतो. निरनिराळ्या देशांत, भाषांत, साहित्यात समान आशयसूत्राने किती आणि कशा कथा, कविता एकत्र बांधता येतात हे पाहणे मनोरंजक ठरले आहे. शिवायज्या वाचकांना 'केल्याने भाषांतर'चे पूर्वीचे अंक वाचायला मिळाले नाहीत त्यांना या पुनर्मुद्रित साहित्याचा लाभ होऊ शकतो या हेतूनेच आम्ही 'प्रारंभ' (पुराणकथा व मिथके यावर आधारित कथा) 'शैशव' (लहान मुलांची मध्यवर्ती व्यक्तिरेखा असलेल्या कथा), 'भवताल'(नागरी व निमनागरी वातावरण कथांच्या आशयाशी प्रामाणिकपणे गुंतून गेले आहे अशा कथा), 'प्रवास' (प्रवासाची अथवा प्रवास या कल्पनेची मांडणी करणाऱ्या कथा), 'रंगभूमी' (निरनिराळ्या भाषांतील एकांकिका, नाटके, नाटुकल्या), 'पत्रव्यवहार' (प्रसिद्ध व्यक्ती लेखक, शास्त्रज्ञ यांच्यात घडलेला पत्रव्यवहार),'प्रेम' (प्रेम या वैश्विक विषयाची विविध भाषांमध्ये साहित्यातून झालेली अभिव्यक्ती) अशा आशयसूत्रात बांधून आधी वाचलेल्या कथांचे आकलन वेगळ्याच परिप्रेक्षयात करण्याची संधी व एखाद्या विषयाची मांडणी विविध भाषातील साहित्यात किती सारख्या व किती निराळा पद्धतीने होऊ शकते याचा अभ्यास करण्याची संधी वाचकांना देण्याचा आम्ही प्रयत्न केला.'[२] हे म्हणणे यथोचित वाटते. 'विशेषांकाची निर्मिती' हे 'केल्याने भाषांतर'चे एक अनोखे कायं आहे. जागतिक वाङ्मयात अढळ स्थान निर्माण केलेल्या अंतोन चेखवच्या १०० व्या पुण्यतिथीनिमित्त 'चेखव विशेषांक' केल्याने भाषांतरचा पहिलाच विशेषांक जुलै- सप्टेंबर २००४ मध्ये प्रकाशित झाला. हा अंक म्हणजे जागतिक वाङ्मयाचा अभ्यास आणि आस्वाद मराठी भाषेच्या परिघात करता यावा यादृष्टीने उचललेले महत्त्वपूर्ण पाऊल होय. चेखवच्या कथा, लघुकथा, एकांकिका, नाटके यांचा परिचय मराठी वाचकांना झाला. २००२ मधील विशेषांकातील नीलिमा रड्डी यांनी अल्फॉन्स दोदे यांची भाषांतरित केलेली 'बालगुप्तहेर'कथा, अनघा भट यांनी मिखाइल शिद्रीन यांची भाषांतरित केलेली 'सश्याचे आत्मसमर्पण' कथा उल्लेखनीय आहे.'पुस्तक परीक्षण' हे 'केल्याने भाषांतर' मधील वाचकांच्या पसंतीस उतरलेले महत्त्वाचे सदर आहे. वेगवेगळ्या भाषेतील लेखकांच्या कलाकृतींचे यथायोग्य केलेले परीक्षण नित्यनियमितपणे वाचकांच्या भेटीला दिले जाते. नावीन्यपूर्ण पुस्तकांची माहिती, आशयानुभव, लेखक परिचय व सांस्कृतिक संदर्भ देऊन पुस्तकांची अभिनव पद्धतीने दिलेली माहिती अनेक अंकात पहावयास मिळते.'केल्याने भाषांतर' मध्ये फक्त परकीय भाषातून थेट मराठीत भाषांतरित झालेले साहित्य प्रकाशित होत असले तरी भाषांतरित साहित्याबरोबरच भाषांतरित पुस्तकांची परीक्षणे, भाषांतरित पुस्तकांचा परिचय या सदरात कोणत्याही भाषेतून भाषांतरित झालेल्या साहित्य कृतींविषयी लिहिता येते.'[३] ऋतुशैशव (अनु. अनघा भट),'इंदिरा गांधी आणीबाणी व भारतीय लोकशाही'(अनु. शर्मिष्ठा खेर),'पुश्किन जीवन आणि काव्य'(अनु. डॉ. पंडित आवळीकर),'चेखवच्या सात कथा'(अनु. चेतन ठकार),'हॅरी पॉटर'(अनु. उज्वला बर्वे),'कोसला ते ककून'(अनु. शर्मिष्ठा खेर),'भाषेतून भाषेकडे आणि भाषांतराकडे' (अनु. स्वाती कर्वे),'लोकांच्या कविता'(अनु. किशोर मोरे)'अरण्येर अधिकार'(अनु. नितीन साळुंखे) यांसारख्या पुस्तक परीक्षणामुळे वाचकांना अधिकाधिक वाङ्मयीन घटकांचा, ग्रंथांचा आस्वाद घेता येतो.

