Vol XIV / Issue XXVIII March- 2025 ISSN:2278-4187

Anusandhan

SCIENCE TECHNOLOGY & MANAGEMENT JOURNAL

[Published by]

RNTU Rabindranath TAGORE UNIVERSITY MADHYA PRADESH, BHOPAL

Mendua, Post-Bhojpur, Bhopal-Chiklod Road, Distt. Raisen (M.P.) India- 464993

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Indexed by Copernicus
Online Version (eISSN 2457-0656) http://rntujournals.aisect.org

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ANUSANDHAN

A SCIENCE TECHNOLOGY & MANAGEMENT JOURNAL OF RNTU

From the Editor-in-Chief

Dear Readers,

Greetings from *Anusandhan*!

It brings me immense joy and pride to present this latest edition of our journal, a testament to the tireless dedication of researchers and practitioners from across the globe. In each issue, we strive to curate a collection of thought-provoking, innovative, and impactful research that not only adds to the existing body of knowledge but also inspires actionable solutions to the challenges we face today.

As we stand on the cusp of a rapidly evolving technological era, the role of science, engineering, technology, and management in shaping our future has never been more pronounced. While advancements such as artificial intelligence, renewable energy solutions, and digital transformation hold great promise, they also bring forth critical concerns. Issues such as ethical AI deployment, sustainable resource management, and the environmental footprint of modern innovations require urgent attention and thoughtful discourse.

Moreover, the integration of science and management practices in addressing global challenges like climate change, water scarcity, and equitable access to technology underscores the need for interdisciplinary collaboration. As members of the global scientific community, we bear a shared responsibility to ensure that our contributions foster sustainable development, ethical practices, and a safer, more inclusive future for all.

In this issue, you will find articles that delve into these burning topics, offering insights and solutions that resonate with the ethos of responsible innovation. We hope these contributions will not only enrich your knowledge but also ignite a sense of purpose and curiosity to explore uncharted territories in your respective fields.

To our readers, I extend my deepest gratitude for your unwavering support and engagement. Your enthusiasm fuels our commitment to excellence and inspires us to continue fostering a platform for meaningful intellectual exchange. Together, let us strive to harness the power of knowledge to create a brighter, more sustainable world.

Happy reading!

Warm regards,

Dr. Rachna Chaturvedi
Chief Editor
Anusandhan: Journal of Science, Engineering, Technology, and Management

ANUSANDHAN

In This Issue

Vol XIV/Issue XXVIII March-2025 **ISSN: 2278-4187**

Effectiveness of Polysulfides in Advanced Physical Applications: Emerging Trends in Allied Health Sciences

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ABSTRACT
Polysulfide, a class of sulphur-rich compounds, have gained increasing attention in advanced physical applications, particularly within allied health sciences. Their unique chemical properties—high reactivity, redox potential, and biocompatibility—enable their use in drug delivery systems, antimicrobial coatings, tissue engineering, and biosensors. Recent advancements highlight their critical role in Nano medicine, oxidative stress regulation, and regenerative therapies, contributing to controlled drug release, enhanced wound healing, and improved diagnostic applications. However, challenges such as stability limitations, potential toxicity, and scalability constraints hinder their broader adoption. Future research should focus on enhancing biocompatibility, refining synthetic methodologies, and expanding biomedical applications to unlock their full potential in next-generation healthcare solutions.

I INTRODUCTION

Polysulfide, a class of sulphur -rich compounds characterized by multiple sulphur atoms linked in a chain, have emerged as key materials in advanced biomedical applications. Their distinctive physicochemical properties, including high reactivity, redox potential, and biocompatibility, make them highly valuable for various healthcare innovations. These compounds exhibit strong interactions with biological molecules, making them particularly useful in drug delivery, biosensors, antimicrobial coatings, and tissue engineering. The increasing focus on polysulfides in allied health sciences is driven by their potential to revolutionize therapeutic and diagnostic approaches. In drug delivery systems, polysulfides facilitate controlled drug release through their redox-sensitive nature, enhancing treatment efficacy while minimizing side effects. Additionally, their antimicrobial properties have positioned them as promising candidates for coatings in medical implants and wound dressings, reducing the risk of infections. In regenerative medicine, polysulfides contribute to tissue repair by promoting cellular responses, making them suitable for applications in wound healing and tissue scaffolds. Recent advancements have highlighted the role of polysulfides in Nano medicine and oxidative stress regulation. Studies indicate that these compounds can modulate redox balance in biological systems, playing a crucial role in preventing cellular damage and enhancing therapeutic outcomes. Despite their promising applications, several challenges hinder their widespread adoption, including stability issues, potential toxicity, and scalability concerns. Addressing these limitations requires further research into optimizing synthetic methodologies, improving biocompatibility, and expanding biomedical applications.

This paper provides a comprehensive overview of the effectiveness of polysulphides in advanced physical applications, particularly in allied health sciences. It explores their significance, recent breakthroughs, critical challenges, and future directions, emphasizing their potential to drive next-generation healthcare solutions. Through an in-depth analysis of current research and emerging trends, this study aims to highlight the transformative impact of polysulphides in medical science.

II LITERATURE REVIEW

The study of polysulfides dates back several decades, initially focusing on their chemical stability, reactivity, and industrial applications, such as vulcanization and corrosion inhibition. As research advanced, their unique redox properties and biocompatibility sparked interest in biomedical applications. Early studies investigated their antioxidant capabilities and interactions with biological systems, laying the foundation for their integration into healthcare. Over time, researchers shifted their focus from industrial uses to medical applications, exploring their role in drug delivery, tissue engineering, and antimicrobial coatings.

(a) Recent Research Trends

Recent studies highlight the increasing significance of polysulfides in healthcare applications:

- **Antioxidant Properties**: Smith et al. (2021) demonstrated that polysulfides exhibit strong antioxidant effects, making them valuable in managing oxidative stress-related disorders, such as neurodegenerative diseases and cardiovascular conditions.
- **Antimicrobial Coatings**: Zhang et al. (2022) explored their role in antimicrobial surfaces, showing their effectiveness in preventing hospital-acquired infections by inhibiting bacterial growth on medical implants and wound dressings.
- **Tissue Engineering**: Jones et al. (2023) investigated their application in regenerative medicine, highlighting their potential to enhance wound healing, promote cellular regeneration, and improve scaffold materials for tissue repair.

(b) Challenges and Limitations in Current Research

Despite significant progress, limitations such as toxicity concerns and stability issues remain.

- Patel et al. (2023) noted the cytotoxic effects of certain polysulfide derivatives, requiring further investigation for safe clinical applications.
- Scalability challenges in large-scale manufacturing have been discussed by Kim et al. (2023).

III SIGNIFICANCE OF POLYSULFIDES IN ALLIED HEALTH SCIENCES

(a) High Redox Potential: Facilitates interactions within oxidative and reductive biological environments, playing a crucial role in oxidative stress regulation and cellular signalling.

(b) Biocompatibility : Ensures safe application in drug delivery systems, medical coatings, and tissue engineering, minimizing adverse biological reactions.

(c) Structural Versatility: Allows tailored chemical modifications to enhance stability, bioavailability, and targeted therapeutic effects, making them adaptable for Nano medicine and regenerative therapies.

(d) Antimicrobial Properties: Effectively prevent infections in wound dressings, medical implants, and biosensors, reducing the risk of pathogen-induced complications in healthcare settings (Zhang et al., 2023).

IV RECENT ADVANCES IN POLYSULFIDE APPLICATIONS

Application	Key Benefits	References
Drug Delivery Systems	Redox-responsive carriers for controlled release	Jones et al. (2023)
Antimicrobial Coatings	Prevents bacterial growth on medical implants	Zhang et al. (2022)
Tissue Engineering	Supports cell adhesion, proliferation, and regeneration	Jones et al. (2023)
Biosensors	Detects oxidative stress markers and biomolecules	Smith et al. (2021)

(a) **Antimicrobial Coatings -** Polysulfide have been incorporated into coatings for medical implants to prevent biofilm formation. Recent studies indicate that polysulfide coatings can inhibit bacterial growth without causing cytotoxicity, making them valuable for wound dressings and catheter surfaces (Zhang et al., 2022).

(b) **Tissue Engineering and Regenerative Medicine -** Polysulfide-based hydrogels have shown promise in tissue engineering applications. Their ability to support cell adhesion, proliferation, and differentiation has led to advancements in regenerative medicine. Studies report that polysulfide-modified scaffolds enhance wound healing and cartilage regeneration (Jones et al., 2023).

(c) **Biosensors and Diagnostic Applications -**

V CRITICAL ISSUES AND CHALLENGES

Polysulfides have gained attention in biosensor technology for detecting oxidative stress markers and disease-related biomolecules. Recent advancements in electrochemical and fluorescence-based polysulfide sensors have significantly enhanced diagnostic accuracy for conditions such as diabetes and cardiovascular diseases (Smith et al., 2021). These sensors leverage the redox properties of polysulfides to provide high sensitivity and rapid detection, improving early disease diagnosis and monitoring. Additionally, their biocompatibility makes them suitable for non-invasive and implantable biosensors, expanding their potential in real-time medical diagnostics. Ongoing research aims to refine their stability, selectivity, and integration with nanotechnology for enhanced performance.

Despite their significant potential in healthcare applications, polysulfides face several challenges that hinder their widespread adoption. One major concern is stability, as polysulfides are highly prone to degradation due to their sensitivity to oxidation and environmental conditions. This instability can affect their long-term effectiveness in drug delivery, tissue engineering, and antimicrobial coatings.

Another critical issue is toxicity, as certain polysulfide derivatives may exhibit cytotoxic effects, raising concerns about their safe use in biomedical applications. Studies indicate that while some polysulfides demonstrate excellent biocompatibility, others may induce oxidative stress, necessitating further investigation into their biological interactions and safe concentration levels (Patel et al., 2023).

Scalability and cost also present significant hurdles. The synthesis of polysulfides involves complex chemical processes that require precise control, leading to high production costs. Additionally, large-scale manufacturing remains challenging, limiting their commercial viability and accessibility for widespread medical use (Kim et al., 2023).

Lastly, regulatory approval is essential for the clinical translation of polysulfide-based materials. Stringent safety evaluations, compliance with biomedical regulations, and thorough clinical testing are necessary before they can be integrated into mainstream healthcare solutions. Addressing these challenges through enhanced synthetic strategies and toxicity assessments will be crucial for their broader adoption in medicine.