'युरोपीय तत्त्वज्ञानाच्या पाऊलखुणा' या मालिकेतील सदरांमध्ये प्रकाशित झालेले युरोपीय भाषेतील ललित साहित्य मराठी वाचकांना प्रचंड भावले.'नोबेल पारितोषिक प्राप्त लेखकांच्या साहित्यकृती आणि त्यांचा आयुष्यपट भाषेविषयी काही सदरे आणि अधिकात अधिक वैविध्यपूर्ण भाषांचा त्यामधल्या साहित्यकृतींचा समावेश अनेक अंकात झालेला दिसतो.'[४]

'केल्याने भाषांतर'ने अनेक प्रकारचे भाषांतरित साहित्य छापले. त्याचबरोबर काही वाङ्मयीन सामाजिक, सांस्कृतिक उपक्रम देखील राबवले.२००३ मध्ये भाषांतरकारांचे संमेलन भरवले. भाषांतरित कथांचे अभिवाचन, नाट्यवाचन, नाट्यप्रयोग, परकीय लेखकांच्या रेखाचित्रांचे प्रदर्शन, मुलाखती यांसारख्या उपक्रमांमुळे 'केल्याने भाषांतर'च्या उपक्रमशीलतेची ओळख संपूर्ण महाराष्ट्राला आणि मराठी वाचकांना नव्याने झाली.'केल्याने भाषांतर' मध्ये प्रसिद्ध झालेल्या शिनीची होशी या जपानी कथाकाराच्या लघुकथांचे 'बोक्कोचान' हे पुस्तक निसीम बेडेकरांनी मराठीत आणले.एव्हा हेलर या जर्मन लेखिकेची कादंबरी विद्यासागर महाजन यांनी 'दुसऱ्या जोडीदाराच्या शोधात' या शीर्षकाने आणली. 'अत्पूश्किना दचेखवा' हा कथासंग्रह अनघा भट यांनी रशियन भाषेतून थेट मराठीत आणला. समकालीन जागतिक कथा असलेला 'कथांतर' आणि मूळ जर्मन आणि रशियन भाषेतील तीन-तीन अशा सहा लघु कादंबऱ्यांचा 'तिकडून आणलेल्या गोष्टी' हा ग्रंथ सुनंदा महाजन आणि अनघा भट यांनी केल्याने भाषांतरच्या लेखनातील सिद्धहस्ततेमुळे आणि पूर्वानुभावामुळे लिहिला. या वाङ्मयीन घडामोडींचा मूलाधार 'केल्याने भाषांतर' हे त्रैमासिक आणि त्यांची मातृसंस्था कलासक्त चॅरिटेबल ट्रस्ट, पुणे ही आहे.'केल्याने भाषांतर'चा पहिला अंक झेरॉक्स प्रती मध्ये निघाला, तेव्हापासून आतापर्यंत म्हणजे सलग २४ वर्षे या त्रैमासिकाचे अंक निघत आहेत.'केल्याने भाषांतर'चा हा प्रवास थक्क करणारा आणि तेवढाच आनंद देणारा आहे. अंकाची सजावट, सुशोभीकरण आणि देखणी मुखपृष्ठे असल्यामुळे प्रत्येक अंक मनाला भावतो. अंकाच्या मुखपृष्ठावर परकीय साहित्यातील लेखकाचे, लेखिकेचे छायाचित्र छापलेले दिसते. अनेक अंकांची मुखपृष्ठे चंद्रमोहन कुलकर्णी, सुप्रिया जोगदेव, लक्ष्मी बेहरे यांनी निर्माण केलेली आहेत. परभाषेतील आशय आणि कलाकृती त्या लेखकांच्या छायाचित्रासह दिल्यामुळे अंकाची शोभा अधिक वाढलेली दिसते. लेखक, लेखिकेच्या दिसण्याबद्दलची उत्सुकतापूर्ण होते. अंकातील आशयसूत्रांचा अर्थ बोलक्या मुखपृष्ठातून व्यक्त होतो. २००३ पासून प्रत्येक अंकावर 'लेखणीसदृश काठीला बांधलेले भाषांतराचे गाठोडे घेऊन येणारा हॅट घातलेला माणूस' असे बोधचिन्ह छापले जात आहे. 'केल्याने भाषांतर'चे बोधचिन्ह समर्पक आणि विचार करायला लावणारे आहेत.'केल्याने भाषांतर'चा हेतू आणि निर्मितीचे प्रयोजन या बोधचिन्हातून स्पष्टपणे प्रसृत होते. विचारगर्भ असा प्रतिकात्मक अर्थ बोधचिन्हातून थेट आणि नेमकेपणाने लक्षात येतो. अनेक अंकांमध्ये भाषांतरकारांची नावे छापणे, मान्यवरांच्या निधनानंतर त्यांच्याविषयी कृतज्ञता व्यक्त करणारे श्रद्धांजलीपर निवेदन अंकातून प्रसिद्ध करणे, वाचकांचा अंकाविषयीचा अभिप्राय आणि सूचना कोणतीही काटछाट न करता छापणे. परकीय भाषेतील शब्दांचा अर्थबोध होण्यासाठी तळटीपा देणे, लेखकांची छायाचित्रे, परीक्षणार्थ वापरलेल्या ग्रंथांची मुखपृष्ठे छापणे, जाहिरातींचा आग्रह न धरता परकीय भाषेतील ललित साहित्य मराठी वाचकांच्या हृदयापर्यंत नेऊन पोहोचविणे,यांसारख्या अनेक बाबींमुळे केल्याने भाषांतरचे वेगळेपण ठसठशीतपणे नजरेत भरते. कोरोनामुळे नियतकालिकांच्या निर्मिती, छपाई, वितरणव्यवस्था यांमध्ये प्रचंड अडचणी निर्माण झाल्या. अनेक नियतकालिके बंद पडली. काहींचे अंक निघाले नाहीत. केल्याने भाषांतर मात्र या संकटात देखील सर्व शक्तीनिशी समर्थपणे डिजिटल स्वरूपात अंक निर्माण करत राहिले. सर्व वर्गणीदारांना पीडीएफ स्वरूपातील अंक पाठवून, त्यानंतर त्यांची छपाई करून ते अंक पोस्टाने पाठवले. ही वाखाणण्यासारखी बाब मानली पाहिजे. अंक उशिरा निघाले. मात्र त्यामध्ये खंड पडलेला दिसत नाही.

परकीय भाषेतील नेमके कोणते साहित्य मराठीत आणायचे? ते का भाषांतरित करायचे? कोणता वाचक वर्ग डोळ्यासमोर ठेवून भाषांतर करायचे? जर्मन, फ्रेंच, रशियन, जपानी, स्पॅनिश भाषेतील अभिजात ललित साहित्य मराठीत आणताना भाषांतराच्या कोणत्या कसोट्या