VI FUTURE DIRECTIONS

To Enhancing overcome these challenges, future research should focus on:

- **(a) Biocompatibility**: Developing modified polysulfides with improved biocompatibility and reduced toxicity.
- **(b) Optimizing Synthetic Methodologies**: Advancing green chemistry approaches for cost-effective and scalable synthesis.
- **(c) Expanding Biomedical Applications**: Exploring new uses in immunotherapy, neuroprotection, and precision medicine.
- **(d) Integrating with Nanotechnology**: Combining polysulfides with nanomaterials to enhance functionality in drug delivery and diagnostics.

VII CONCLUSION

Polysulfides have emerged as promising materials in allied health sciences, offering diverse applications in drug delivery, antimicrobial coatings, tissue engineering, and biosensing. While significant progress has been made, addressing stability, toxicity, and scalability challenges is crucial for their widespread adoption. Continued research and innovation will pave the way for polysulfides to play a transformative role in next-generation healthcare solutions.

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Innovations in Renewable Energy: Driving the Transition Toward a Sustainable Future

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ABSTRACT
The accelerating transition toward sustainable energy systems represents one of the most critical global challenges and opportunities of the 21st century. At the heart of this transformation lies a surge of innovation in renewable energy technologies that is reshaping how energy is generated, distributed, and consumed. Driven by the dual imperatives of mitigating climate change and reducing dependency on finite fossil fuel resources, countries and corporations alike are investing heavily in the research, development, and deployment of clean energy solutions. These innovations are not only increasing the efficiency and affordability of renewable energy sources but are also enabling their integration into existing energy infrastructures at an unprecedented scale. Among the most significant technological breakthroughs are those occurring within the core renewable sectors: solar, wind, hydroelectric, geothermal, and bioenergy. Solar power, long heralded for its potential, is undergoing a revolution with the emergence of perovskite solar cells. These next-generation photovoltaic materials offer higher efficiency and lower production costs compared to traditional silicon-based cells, making solar energy more accessible to both industrialized and developing regions. In the wind energy sector, the development of offshore floating wind turbines is overcoming geographical limitations previously imposed by shallow water depths. This innovation allows for the exploitation of strong and consistent winds in deeper ocean areas, significantly expanding the potential for wind power generation. Hydropower, traditionally associated with large-scale dam projects, is also being reimagined through the advent of small modular hydro systems. These decentralized units offer a more flexible and environmentally friendly approach, especially suitable for rural and remote areas with limited access to the grid. Meanwhile, geothermal energy is benefitting from the advancement of Enhanced Geothermal Systems (EGS), which artificially stimulate underground reservoirs to generate heat in regions without natural hydrothermal activity. This broadens the geographic applicability of geothermal power, making it a more viable option globally. In the realm of bioenergy, algae-based biofuels are showing tremendous promise due to their high energy yield, rapid growth rates, and ability to thrive in non-arable environments, including saltwater and wastewater. Beyond generation technologies, systemic innovations are enhancing the integration and performance of renewable energy. Smart grids, which use sensors, automation, and data analytics, enable more reliable and efficient energy distribution by dynamically adjusting to fluctuations in supply and demand. Coupled with advances in energy storage—particularly next-generation batteries and hydrogen technologies—these systems help mitigate the intermittency issues that have traditionally challenged renewable sources like solar and wind. Additionally, the adoption of digital tools such as artificial intelligence (AI) and the Internet of Things (IoT) is enabling predictive maintenance, real-time monitoring, and optimized performance across the energy value chain. Ultimately, these technological advancements are not occurring in isolation. They are having profound implications for global energy policy, economic development, and climate change mitigation. As governments aim to meet net-zero carbon targets and support sustainable growth, the deployment of innovative renewable energy solutions is becoming a cornerstone of strategic planning. These innovations are creating new jobs, reducing greenhouse gas emissions, and empowering communities with cleaner, more resilient energy systems. Together, they represent a pivotal shift in how humanity powers its future.

I INTRODUCTION

The urgency of combating climate change, coupled with the depletion of fossil fuel resources, has led to a global push toward renewable energy sources. Renewable energy technologies have evolved rapidly over the last decade, making them increasingly cost-competitive and scalable. Innovations in materials science, engineering, and digital technologies are playing a pivotal role in this energy transition.

II INNOVATIONS IN RENEWABLE ENERGY TECHNOLOGIES

(a) Solar Energy

- **Perovskite Solar Cells-** Traditional silicon-based photovoltaic (PV) cells have long dominated the solar energy market due to their reliability and proven performance. However, recent advancements in perovskite solar cell technology are beginning to challenge the status quo. Perovskite solar cells are named after their light-absorbing material, which has a unique crystal structure and exceptional optoelectronic properties. These materials can absorb sunlight efficiently and convert it into electricity at a fraction of the cost and energy required to manufacture traditional silicon cells. One of the most remarkable aspects of perovskite technology is the rapid improvement in its efficiency. In just over a decade, laboratory research has advanced perovskite solar cell efficiency from under 4% to over 25%, rivaling high-end silicon-based cells. Furthermore, researchers are developing tandem solar cells that layer perovskite materials on top of silicon or other substrates. These tandem cells allow for broader light absorption and have demonstrated the potential to exceed 29% efficiency, with future projections surpassing 30%. In addition to their performance, perovskite cells can be produced using low-cost, scalable techniques such as printing and coating. If challenges related to long-term stability and environmental durability are addressed, perovskite solar cells could play a transformative role in the future of renewable energy.
- **Bifacial Panels and Solar Tracking -** Bifacial solar panels are an advanced photovoltaic technology capable of capturing sunlight from both the front and rear sides of the panel. This design allows them to harness reflected light from surfaces such as the ground or nearby structures, significantly enhancing energy generation. When integrated with solar tracking systems—which adjust the panel's position to follow the sun's movement throughout the day—the efficiency gains are even greater. This dynamic combination can boost total energy output by up to 30% compared to traditional fixed, monofacial panels, making it an increasingly attractive solution for maximizing solar power yield in large-scale installations.

(b) Wind Energy

- **Floating Offshore Wind Turbines -** Fixed-bottom offshore wind turbines are typically installed on foundations anchored to the seabed, which restricts their deployment to shallow coastal waters, usually less than 60 meters deep. This limitation excludes many areas around the world with deeper ocean floors that also have strong and consistent wind resources. Floating offshore wind turbines offer a transformative solution by allowing wind farms to be installed in much deeper waters—often over 200 meters—where traditional fixed structures are not viable. These floating platforms are moored to the seabed with flexible anchors and can support large turbine structures, enabling access to previously untapped wind resources. Notable projects like Hywind Scotland, the world's first commercial floating wind farm, have successfully demonstrated the technical and economic feasibility of this technology. With proven performance in harsh marine conditions, floating wind turbines significantly broaden the geographical scope of offshore wind development, paving the way for increased global renewable energy capacity.

- **Vertical-Axis Wind Turbines (VAWTs) -** Vertical-axis wind turbines (VAWTs), although generally less efficient than their horizontal-axis counterparts, offer unique advantages that make them well-suited for specific environments. Their compact, vertical design allows them to capture wind from any direction, making them ideal for turbulent, inconsistent wind conditions often found in urban areas. Additionally, VAWTs operate more quietly and can be installed closer to the ground, reducing maintenance costs and increasing accessibility. Their smaller footprint also allows for easier integration into buildings or densely populated areas, where space and aesthetics are important. These features make VAWTs a practical solution for localized, small-scale wind energy generation.

(c) Hydroelectric Innovations

- **Small Modular Hydropower (SMH) -** Small Modular Hydropower (SMH) units represent a sustainable and flexible alternative to traditional large-scale hydroelectric dams. These systems are decentralized, meaning they can be deployed independently in various locations, making them especially well-suited for rural and remote communities that lack access to centralized power grids. Unlike large dams, which often involve significant ecological and social disruption—such as habitat loss, displacement of communities, and altered river ecosystems—SMH units typically have minimal environmental impact. They often utilize existing waterways or small diversions without requiring large reservoirs, preserving the natural flow of rivers. Additionally, SMH systems are relatively quick and cost-effective to install, allowing for faster implementation and return on investment. Their modular design means they can be scaled according to local energy needs, providing a reliable, renewable power source tailored to specific regions. This makes them an ideal solution for advancing energy access and sustainability in hard-to-reach or ecologically sensitive areas.
- **Hydrokinetic Turbines -** Hydrokinetic turbines are an innovative form of renewable energy technology that harness energy from the natural flow of water in rivers, tidal currents, or ocean streams without the need for traditional dam infrastructure. Unlike conventional hydropower systems that rely on the construction of large reservoirs, hydrokinetic turbines are placed directly in flowing water, allowing them to generate electricity while preserving the natural course of the river or tidal flow. This makes them particularly well-suited for applications where large-scale projects are impractical or ecologically harmful. Their minimal infrastructure requirements mean they can be quickly and easily deployed, making them an ideal solution for off-grid or remote communities that lack access to centralized electricity systems. Additionally, hydrokinetic systems have a very low environmental footprint—they do not obstruct fish migration paths, significantly alter aquatic ecosystems, or cause the sedimentation issues often associated with dams. These turbines can operate efficiently in a wide range of flow conditions, and their modular design allows for flexible scalability depending on local energy demands. As a result, hydrokinetic technology is gaining attention as a sustainable, low-impact option for expanding renewable energy access while maintaining the ecological integrity of rivers and coastal environments.

(d) Geothermal Advancements

- **Enhanced Geothermal Systems (EGS) -** Enhanced Geothermal Systems (EGS) are a cutting-edge approach to expanding the reach of geothermal energy beyond areas with naturally occurring hydrothermal reservoirs. Unlike conventional geothermal systems that rely on naturally heated water and permeable rock, EGS technologies use hydraulic stimulation—similar to techniques used in oil and gas extraction—to create fractures in dry, impermeable rock formations deep underground. This process increases the rock's permeability, allowing water to circulate through and absorb heat from the earth’s interior. The heated water is then brought to the surface to generate electricity. By engineering these reservoirs, EGS can unlock geothermal potential in vast new regions.

- **Closed-Loop Systems -** Closed-loop geothermal systems use sealed pipes to circulate a fluid through underground rock formations, preventing direct contact between the geothermal fluid and the surrounding environment. This design eliminates concerns like mineral scaling, which occurs when dissolved minerals in the geothermal fluid precipitate and clog pipes, reducing system efficiency. Additionally, by keeping the circulating fluid contained within the sealed pipes, the risk of contaminating groundwater with harmful chemicals or minerals is avoided. Closed-loop systems, therefore, offer a cleaner, more sustainable approach to geothermal energy, as they do not compromise water quality or require complex water treatment processes.