वापरायच्या? अशा अनेक प्रश्नांची सकारात्मक उत्तरे 'केल्याने भाषांतर'च्या यशस्वी वाटचालीत मिळतात. त्याचे मुख्य कारण म्हणजे 'केल्यानेभाषांतर'मधील अनुवादकाने स्वीकारलेली 'भाषांतराची शैली' होय. परकीय भाषेतून थेट मराठीत भाषांतर करताना सामाजिक, सांस्कृतिक, धार्मिक, राजकीय, वैचारिक, ऐतिहासिक संदर्भ, भौगोलिक वैशिष्ट्य, प्रथा, परंपरा यातील जुने - नवे संदर्भ लक्षात घेऊन लक्ष्य भाषेत यथोचित आणि समर्थपणे आणणे, मूळ संहितेतील साहित्यिक सौंदर्याला बाधा न पोहोचवता भाषांतरित संहिता तयार करणे, भाषांतरित केलेली संहिता मूळच्या आशयाशी, विषयाशी, लेखकांच्या म्हणण्याशीप्रामाणिक ठेवणे, परकीय भाषेतील संबोध, प्रतिमा, प्रतिके मिथ्थके, म्हणी, वाक्प्रचार, उखाणे, परंपरागत आणि पुनर्स्थापित सामाजिक- सांस्कृतिक-भाषिक संकेत यातील दुर्बोधता आणि क्लिष्टता दूर करण्यासाठी भाषांतरित संहितेत स्पष्टीकरण देणे यांसारख्या अनेक बाबींचा पुरस्कार 'केल्याने भाषांतर'मधील भाषांतरकारांनी भाषांतर करताना स्वीकारलेला आहे. त्यामुळे भाषांतराची अनोखी शैली संपादन केलेली अनेक मंडळी 'केल्याने भाषांतर'साठी लिहित आहे. 'केल्याने भाषांतर'च्या यशस्वीतेत शैली संपादन आणि नियमितपणाचा मोठा वाटा आहे.

निष्कर्ष

परकीय भाषेतील ललित साहित्य थेट मराठीत भाषांतरित करणारे आणि निव्वळ भाषांतराला वाहिलेले 'केल्याने भाषांतर' हे त्रैमासिक २४वर्षे अविरतपणे सुरू आहे. परकीय भाषेतील लेखकांच्या कलाकृतींचे मराठीत भाषांतर केल्यामुळे मराठी वाचकांची आंतरसांस्कृतिक समज वाढून बहुभाषिकता, बहुसांस्कृतिकता, वाङ्मयीन पर्यावरणातील साम्य-भेद, कला-संस्कृतीमधील समाज संदर्भ, भाषिक संकेत यांच्या आस्वाद आणि आकलनास चालना मिळून संशोधन निर्माण होऊ लागले. भारतीय आणि परकीय भाषांमधील साहित्य मराठीत आणणाऱ्या भाषांतर कारांमध्ये सुसंवाद निर्माण झाला. भाषांतरित साहित्यामुळे परकीय भाषांतील साहित्याचा इतिहास, वाङ्मय प्रकार आणि त्यातील नवे प्रवाह, वाङ्मयाचे बदलते स्वरूप व संदर्भ समजून घेऊन भाषांतर आणि तौलिक साहित्याभ्यासास चालना मिळाली. स्त्रोत भाषा आणि लक्ष्य भाषेची उत्तम जाण असलेल्या भाषांतरकारांचा समूह तयार झाल्यामुळे केल्याने भाषांतरने चळवळीचे रूप धारण केले आहे.'केल्याने भाषांतर'च्या वाङ्मयीनपूरक उपक्रमांमुळे परकीय भाषेतील साहित्य वाचकांपर्यंत पोहोचण्यास मदत होते, त्यामुळे जागतिक साहित्याविषयी उत्कंठा आणि जिज्ञासेची पूर्तता होते. परकीय साहित्याच्या वाचनाची भूक वाढलेल्या वाचकांच्या वाङ्मयीन अभिरुचीचे दिशा दिग्दर्शन 'केल्याने भाषांतर' करत आहे हे निर्विवादपणे मान्य करावे लागते.

संदर्भ

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– डॉ. सहदेव शरद चव्हाण

मराठी विभागप्रमुख, भारतीय जैन संघटनेचे कला, विज्ञान आणि वाणिज्य महाविद्यालय वाघोली, पुणे - ४१२२०७

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The comparative study of the bioactivity of polyquinone and corresponding derivatives

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Abstract

Quinone and corresponding compounds available in literature shows remarkable bioactivity against various microbes which include bacteria, fungi and the most prominently viruses. The bioactivity of any biomolecule is rest on on various parameters like compound itself, target system, surrounding excreta. This paper has enlightened on bioactivity of quinone based polymers and structural effects how they emphasize, work effectivity against microbes. During the experimental condition different prepared polyquiones and their derivatives are used to check the bioactivity against various pathogenic cultures of bacteria, viruses and fungi. For the few targeted pathogenic cultures extremely, good results are obtained which also justifies the QSAR of the molecule.