(e) Bioenergy

- **Algae-Based Biofuels -** Algae-based biofuels have emerged as a promising alternative to traditional biofuels due to their high energy yield. Algae can produce up to 30 times more energy per acre than conventional land crops, making them a highly efficient source of biofuel. One of the most significant advantages of algae is that it can be cultivated on non-arable land, including areas with saline or wastewater, which would otherwise be unsuitable for food crops. Moreover, advances in genetic engineering have led to strains of algae with higher lipid content, the key component for biofuel production, significantly boosting yields and making algae-based biofuels more economically viable and sustainable.
- **Waste-to-Energy Technologies -** Innovations in anaerobic digestion and gasification are transforming waste management by converting agricultural, industrial, and municipal waste into valuable energy. Anaerobic digestion involves the breakdown of organic waste by microorganisms in the absence of oxygen, producing biogas, primarily methane, which can be used for heating, electricity generation, or as a vehicle fuel. Gasification, on the other hand, involves heating waste materials in a controlled, low-oxygen environment to produce syngas, a mixture of carbon monoxide and hydrogen, which can be used to generate electricity or as a feedstock for chemical production. Both technologies reduce waste volume, mitigate greenhouse gas emissions, and provide renewable energy solutions.

III INTEGRATION TECHNOLOGIES

(a) Energy Storage

- **Next-Generation Batteries -** Recent advancements in battery technology, such as lithium-silicon, solid-state, and flow batteries, are providing significant improvements over traditional lithium-ion batteries, particularly in terms of energy density and lifespan. Lithium-silicon batteries, for example, replace the graphite anode found in conventional lithium-ion cells with silicon, which has a much higher capacity to store lithium ions. This results in batteries that can store more energy in the same amount of space, offering a higher energy density and potentially longer-lasting power. Solid-state batteries, on the other hand, use a solid electrolyte instead of the liquid or gel electrolytes found in traditional lithium-ion cells. This innovation not only increases energy density but also improves safety by eliminating the risk of leakage or fire hazards associated with liquid electrolytes. Solid-state batteries also tend to have a longer cycle life and are less prone to degradation over time. Flow batteries are another promising technology, especially for large-scale energy storage. They store energy in liquid electrolytes that flow through a cell, and their design allows for much higher energy densities and longer operational lifespans than conventional batteries, making them ideal for grid storage applications. Together, these advanced battery technologies hold great potential for enhancing energy storage efficiency and sustainability.

- **Hydrogen Storage -** Green hydrogen, produced through the process of electrolysis using renewable electricity, is emerging as a crucial solution for long-term energy storage and decarbonization, particularly for sectors that are difficult to electrify. Electrolysis involves splitting water into hydrogen and oxygen using electricity, and when this electricity comes from renewable sources like wind, solar, or hydro, the hydrogen produced is considered "green" due to its zero carbon emissions. Green hydrogen can serve as an energy storage medium by storing excess renewable energy generated during periods of low demand. This stored hydrogen can then be converted back into electricity or used as a fuel in industries where direct electrification is challenging, such as heavy transport, shipping, and industrial processes like steel and cement manufacturing. Additionally, hydrogen can be stored for extended periods and transported over long distances, making it a versatile energy carrier. As renewable energy sources expand, green hydrogen plays a vital role in creating a more flexible and sustainable energy system.

(b) Smart Grids and IoT - Smart grids leverage advanced technologies such as sensors, automation, and artificial intelligence (AI) to optimize the distribution of electricity in real-time, balancing supply and demand dynamically. Sensors collect data on energy usage, while automation systems can adjust the grid's operation instantly to respond to fluctuations. AI algorithms analyze this data to predict demand and supply patterns, making adjustments to accommodate variable and intermittent energy sources like solar and wind, which are often weather-dependent. This flexibility allows for higher integration of renewable energy into the grid, enhancing efficiency, reducing waste, and ensuring a more stable and resilient energy system.

IV SOCIOECONOMIC AND POLICY IMPLICATIONS

Government incentives, carbon pricing, and international cooperation play a vital role in scaling renewable energy innovations and facilitating the global transition to a sustainable energy future. Incentives such as tax credits, subsidies, and grants can encourage private investment in clean energy technologies, making them more affordable and accessible. Carbon pricing mechanisms, like carbon taxes or cap-and-trade systems, incentivize businesses to reduce emissions by assigning a cost to carbon pollution, thus creating economic pressure to adopt greener technologies. International cooperation is also essential, as countries collaborate on research, share best practices, and create global agreements to address climate change collectively.

Moreover, the green energy revolution is fostering job creation across a variety of sectors, from manufacturing solar panels to operating wind farms. Decentralized energy systems, such as small-scale solar or wind installations, provide local communities with greater energy autonomy, reducing reliance on centralized power grids and enhancing energy security. This shift is reshaping global development paradigms, empowering both developed and developing regions with sustainable and resilient energy solutions.

V CHALLENGES AND FUTURE DIRECTIONS

While significant advancements have been made in renewable energy technologies, several challenges persist in scaling these innovations to meet global energy demands. One of the primary obstacles is managing intermittency—the fluctuation in power generation from renewable sources like solar and wind, which depend on weather conditions. Effective solutions, such as energy storage technologies and grid integration, are critical for maintaining a stable supply, but these technologies need further development and widespread deployment.

Another challenge lies in securing supply chains for the critical materials required for renewable energy infrastructure, such as lithium, cobalt, and rare earth elements. These materials are essential for batteries, wind turbines, and solar panels, but their availability is limited, and mining practices can have significant environmental and social impacts. As the demand for these materials rises, ensuring sustainable and ethical sourcing becomes increasingly important.

Future research must focus on developing circular economy models, which prioritize the reuse, refurbishment, and recycling of materials in renewable energy systems. This approach not only reduces the environmental footprint of production but also alleviates pressure on raw material extraction. Additionally, minimizing the environmental impacts of renewable infrastructure—such as the land use, waste, and resource consumption associated with manufacturing and decommissioning—is essential to ensure that the transition to renewable energy is both sustainable and responsible.

VI CONCLUSION

Innovations in renewable energy are rapidly reshaping the global energy landscape, making the transition to a decarbonized future more achievable than ever before. Breakthroughs in solar, wind, geothermal, and energy storage technologies are increasing the efficiency, affordability, and scalability of renewable power sources. These advancements are reducing the cost of clean energy, making it a competitive alternative to fossil fuels, and significantly lowering carbon emissions, a critical step in combating climate change. However, to fully realize the potential of these technologies, sustained investment is crucial. This includes funding for research and development to further improve the efficiency and cost-effectiveness of renewable technologies, as well as expanding infrastructure to support widespread deployment, such as energy storage systems and smart grids.

Policy reform is also vital in accelerating the transition, with governments playing a key role in creating supportive frameworks through incentives, subsidies, and regulations that encourage clean energy adoption. Additionally, aligning international cooperation on renewable energy standards and climate goals will ensure a cohesive, global effort toward achieving net-zero emissions. In summary, continued investment in research, infrastructure, and policy reform is essential to unlock the full potential of renewable energy technologies and create a sustainable, decarbonized future.

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Future Prospects for use of AI (Artificial Intelligence) in Logistics Industry in India

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ABSTRACT
The rapid evolution of Artificial Intelligence (AI) is transforming supply chain management (SCM), creating opportunities for efficiency, agility, and data-driven decision-making. This comprehensive study explores the multifaceted impact of AI on SCM into AI applications across various supply chain functions, such as Demand forecasting, Projection vs Recourse Planning, inventory management, logistics, Transportation, Vendor Management and customer service. AI-driven demand forecasting and inventory optimization techniques are significantly improving the ability of companies to predict market demand, thereby reducing instances of overstock and stock outs, Transportation, Vendor performance and enhancing overall operational efficiency. In logistics, AI is optimizing transportation routes and enabling predictive maintenance, reducing operational costs, minimizing delays, and ensuring better resource utilization. The study further examines how AI assists in supplier management and risk assessment by identifying reliable suppliers, managing risks, and mitigating potential disruptions. Through the integration of machine learning algorithms, AI enhances warehouse automation, enabling robotics and computer vision technologies to streamline warehouse operations and maximize space utilization. Additionally, AI applications in customer service—such as chatbots and personalization algorithms—are highlighted, showing a direct impact on customer satisfaction and retention. AI's role in sustainability and supply chain transparency, particularly when paired with block chain technology, is also analyzed, revealing benefits in environmental impact reduction, quality control, and regulatory compliance. This study also considers the challenges posed by AI in SCM, including the need for substantial data management, cybersecurity concerns, and ethical implications, particularly related to workforce displacement.

Keywords: - Demand for casting, Projection, Inventory Management, Block chain, Cybersecurity, Transportation & Logistics etc.

I INTRODUCTION

Artificial Intelligence (AI) is a branch of computer science that aims to create systems capable of performing tasks that typically require human intelligence. These tasks include learning, reasoning, problem-solving, understanding language, perception, and decision-making etc.

AI is used in logistics for a variety of purposes, such as forecasting demand, planning shipments, optimizing warehousing, and gaining step-by-step visibility into routes, cargo conditions, and potential disruptions. AI algorithms can help logistics professionals predict transit times, determine the best carrier at the best price, and identify alternate routes and carriers in the event of transport disruptions. They can also be used to automate some elements of customer service, both via AI-powered chatbots that can help handle basic customer inquiries and through AI-based tools that analyze customer complaints and feed that data back to logistics teams.

The Use of Artificial Intelligence in Supply Chain Management in the age of digital transformation, the integration of Artificial Intelligence (AI) into business operations has emerged as a game-changer, especially in the scope of supply chain management (SCM). Supply chains, traditionally characterized by complexity and dependency on manual processes, are increasingly leveraging AI to address challenges such as inefficiencies, unpredictability, and rising customer expectations. The dynamic nature of modern supply chains requires organizations to be agile, data-driven, and capable of making real-time decisions—a paradigm shift that AI facilitates.

AI encompasses advanced technologies such as machine learning, natural language processing, robotics, and predictive analytics, which are reshaping the traditional SCM landscape. These technologies enable companies to forecast demand more accurately, optimize inventory, and improve logistics and distribution efficiency. For instance, AI-powered algorithms can analyze vast datasets in real-time to identify patterns and predict disruptions, enabling preemptive actions to mitigate risks. Additionally, the use of AI in supplier management enhances decision-making by evaluating supplier reliability, cost efficiency, and risk factors.

II IMPORTANCE OF AI IN SUPPLY CHAIN MANAGEMENT

AI is driving the automation of repetitive tasks, such as order processing and warehouse operations, through robotics and intelligent systems. This not only reduces labor costs but also minimizes errors and accelerates operations. In the logistics domain, AI is revolutionizing transportation management by optimizing routes, scheduling, and fleet operations, thus reducing fuel consumption and improving delivery timelines. As sustainability becomes a priority for businesses worldwide, AI plays a pivotal role in fostering greener supply chains. By enabling efficient resource utilization, reducing waste, and facilitating transparent tracking of goods, AI contributes to reducing the environmental footprint of supply chain activities.

By presenting current case studies and examples, this research highlights AI's transformative role in SCM and offers a strategic roadmap for organizations seeking to adopt AI in their supply chain operations. Ultimately, the study concludes that while AI presents immense opportunities, successful integration requires careful planning, investment in digital infrastructure, and a balanced approach to ethical and operational challenges. This comprehensive analysis provides a foundation for future research on AI in SCM, emphasizing the potential for AI to enable a more resilient, efficient, and sustainable supply chain in the digital age.

(a) **Purpose of AI using in Supply Chain Management -** This study delves into the diverse applications of AI in supply chain management, exploring its benefits, challenges, and future potential. By examining real-world examples and trends, it highlights how AI is enabling organizations to navigate the complexities of the modern supply chain and drive sustainable growth in an increasingly competitive global market.

(b) **Advantage of AI used in Supply Chain Management -** AI is revolutionizing supply chain management by offering a multitude of benefits that enhance efficiency, reduce costs, and improve decision-making. Here are some of the key advantages:

(c) **Enhanced Demand Forecasting:**

- **Accurate Predictions:** AI algorithms analyze historical data, market trends, and external factors to provide more accurate demand forecasts.
- **Optimized Inventory Management:** This leads to better inventory management, preventing stockouts and overstocking.
- **Reduced Costs:** Optimized inventory levels reduce holding costs and minimize the risk of obsolescence.

(d) Improved Supply Chain Visibility:

- **Real-Time Tracking:** AI-powered systems track shipments in real-time, providing visibility into the entire supply chain.
- **Proactive Issue Resolution:** This enables proactive identification and resolution of potential issues, such as delays or disruptions.
- **Faster Response Times:** Faster response times to disruptions lead to improved customer satisfaction and reduced costs.

(e) Optimized Logistics and Routing:

- **Efficient Route Planning:** AI algorithms optimize delivery routes, reducing transportation costs and fuel consumption.
- **Reduced Delivery Times:** Optimized routes lead to faster delivery times, improving customer satisfaction.
- **Lower Environmental Impact:** Reduced fuel consumption contributes to a lower environmental impact.

(f) Automated Decision Making:

- **Faster Decision-Making:** AI-powered systems can make faster decisions compared to manual processes.
- **Data-Driven Decisions:** Decisions are based on data analysis, reducing the risk of errors.
- **Increased Efficiency:** Automated decision-making streamlines operations and reduces manual effort.

(g) Risk Management:

- **Risk Identification:** AI can identify potential risks and vulnerabilities in the supply chain.
- **Proactive Mitigation:** This enables proactive mitigation strategies to minimize the impact of disruptions.
- **Improved Resilience:** A more resilient supply chain can better withstand unforeseen events.

(h) Cost Reduction:

- **Reduced Operational Costs:** AI-powered automation reduces labor costs and operational expenses.
- **Optimized Resource Utilization:** AI optimizes resource utilization, reducing waste and inefficiencies.
- **Improved Profit Margins:** Overall cost reduction leads to improved profit margins.

(i) Customer Satisfaction:

- **Faster Delivery Times:** AI-optimized logistics lead to faster delivery times.
- **Improved Order Accuracy:** AI-powered systems reduce errors in order processing and fulfillment.
- **Enhanced Customer Experience:** Faster delivery times and accurate orders contribute to a better customer experience.

(j) Sustainability:

- **Reduced Environmental Impact:** AI-optimized logistics and inventory management reduce carbon emissions and waste.
- **Sustainable Practices:** AI can help identify and implement sustainable practices throughout the supply chain.

By leveraging AI, businesses can achieve a more efficient, resilient, and sustainable supply chain, ultimately leading to increased profitability and customer satisfaction.

(k) Limitations of AI used in Supply Chain Management: While AI offers significant potential for optimizing logistics operations, it's crucial to recognize its limitations, especially when considering the complexities of real-world supply chains:

(l) Data Quality and Quantity:

- **Data Accuracy:** AI algorithms rely on accurate and reliable data. Inaccurate or incomplete data can lead to flawed predictions and suboptimal decisions.
- **Data Consistency:** Ensuring data consistency across various systems and sources is crucial for effective AI implementation.
- **Data Privacy and Security:** Handling sensitive supply chain data requires robust security measures to protect against breaches.

(m) Complexity and Cost:

- **Implementation Costs:** Implementing AI solutions can be costly, requiring significant investments in technology, infrastructure, and skilled personnel.
- **Complexity:** AI models can be complex to develop, deploy, and maintain, requiring specialized expertise.
- **Integration Challenges:** Integrating AI systems with existing legacy systems can be challenging and time-consuming.

(n) Lack of Human Expertise:

- **Overreliance on AI:** Overreliance on AI can lead to a decline in human judgment and decision-making skills.
- **Human Oversight:** Human oversight is essential to monitor AI performance, identify biases, and make critical decisions, especially in unforeseen circumstances.

(o) Unforeseen Circumstances:

- **Black Swan Events:** AI models may struggle to predict and respond to unforeseen events, such as natural disasters or geopolitical crises.
- **Dynamic Environments:** Supply chains are dynamic and subject to rapid changes, which can limit the effectiveness of AI-powered predictions.

(p) Specific Logistics Challenges:

- **Real-time Variability:** Logistics operations involve numerous variables that change in real-time, such as traffic conditions, weather, and unexpected delays. AI models may struggle to adapt to these rapid changes.
- **Last-Mile Delivery:** The last-mile delivery segment is complex, with various factors influencing delivery times and costs. AI may not fully account for these complexities.
- **Human Element:** Logistics often involves human interaction, such as customer service and driver behavior. AI may not fully capture the nuances of human interactions.

(q) To mitigate these limitations, it's essential to:

- **Prioritize Data Quality:** Invest in data cleaning, validation, and enrichment processes.
- **Build Strong AI Teams:** Hire skilled data scientists and AI engineers to develop and maintain effective AI solutions.
- **Foster Human-AI Collaboration:** Combine human expertise with AI capabilities to achieve optimal results.
- **Address Ethical Concerns:** Implement ethical guidelines and conduct regular audits to ensure fairness and transparency.
- **Stay Updated on AI Advancements:** Continuously monitor the latest AI trends and technologies to stay ahead of the curve.

By carefully considering these limitations and taking proactive measures, organizations can harness the power of AI to optimize their logistics operations while minimizing potential risks.

III FUTURE OF INDIAN LOGISTICS WITH AI & ML

The Indian logistics industry is one of the largest and most unorganized in the world. It is estimated that the industry employs over 20 million people and accounts for about 14% of the country's GDP. However, the industry is also highly inefficient, with a lot of manual work and a high potential for errors.

Artificial intelligence (AI) and machine learning (ML) are poised to revolutionize the Indian logistics industry. These technologies can be used to automate many of the manual tasks that are currently done by humans, such as creating MIS reports, generating invoices, and calling transporters. This will free up human resources by 80% to 90%, so they can focus on more strategic and value-added tasks.

If you are using any TMS/LMS (Transport/Logistics Management Software) today and put your data of day-to-day movement in it for the coming 10 years it will do everything for you in the future without any human help. Let's say you are placing 5000 trips in the month after 10 years your TMS will have 60000 trips. These trips will be having all kinds of pointers for predicting your rates, selecting transporters, raise indent to them, in future all trucks will be with GPS with that your TMS can track vehicles, and with geo-fence TMS will know whether the vehicle is delivered, or not and at the end it will make payment to your transporter after invoice verification.

IV CONCLUSION

The Indian logistics sector stands on the brink of a transformative shift due to the advent of Artificial Intelligence (AI). By streamlining repetitive processes, enhancing operational efficiency, and refining decision-making capabilities, AI has the potential to significantly boost productivity, lower expenses, and elevate customer satisfaction.

- **The primary advantages of AI in logistics include**:
  - **(i) Improved Demand Forecasting:** Precise predictions facilitate better inventory management and cost reductions.
  - **(ii) Enhanced Supply Chain Transparency:** Real-time monitoring and proactive problem-solving improve operational efficiency and customer satisfaction.
  - **(iii) Streamlined Logistics and Routing:** AI-driven route optimization minimizes transportation expenses and accelerates delivery times.
  - **(iv) Automated Decision-Making:** Quicker and more precise decisions enhance operational workflows and decrease errors.
  - **(v) Risk Mitigation:** AI can detect and address potential risks, thereby strengthening supply chain resilience.
  - **(vi) Cost Efficiency**: Automation and optimized resource allocation result in reduced operational costs and increased profit margins.
  - **(vii) Customer Experience:** Quicker delivery and greater order accuracy significantly improve customer interactions.
  - **(viii) Sustainability:** AI-driven optimization and eco-friendly practices foster a more sustainable supply chain.

Nonetheless, challenges such as data integrity, complexity, and ethical issues must be addressed to fully unlock AI's potential. By prioritizing data quality, cultivating skilled AI teams, and promoting collaboration between humans and AI, organizations can leverage AI to develop a more efficient, resilient, and sustainable logistics landscape.

The outlook for Indian logistics is promising, with AI set to play a crucial role in fostering innovation and growth. By adopting AI technologies, the industry can navigate its challenges and position itself as a global frontrunner in logistics and supply chain management.