Keywords

Quinone, quinonic derivatives, bioactivity, structural effect, pathogenic activity

Introduction

Quinones are the class of compounds which responds against wide range of pathogens. Along with quinones amines are also showing bioactivities against special range of pathogens. [5] The polymers prepared with the help of these compounds were tested for bioactivity against various reaction conditions. [8] For the checking of bioactivity different methods are available like disk diffusion method, microdilution technique, borth method and agar method [10]. Among all listed methods for the experiment Agar dilution and microdilution method is used. For the checking of bioactivity during the experimental condition we have used three different types of fungi namely Asperillus flavus, Candida albicans [2] and Aspergillus niger and three bacteria which include two-gram positive bacteria and one-gram negative bacteria. The gram-positive bacteria include staphylococcus aureus and Bacillus subtilis. The gram negative strain of Escherichia coli .

Experimental

During the experimental condition synthesized desire compounds were subjected for testing of invitro antimicrobial activity. As per described in introduction, the antifungal activity was evaluated against three fungi stains A. flavus [NCIM-539], C.albicans [NICM-3471] and A. niger [NICM-1196]. The two gram positive bacterial strains of S.aureus[NICM-2901], B.subtilus [NICM-2063] and gram negative bacteria e. coil [NICM-2256]. For studying antimicrobial properties of compounds, Minimum Inhibitory Concentration (MIC, µg/mL), Minimum Bacterial Concentration (MBC) and Minimum Fungicidal Concentration (MFC) were studied by modified microdilution technique. For Fungal strains agar dilution technique, on Potato Dextrose Agar (PDA) Medium were used for MIC determination. The MBC and MFC of compounds were determined by serial sub cultivation after inoculated for 72 h with tested compounds dissolved in saline containing 5% DMSO. The lowest concentration with no visible growth was defined as MBC/MFC indicating 99.5% killing of the original inoculums. [6] All the experiments performed in triplicates and mean reading is taken as final reading. 5% DMSO was used as a negative control along with Fluconazole and Miconazole as the standard antifungal drugs and Ciprofloxacin as the standard antibacterial drugs For bacterial strains MIC determination were done by a serial of microdilution technique using 96-well microtiter plate reader. Compounds are prepared in saline (0.8% NaCl) solution containing 5% Dimethyl sulfoxide (DMSO) for dissolution. All microbial strains were incubated with different concentration of each compound in 96-well microtiter plate for 20 h at 37 oC on Rotary shaker (160 rpm). After incubation the lowest concentration value without growth were defined as MICs.

The compounds used for the analysis has structure like

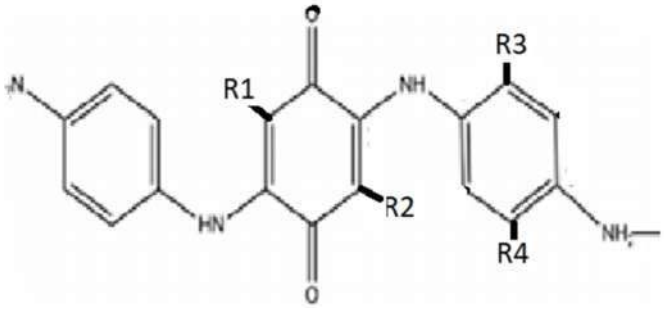


Table 1: Details about compound substituents

Compound	R1	R2	R3	R4
1	H	H	H	H
2	Cl	H	H	H
3	Cl	Cl	H	H
4	H	H	Cl	H
5	H	H	Cl	Cl

The polyquinone prepared with the help of quninone and phenylene diamine along with mono chloro, dichloro derivatives are used to check the bioactivity. All above polymeric species vary with polar group substituents therefor they show variation in bioactivity as their mode of interaction varies. Polarity of the compounds influences more for binding of compounds with pathogens and therefore various results are observed.

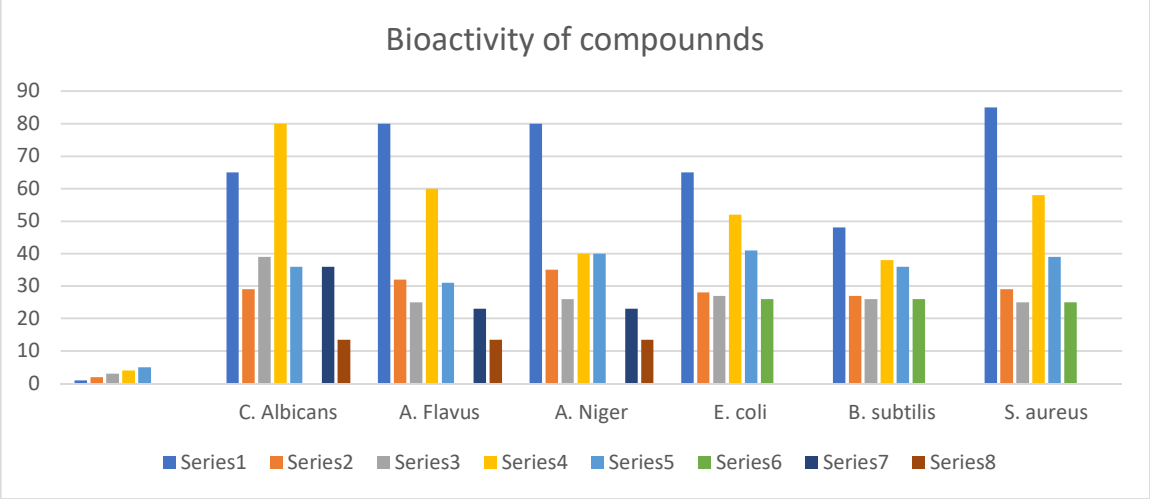
Observations

Table 2: Observations for antipathogenic activity

Compounds	MIC values[a] (µg/ml)					
	C. Albicans	*A. Flavus*	*A. Niger*	*E. coli*	*B. subtilis*	*S. aureus*
1	65	80	80	65	48	85
2	29	32	35	28	27	29
3	39	25	26	27	26	25
4	80	60	40	52	38	58
5	36	31	40	41	36	39
Ciprofloxacin	-	-	-	26	26	25
Fluconazole	36	23	23	-	-	-
Miconazole	13.5	13.5	13.5	-	-	-
All the values are taken as average of three readings.						