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Artificial Intelligence: Transforming the Future of Technology

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ABSTRACT
Artificial Intelligence (AI) has undergone a remarkable transformation, evolving from a purely theoretical concept rooted in early computer science and philosophy into one of the most powerful and disruptive technologies of the 21st century. Initially imagined as a way to replicate human reasoning through logical rules and symbolic processing, AI has expanded into a broad and complex field that encompasses diverse methods for enabling machines to mimic or exceed human intelligence. This evolution has been driven by advances in computational power, access to vast datasets, and breakthroughs in algorithms, particularly in areas such as machine learning, deep learning, and natural language processing. As a result, AI is no longer confined to academic labs or science fiction; it has become a transformative force that is reshaping industries, economies, and societies. This paper aims to provide a comprehensive overview of AI's journey, beginning with its historical origins and theoretical foundations. It traces the development of AI from rule-based systems to modern approaches that leverage neural networks and probabilistic reasoning. Particular attention is given to key technologies such as supervised and unsupervised learning, reinforcement learning, and deep neural networks, which have enabled machines to learn from data, recognize patterns, and make decisions with increasing autonomy and sophistication. Moreover, the paper examines the practical applications of AI across various domains. In healthcare, AI systems assist in disease diagnosis, personalized medicine, and medical imaging analysis. In finance, algorithms are used for fraud detection, credit scoring, and market prediction. Autonomous vehicles, robotic systems, and intelligent assistants illustrate how AI is becoming embedded in physical and digital infrastructure alike. However, alongside these advancements come significant ethical and societal considerations. Issues such as data privacy, algorithmic bias, and the displacement of human labor raise important questions about the responsible development and deployment of AI. The paper explores these concerns in detail, emphasizing the need for transparency, accountability, and inclusive governance in AI systems. Ultimately, the paper concludes by looking ahead to the future of AI, highlighting both the immense potential for societal benefit and the critical challenges that must be addressed to ensure that AI technologies align with human values and priorities.

I INTRODUCTION

Artificial Intelligence (AI) refers to the ability of machines to perform tasks that typically require human intelligence, such as reasoning, learning, problem-solving, perception, and language understanding. At its core, AI involves the development of algorithms and models that enable computers to simulate cognitive processes, allowing them to adapt to new information, make decisions, and improve over time without being explicitly programmed for every scenario. The term "Artificial Intelligence" was first introduced in 1956 by computer scientist John McCarthy during the Dartmouth Conference, which is widely regarded as the founding event of AI as a scientific discipline. Since then, AI has experienced several waves of enthusiasm and disillusionment—periods of rapid advancement followed by so-called "AI winters" when progress slowed and interest waned due to technological limitations.

Despite these fluctuations, AI has continually evolved, particularly with the advent of more powerful hardware, increased data availability, and significant progress in machine learning techniques. In recent decades, these factors have fuelled a resurgence in AI research and application, leading to breakthroughs in natural language processing, computer vision, and robotics. Today, AI is deeply embedded in everyday technologies, influencing how we communicate, work, travel, and access information. Common examples include virtual assistants like Siri and Alexa, recommendation systems used by Netflix and Amazon, and self-driving cars developed by companies like Tesla and Waymo. As AI becomes increasingly integrated into modern infrastructure, it is not only enhancing efficiency and convenience but also reshaping societal structures and redefining the boundaries of human-machine interaction.

II FOUNDATIONS AND EVOLUTION OF AI

Artificial Intelligence (AI) is an interdisciplinary field that integrates knowledge and techniques from various domains, including computer science, mathematics, cognitive psychology, and neuroscience. Each of these disciplines contributes a unique perspective and set of tools that inform the design and functionality of intelligent systems. Computer science provides the foundational structures, algorithms, and computational models needed to process and analyze data. Mathematics, particularly statistics and linear algebra, underpins machine learning algorithms and optimization techniques. Cognitive psychology offers insights into how humans think, learn, and solve problems—insights that help shape the design of AI systems intended to mimic or replicate human cognition. Meanwhile, neuroscience contributes an understanding of the brain's neural architecture, inspiring the development of artificial neural networks and deep learning models.

The early development of AI in the mid-20th century focused on symbolic reasoning and rule-based systems. These early systems used explicit logic rules to manipulate symbols and solve well-defined problems, such as puzzles or mathematical proofs. However, they lacked flexibility and struggled with real-world ambiguity and complexity. In the 1980s, the field experienced a surge of interest with the emergence of expert systems, which encoded domain-specific knowledge into structured frameworks to simulate decision-making in areas like medical diagnosis or engineering.

By the early 2000s, the limitations of rule-based systems became evident, prompting a shift toward data-driven approaches. The rise of machine learning and neural networks marked a turning point, allowing systems to learn patterns from vast datasets and adapt to new information—capabilities that now define modern AI applications across countless industries.

(a) Machine Learning and Deep Learning

Machine Learning (ML) is a branch of Artificial Intelligence (AI) that enables computers to learn patterns, make decisions, and improve performance over time without being explicitly programmed for each specific task. Instead of following predefined rules, ML algorithms are trained using large datasets, from which they identify patterns, correlations, and structures that help them make predictions or classifications. This learning process mimics aspects of human learning, where exposure to information enhances understanding and capability. ML encompasses several types, including supervised learning, where the algorithm is trained on labeled data; unsupervised learning, which explores hidden patterns in unlabeled data; and reinforcement learning, where systems learn optimal behaviors through trial and error. A significant subset of ML is deep learning, which has revolutionized the field in recent years. Deep learning utilizes artificial neural networks inspired by the structure and function of the human brain, particularly its interconnected neurons. These networks consist of multiple layers—hence the term "deep"—through which data is processed in increasingly abstract representations. This architecture allows deep learning models to analyze complex and unstructured data such as images, speech, and text with remarkable accuracy.

One of the most notable achievements of deep learning has been its success in image recognition, where models can identify objects, faces, and even emotions in photographs. Similarly, in natural language processing (NLP), deep learning powers tools like language translation, sentiment analysis, and conversational agents such as chatbots. These advances, as described by Goodfellow et al. (2016), have pushed the boundaries of what machines can understand and accomplish.

III APPLICATIONS OF AI

AI is revolutionizing multiple sectors:

(a) Healthcare - Artificial Intelligence (AI) is playing a transformative role in the healthcare and biomedical sciences sector, significantly improving efficiency, accuracy, and outcomes. In disease diagnosis, AI-powered systems analyze patient data, such as symptoms, lab results, and medical histories, to assist clinicians in identifying conditions more quickly and accurately. In medical imaging, AI algorithms are trained to detect anomalies in X-rays, MRIs, and CT scans—sometimes outperforming human radiologists in recognizing early signs of diseases like cancer. Furthermore, AI accelerates the process of drug discovery by analyzing complex biological data and predicting the effectiveness of potential drug compounds. One of the most groundbreaking applications is DeepMind's AlphaFold, which successfully predicted the 3D structures of proteins based on their amino acid sequences. This achievement has solved one of biology's greatest challenges—protein folding—and opened new pathways for understanding diseases and designing targeted treatments (Jumper et al., 2021), potentially revolutionizing molecular biology and personalized medicine.

(b) Finance - Artificial Intelligence (AI) has become an integral part of the financial industry, enhancing decision-making, security, and customer experience. In fraud detection, AI systems analyze massive volumes of transaction data in real time to identify unusual patterns and flag potentially fraudulent activities. By continuously learning from new data, these systems can adapt to evolving fraud tactics more effectively than traditional rule-based systems. In algorithmic trading, AI models process vast datasets—including market trends, economic indicators, and news sentiment—to make rapid, data-driven trading decisions. These algorithms can execute high-frequency trades with minimal human intervention, optimizing returns while managing risk. Additionally, AI enables personalized financial advice through robo-advisors, which assess a user's financial goals, risk tolerance, and spending patterns to recommend tailored investment strategies. This level of personalization and efficiency is transforming how individuals and institutions manage money, making financial services more accessible, responsive, and intelligent across the global economy.

(c) Autonomous Systems - autonomous technologies such as self-driving cars, drones, and robotics depend heavily on Artificial Intelligence (AI) to function effectively and safely in dynamic environments. These systems integrate AI with sensors, cameras, and real-time data processing to perceive their surroundings, make decisions, and take appropriate actions. For instance, self-driving cars use AI to interpret data from LiDAR, radar, and GPS to recognize traffic signals, detect pedestrians, and navigate complex road scenarios without human intervention. Similarly, drones employ AI algorithms for flight path optimization, obstacle avoidance, and target recognition in applications ranging from delivery services to environmental monitoring. In robotics, AI enables machines to perform intricate tasks, such as assembling products, assisting in surgeries, or providing eldercare, often while interacting naturally with humans. By enabling machines to learn from experience and adapt to new situations, AI enhances the autonomy, efficiency, and safety of these systems, making them increasingly valuable in both commercial and domestic settings.

(d) Natural Language Processing - AI systems such as OpenAI's ChatGPT represent a major advancement in natural language processing (NLP), enabling machines to understand, generate, and respond to human language with remarkable fluency. These models are trained on vast datasets containing books, websites, and dialogues, allowing them to produce coherent and contextually relevant text across a wide range of topics. ChatGPT, in particular, is capable of generating human-like responses in conversation, making it useful for customer service, education, and content creation. Additionally, such AI systems can accurately translate languages, bridging communication gaps across cultures and enabling real-time multilingual interactions. These capabilities are transforming how users interact with technology by providing intuitive, conversational interfaces that simplify complex tasks—whether it's drafting emails, answering questions, tutoring students, or assisting developers with coding. As demonstrated by Brown et al. (2020), models like ChatGPT mark a significant leap toward more intelligent, accessible, and human-centered AI applications in everyday life.

IV ETHICAL AND SOCIETAL IMPLICATIONS

AI raises ethical questions about bias, transparency, and job displacement.

(a) Bias and Fairness - AI systems, while powerful, are not immune to the biases inherent in the data used to train them. If the training data reflects historical inequalities or societal prejudices, the AI can inadvertently learn and perpetuate these biases. This can result in unfair outcomes in critical areas such as hiring, policing, and lending. For instance, biased algorithms might favor certain demographic groups over others, leading to discriminatory practices. Buolamwini and Gebru (2018) highlight the risks of such biases, emphasizing the need for diverse, representative training data and robust auditing processes to ensure fairness and equity in AI-driven decisions.

(b) Privacy and Surveillance -Facial recognition and data mining technologies, while advancing security and convenience, raise substantial privacy concerns. These systems can track individuals across various platforms, often without their consent, leading to the potential misuse of personal data. Sensitive information, from personal habits to location history, can be extracted and exploited by both corporations and governments. As AI technologies rapidly evolve, existing regulatory frameworks are struggling to keep up, failing to adequately address these emerging privacy issues. This gap highlights the urgent need for updated laws and ethical guidelines that protect individuals' rights while allowing for innovation in AI applications.

(c) Employment Impact- Automation, powered by AI and robotics, poses a significant threat to many traditional job categories, especially in sectors like manufacturing, retail, and transportation. As machines and algorithms take over routine tasks, workers in these fields may face job displacement, leading to economic and social challenges. To mitigate these effects, workforce reskilling is essential. Workers must acquire new skills in areas like technology, data analysis, and problem-solving to remain competitive. As Brynjolfsson and McAfee (2014) suggest, adapting to this shift will require not only individual effort but also systemic changes in education and social policies to ensure a smooth transition to a more automated economy.