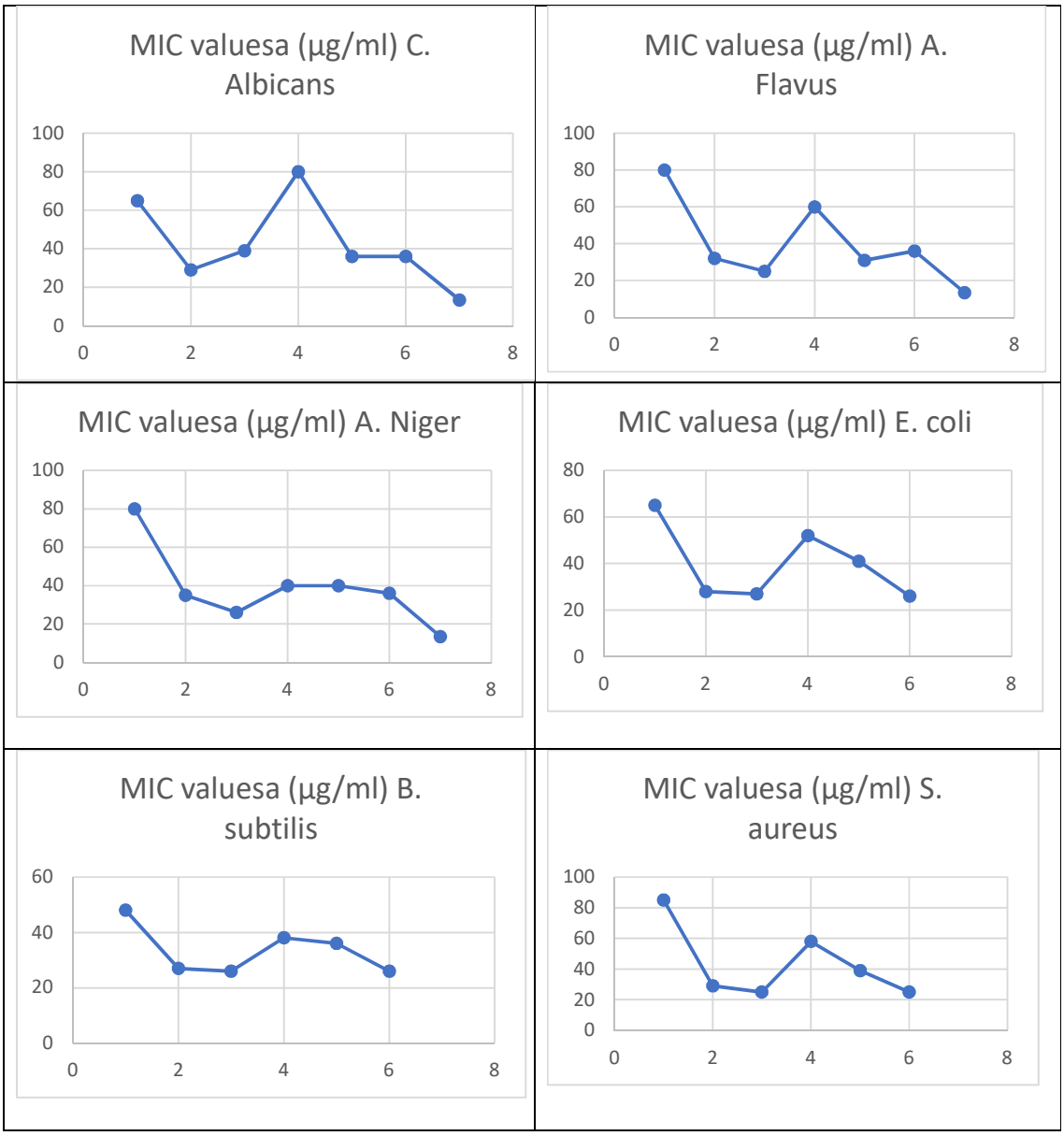
Graph

Graph1: Bioactivity observed for polyquinones



Result and discussion

Table 3 : Individual graphs for interaction of various compounds against pathogens



During the experimental conditional it has been observed that all the polymeric compounds are bioactive in nature but vary or interact differently to show minimum inhibitory concentration [MIC], minimum bacterial concentration [MBC], minimum fungal concentration [MFC]. All the compounds differ with results due to the variation in structures, substitution effect, polarity of compound, interaction of compound with media and binding with pathogen. QSAR plays important roll. [7]. Along with this nature of pathogen, size of pathogen and its activity all together impacted on MIC values [3]. The concentration of pathogen has impact on MIC value [4] Base polymeric compound is less polar in nature and shows least bioactivity as compared to all reaming treated polyquinonic compounds whereas compounds 2 and 3 has showed highest bioactivity and both are chloro-substituted compounds. As compared compound 2, compound 3 has shown more pathogenic activity with minimum MIC as it the dichloro-derivative and more polar as compared to compound 1 and 2. Again among compound 4 and 5, dichloro-derivative has shown more bio activity as

compared to monochloro-derivative. The second polymer shows highest bioactivity against C. Albicans whereas Fourth polymer shows least bioactivity as compared to fluconazole. For A. Flavus polyquione three shows good inhibitory activity followed by second and fifth polymers has showed comparable bioactivity and for A. Flavus first polymer has showed least inhibitory activity. For the fungi A. Niger strain compound three is most effective followed by surprisingly polymer four and five has shown same interaction. In case of gram negative Bacterial E.coil , it has been observed compound three shows comparable bioactivity with Ciprofloxacin but remaining all compounds were less effective. For remaining two-gram positive bacteria B. subtilis and B. subtilis compound three has showed comparable inhibitory activity. S. Aureus has showed least pathogenic activity as compared to standard antibiotic.

Conclusion

After performing experiment and testing bioactivities for synthesized polymeric compounds it has been observed that all polymeric compounds show bioactivities and vary with MIC due to structural effects along with this polarity influences the pathogenic activity. Among all developed compounds Compound three has showed satisfactory bioactivity as compared to all remain compounds.

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