V FUTURE OUTLOOK

The future of Artificial Intelligence (AI) is increasingly centered around collaboration between humans and machines. Rather than replacing humans, AI is expected to augment human capabilities, creating new opportunities for innovation and productivity across various sectors. This evolving relationship will require AI systems to work seamlessly with humans, enhancing decision-making, creativity, and problem-solving. To achieve this, AI must be designed to be transparent and understandable. This is where **Explainable AI (XAI)** comes into play—an approach aimed at making AI decision-making processes more interpretable and accountable. XAI is crucial for fostering trust and ensuring that AI systems are used ethically, especially in high-stakes areas such as healthcare, finance, and criminal justice, where users must understand how decisions are made.

In parallel, as AI technologies continue to develop, stronger **regulations** will be needed to address ethical, privacy, and security concerns. Current regulatory frameworks struggle to keep pace with the rapid advancements in AI, making it essential to establish comprehensive and adaptable policies. These regulations will not only safeguard individual rights but also provide clear guidelines for developers and organizations to follow, promoting responsible innovation. Ensuring that AI benefits society as a whole requires a regulatory framework that addresses issues such as algorithmic bias, data privacy, and accountability for AI-driven decisions.

Moreover, **human-centric design** will be a guiding principle in AI development. This approach prioritizes the well-being, autonomy, and dignity of individuals, ensuring that AI systems enhance rather than undermine human values. As AI continues to integrate into everyday life, the focus will shift towards creating systems that work in harmony with human needs and goals, promoting inclusivity and fairness.
Another exciting frontier in AI research is **Artificial General Intelligence (AGI)**, where machines could perform any intellectual task that a human can. Unlike narrow AI, which is specialized for specific tasks, AGI would possess the flexibility and adaptability to solve problems across a broad range of domains. While AGI remains a distant goal, its development could revolutionize industries and unlock new possibilities for human achievement, although it also raises significant ethical and safety concerns. Ensuring that AGI is developed responsibly will require careful consideration of its potential risks and societal impact.

VI CONCLUSION

Artificial Intelligence (AI) stands as one of the most transformative technologies of the 21st century, offering unparalleled benefits across a wide array of disciplines, from healthcare and education to finance, entertainment, and beyond. In healthcare, AI enhances diagnostic accuracy, accelerates drug discovery, and enables personalized treatment plans, thereby improving patient outcomes. In education, AI-powered platforms adapt to individual learning styles, providing personalized learning experiences and increasing access to education globally. In finance, AI streamlines operations, detects fraud, and optimizes investment strategies, reshaping the way financial markets operate. These examples merely scratch the surface of AI's potential, as its applications continue to expand in new, innovative directions.

However, as AI's capabilities grow, so too does its power and influence over everyday life. This power necessitates careful and responsible development to avoid unintended consequences. AI systems are not immune to errors or biases, and flawed algorithms can perpetuate inequality or make decisions that harm vulnerable populations. For instance, biased AI systems in hiring, policing, or lending can exacerbate existing societal disparities. Thus, it is crucial to ensure that AI systems are developed with fairness, transparency, and accountability in mind.

Ethical scrutiny is essential in guiding the development of AI technologies. Stakeholders—ranging from technologists to policymakers, ethicists, and affected communities—must actively engage in discussions about the ethical implications of AI. Issues such as privacy, consent, data security, and the potential displacement of workers need to be addressed through thoughtful policies and regulations. Furthermore, ongoing public discourse about the societal impact of AI is necessary to ensure that its growth benefits humanity as a whole, rather than creating more significant divides between those who have access to AI-driven tools and those who do not.

In conclusion, while AI holds immense promise, it must be developed responsibly to ensure that it serves humanity's best interests, fostering equality, fairness, and positive social outcomes.

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Comparative Study of Deep Learning and Auricular Therapy in Diagnosing Sciatica through Ear Skin Alterations

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ABSTRACT
Sciatica is a painful condition involving radiating discomfort along the sciatic nerve, often impairing movement and quality of life. While conventional diagnostic tools such as physical assessments and imaging remain standard, recent studies suggest that visible changes in the external ear's skin may serve as early indicators for sciatica. Auricular therapy, a form of complementary medicine, has historically proposed connections between ear skin features and internal health conditions. This research presents a comparative review of three key studies: (1) an investigation into surface-level skin abnormalities—such as deformation, papules, vascular expansion, pigmentation changes, and peeling—used in auricular diagnosis via deep learning, and (2) an analysis of a diagonal earlobe crease as a potential cardiovascular risk marker using machine learning approaches. The paper explores how these findings intersect with sciatica diagnosis and introduces a conceptual model that combines auricular therapy with deep learning for more precise and automated disease detection.

Keywords: Sciatica, Auricular Diagnosis, Deep Learning, External Ear Skin Features, Convolutional Neural Networks, Biomarkers, Machine Learning, Comparative Study

I INTRODUCTION

The auricle, or outer portion of the ear, has long been recognized for its diagnostic potential in identifying systemic health disorders. Auricular-therapy, grounded in traditional Chinese medicine and widely practiced in alternative healing systems, posits that specific zones of the ear correspond to internal organs and bodily functions. Advances in artificial intelligence—particularly in deep learning—have shown promise in detecting subtle dermatological variations that may reflect underlying health issues. Notably, two prominent studies have expanded this area of research: one investigated skin anomalies on the ear such as vascular expansion and pigmentation irregularities, while the other examined the diagnostic relevance of a diagonal crease on the earlobe in assessing cardiovascular risk. Building on these insights, the present study examines how such auricular indicators can be interpreted through a deep learning framework to support the diagnosis of sciatica, aiming to bridge traditional practices with modern computational techniques. [1]

Fig. 3 Reflection of body on Ear [4]

II DEEP LEARNING AND AURICULAR THERAPY IN SCIATICA DIAGNOSIS

Modern deep learning techniques—particularly those utilizing Convolutional Neural Networks (CNNs) and U-Net architectures for image segmentation—have shown significant potential in recognizing subtle skin variations on the ear. These approaches enable automated, high-precision analysis of auricular images, helping to minimize diagnostic bias and improve reliability. In auricular therapy, specific alterations in defined ear regions are believed to reflect neurological conditions, including sciatica. By combining these traditional diagnostic insights with the advanced pattern recognition capabilities of deep learning, there is an opportunity to enhance both the early identification and intervention of sciatica. This integration may pave the way for more objective, technology-assisted diagnostic methods in complementary medicine. [2]

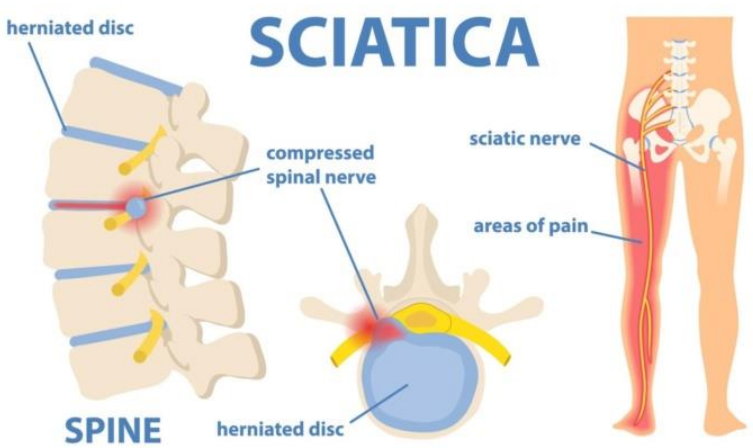


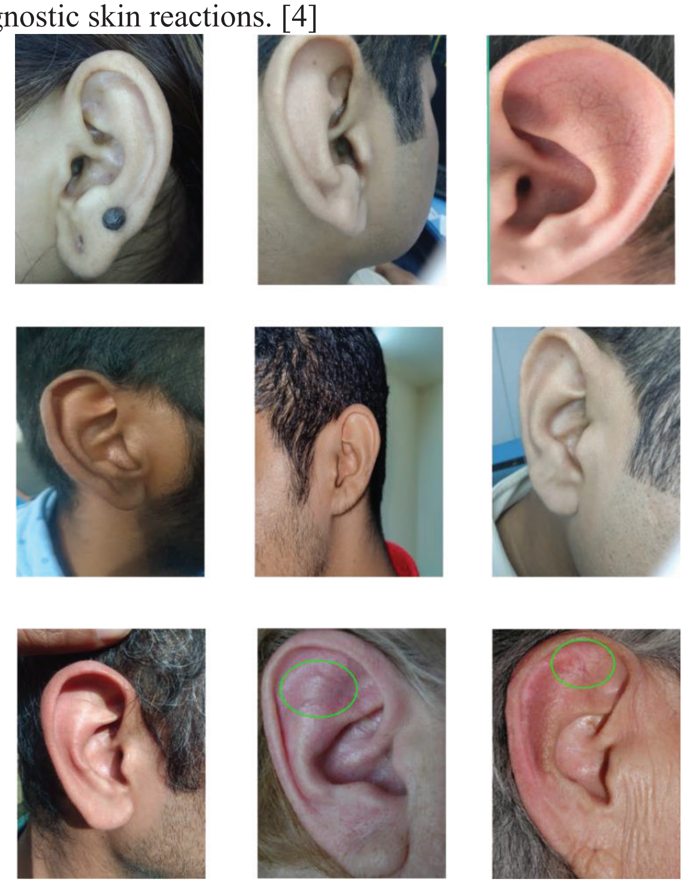
Fig. 1 Sciatica Pain [11]

Sciatica refers to a painful condition where discomfort radiates along the sciatic nerve, which runs from the lower spine through the hips and buttocks, continuing down each leg. The condition is typically triggered by compression of nerve roots in the lumbar region, often due to a herniated disc or bone spurs, which exert pressure on the nerve. This pressure can cause localized inflammation, sharp pain, and occasionally numbness in the leg on the affected side. Although many cases—especially those involving disc herniation—respond well to non-surgical treatments within several weeks or months, more serious symptoms such as pronounced leg weakness or disruptions in bladder or bowel control may necessitate surgical evaluation and intervention. [3]

Auricular therapy is based on the principle that distinct areas of the external ear correspond to various internal organs and bodily systems. This approach suggests that observable changes in the ear's skin—such as alterations in tone, surface texture, or tenderness—may signal imbalances or disorders in the related parts of the body, including the sciatic nerve. While this therapeutic method has a long-standing presence in traditional medicine, robust scientific validation for its diagnostic accuracy remains limited. [4]

Some illnesses manifest through specific reactions in defined regions of the auricle, where localized skin responses at particular ear points may indicate internal dysfunction. These reactions, often labeled as "skin alterations," serve as diagnostic clues. As Dr. Huang explains, "Over 250 auricular points on the ear correspond to different physiological functions and organs." Through careful observation of these areas, practitioners aim to identify underlying medical issues. [5]

Skin-based indicators, or biomarkers, provide important insight into both current health conditions and a patient's medical history. French physician Dr. Nguyen noted correlations between particular ear skin changes and dysfunctions in certain organs, observing that chronic diseases frequently leave visible traces on the auricle. Additionally, Marco Romali reported a comprehensive documentation of 8,828 cases involving such diagnostic skin reactions. [4]



(a) Integration of Deep Learning with Auricular Therapy - Combining deep learning with auricular therapy enables more precise and automated diagnosis by evaluating visible skin features on the ear. Convolutional Neural Networks (CNNs) are employed to analyze ear images, recognizing patterns such as discoloration, vascular enlargement, surface irregularities, and skin flaking. By training on annotated datasets, these models improve in accurately identifying skin anomalies linked to specific health conditions. This approach merges the diagnostic wisdom of traditional auricular practices with the analytical power of artificial intelligence, enhancing the potential for early and non-invasive disease detection.

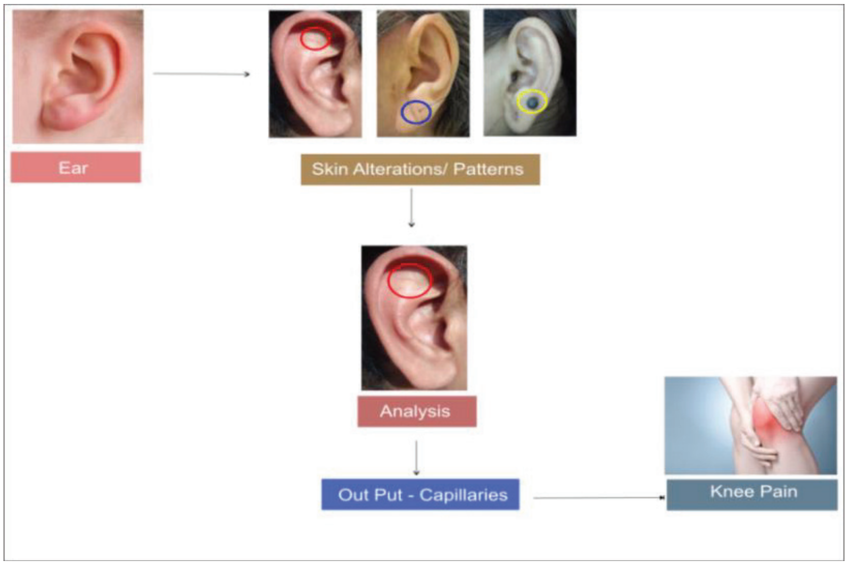


Fig. 5 Traditional Approach to find out disease in auricular therapy

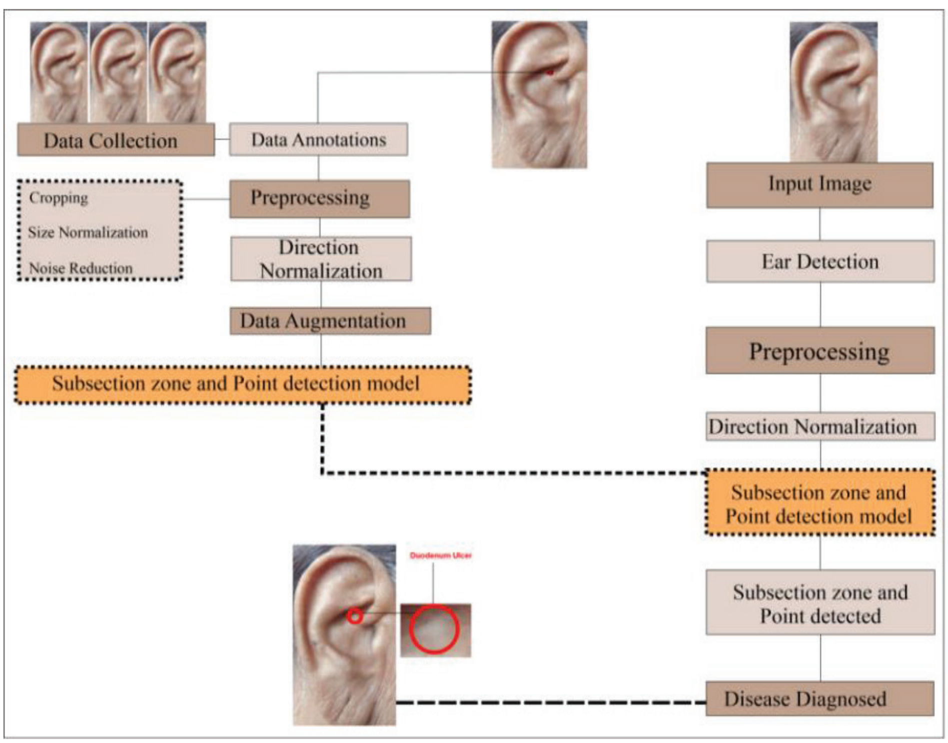


Fig. 6 Integrated Approach to find out disease in auricular therapy using deep learning method

(b) Role of Deep Learning in Medical Diagnostics - Deep learning, a specialized field within artificial intelligence, has revolutionized medical image interpretation. Models such as Convolutional Neural Networks (CNNs) have been successfully applied to various diagnostic imaging types, including X-rays, MRI scans, and dermatological photographs. These networks are particularly effective in detecting complex visual cues and subtle patterns that may not be easily recognized by clinicians, making them highly valuable for identifying biomarkers, including those seen on the ear.

To improve efficiency and accuracy in analyzing high-resolution medical imagery, deep learning frameworks often divide images into smaller patches or tiles. This technique is especially beneficial in the biomedical domain, where image segmentation plays a crucial role. By applying segmentation techniques, these AI models help isolate relevant features and enhance diagnostic precision in clinical applications. [6]

III LITERATURE REVIEW

(a) Study 1: Deep Learning-Based Detection of Frank's Sign - Frank's Sign (FS) is identified as a diagonal crease extending across the earlobe, previously associated with risks of cardiovascular and cerebrovascular conditions, cognitive impairment, and aging. Despite its potential clinical value, automated methods for detecting FS have been underexplored. This research introduces the **Automatic Detection Algorithm of Frank's Sign (ADAFS)**, the first deep learning-driven system applied to a 3D Nifti dataset for FS recognition. Four advanced models—**3D U-Net**, **3D Attention U-Net**, **3D Nested U-Net**, and **3D USE-Net**—were trained using a five-fold cross-validation method. The models classified FS into four categories: presence on the left side, right side, both sides, and absence of the sign. [7]

(b) Study 2: Auricular Diagnosis Assistance System Using Deep Learning - In a 2022 study, **Chiang et al.** developed a deep learning-based system to identify nine diseases based on auricular responses. These included conditions such as hepatitis, mastitis, cervicitis, prostatitis, and various forms of headaches (frontal, occipital, vertex, and general migraine). The research utilized an enhanced **U-Net architecture** featuring batch normalization; atrous (dilated) convolutions, fewer convolutional layers, and a multi-rate expansion mechanism. This architecture achieved a diagnostic accuracy of **99.60%**, underscoring the potential of deep learning in improving auricular diagnostic tools. [8]

Table 1

Sno	Title	Author	Publications	Work and methods	Skin Alterations or pattern on ear	Disease
1	Deep learning based automatic detection algorithm of Frank's sign and its application	Sungman Jo Ki Woong Kim	2023	3D U-Net, 3D Attention U-Net, 3D Nested U-Net, 3D USE-Net	a diagonal crease in the ear lobe extending from the tragus across the lobule to the rear edge of the auricle	Cardiovascular and cerebrovascular diseases
2	A Vision-Based Auricular Diagnosis Assistance System with Deeping Learning	Chiang et. Al.	2022	9 disease and their auricular points on external ear Deep learning method	Distortion, papule, vascular dilation, discoloration, desquamation	migraine

IV COMPARATIVE ANALYSIS

The following table provides a comparative analysis of two previous research studies on deep learning applications for detecting ear skin biomarker and their related diseases. This study differs from Study 1 and Study 2 in terms of ear zones, types of skin alterations, associated diseases, applied methods, and achieved accuracy.

Table Study 1

S No.	**Focus**	**Ear Zone**	**Skin Alterations**	**Disease**	**Methods**	**Integration with Auricular Therapy**
1	Ear Lobe Crease & Cardiovascular Risk	Ear Lobe	Crease	Cardiovascular Disease	U Net Model	No Relation with Auricular Points

Table Study 2

S No.	Focus	Ear Zone	Skin Alterations	Disease	Methods	Integration with Auricular Therapy
1	Skin Colors	Superior Concha	Distortion, papule, vascular dilation, discoloration, desquamation	migraine	U-Net Model	Yes

Table This Study

S No.	Focus	Ear Zone	Skin Alterations	Disease	Methods	Integration with Auricular Therapy
1	Capillaries	Inferior Crus of Antihelix	Capillaries	Sciatica	Core –CNN With binary image classification	Yes

V METHODOLOGY

(a) Experimental Configuration - This study was carried out remotely using the cloud-based platform **Google Colab**, which enabled efficient development and execution of deep learning models. The experiments were conducted using **Python version 3.12.5**, with support from key libraries such as **PyTorch** for model implementation, **OpenCV** for image processing, **TensorFlow** for supplementary tasks, and **Matplotlib** and **NumPy** for visualization and numerical computation.

(b) Data Acquisition and Resources

(i) Ear Image Dataset - The dataset used in this research consists of high-quality ear images obtained from multiple sources. Public datasets were sourced from platforms like **Kaggle** [9] and **Roboflow Universe** [10], while additional images were collected independently to increase diversity. The self-collected data includes images from individuals of various age groups, genders, and ethnic backgrounds to ensure a representative sample. The dataset is split into two major categories:

- **Control Group:** Individuals not experiencing sciatica symptoms.
- **Test Group:** Individuals clinically diagnosed with sciatica using standard diagnostic procedures.

This division supports a comparative approach, allowing for the analysis of potential visual markers on the ear that may be linked to sciatica.

(ii) Reference Auricular Maps - To aid in locating diagnostic zones on the ear, auricular maps based on **Traditional Chinese Medicine (TCM)** were digitized and used as reference guides. These maps, drawn from existing scholarly sources, outline the relationships between specific ear points and internal organs or body systems, offering a valuable framework for mapping potential indicators of disease. [6]

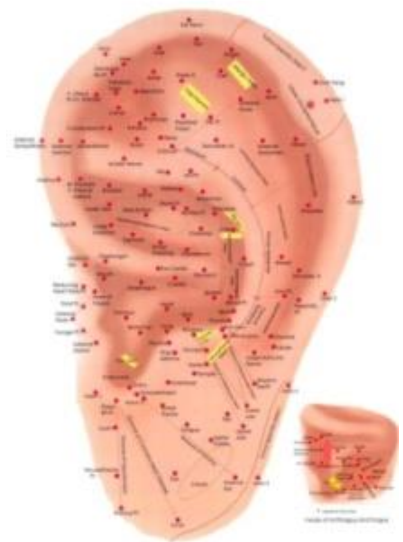


Fig. 7 Auricular Points According to Dr. Huang Lichun [5]

(iii) Image Data Preprocessing - To maintain consistency and enhance the reliability of model inputs, ear images were subjected to multiple preprocessing steps designed to improve quality and standardize variations in lighting, orientation, and resolution. Using auricular therapy charts, specific regions of interest (ROIs) linked to sciatica were identified on each image. From these zones, key visual features—including skin tone, surface texture, and vascular patterns—were extracted for subsequent analysis. The preprocessing pipeline involved resizing all images to a uniform 512×512-pixel resolution, normalizing pixel intensities to a [0,1] range to ensure model stability, and applying data augmentation techniques such as rotation, horizontal flipping, zoom adjustments, and contrast variation. These augmentation methods artificially expanded the dataset, introducing diversity to improve the model's generalization capabilities.

(iv) Dataset Partitioning- For effective model training and evaluation, the dataset was divided into two segments:

- **Training Set (85%)** – A total of **850 images** were used to train the deep learning model, enabling it to recognize patterns associated with sciatica and non-sciatica conditions.
- **Validation Set (15%)** – This set comprised **150 images**, which were utilized to monitor the model's performance during training and reduce the risk of overfitting.

(c) Application of Deep Learning Models

- A **Convolutional Neural Network (CNN)** model was employed to perform binary classification on the processed ear images. The goal was to differentiate between images from individuals with **sciatica pain** and those without it. CNNs are designed specifically for analyzing visual data, as they are capable of capturing spatial hierarchies through convolutional layers.

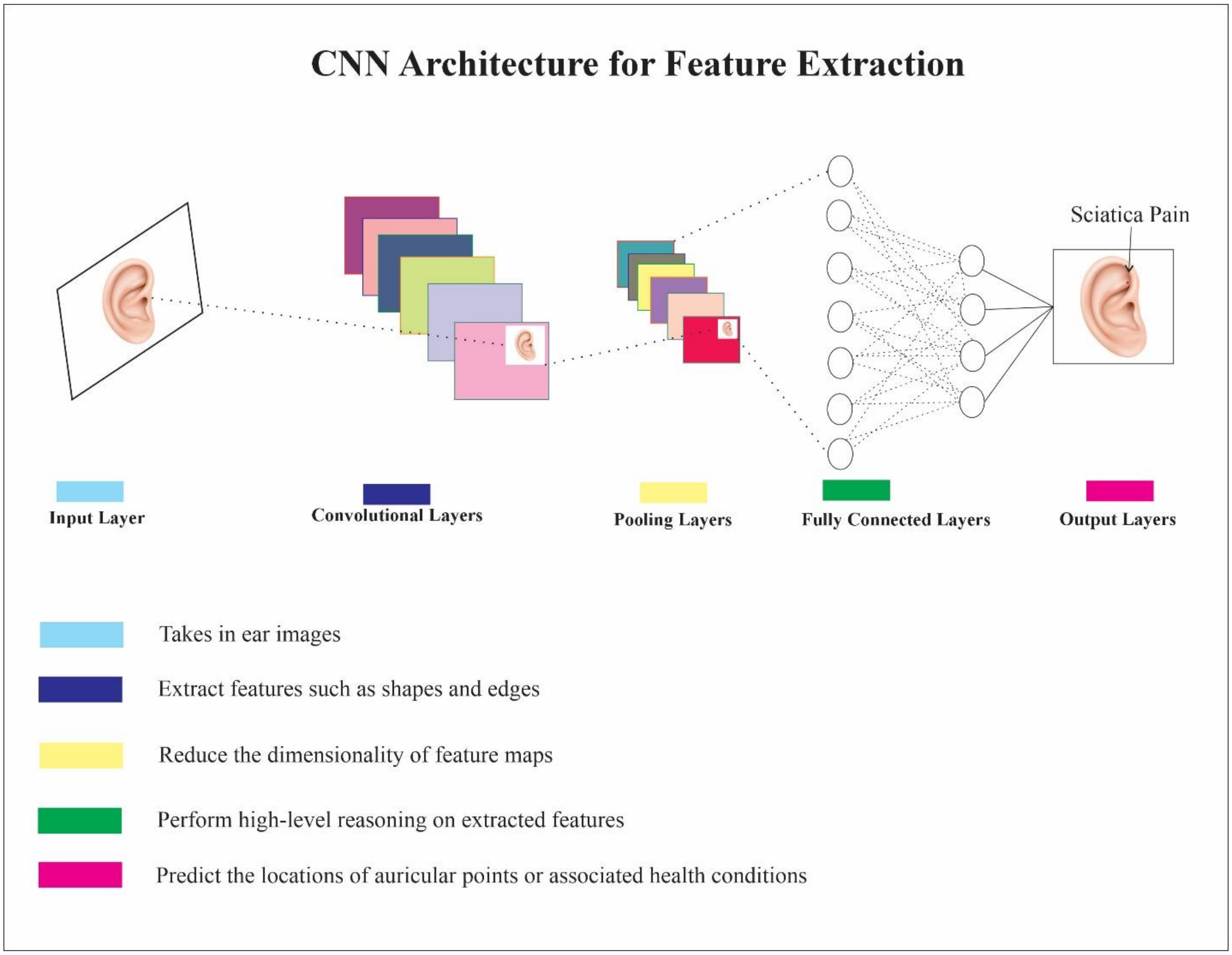


Fig: 8 CNN Architecture for find out skin patterns of Sciatica Pain

- **Steps Employed in a Convolutional Neural Network (CNN):** A Convolutional Neural Network (CNN) processes visual data through a structured sequence of layers. The **input layer** receives raw image data, serving as the starting point for analysis. Next, the **convolutional layer** applies learnable filters to detect essential features such as edges, textures, and patterns. Following this, the **pooling layer** downsamples the feature maps, reducing spatial dimensions to lower computational costs and minimize overfitting. The **fully connected layer** then consolidates these extracted features, enabling high-level interpretation for decision-making. Finally, the **output layer** produces the model's prediction, often in the form of class probabilities for classification tasks. This layered architecture allows CNNs to efficiently analyze and interpret complex visual data.

VI RESULTS AND DISCUSSION

(a) Model Performance - In this study, binary image classification was employed to evaluate accuracy, with the model achieving an 88% accuracy rate in classifying ear images. The model's performance could potentially improve with a larger dataset or more images. The findings indicate that changes in ear skin characteristics may reliably indicate sciatica pain, aligning with the principles of auricular therapy.

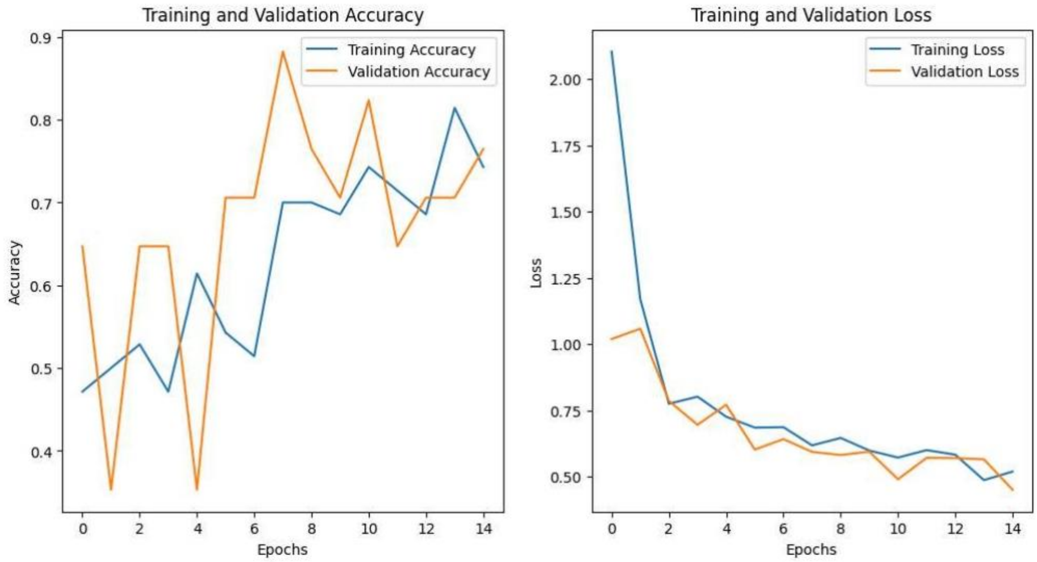


Fig: 9 Learning Curves of the Model

(b) **Analysis of Ear Skin Alterations** - The study detects distinct patterns in ear skin changes linked to sciatica pain, including localized redness, heightened vascularity, and variations in texture. These observations support the principles of auricular therapy and offer a scientific foundation for deeper investigation into this area.

(c) **Limitations** - The study has certain limitations, such as the use of a relatively small dataset and possible biases in the image collection process. Moreover, the model's accuracy may differ depending on factors like population diversity, ear anatomy, and the quality and quantity of images. To strengthen the validity of these findings, further research involving larger and more diverse datasets is essential.

VII CONCLUSION

The comparative analysis underscores the promise of deep learning in diagnosing sciatica by analyzing auricular skin changes. Although all three studies provide significant insights, combining these methods with auricular therapy could improve diagnostic consistency. Future research should investigate hybrid models that integrate various deep learning approaches with auricular therapy principles to boost detection accuracy and ensure better generalization across diverse conditions.

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Effect of Natural Farming Systems and Organic Amendment Technology of Soil fertility and Environmental Quality: A Review Paper

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ABSTRACT
The review showed that both that Innovative agronomic practices are needed to increase food supply while minimizing tradeoffs to feed a rapidly growing human population. Any material applied to a soil to improve its physical properties, such as infiltration, aeration, water-holding capability, permeability, drainage, and compaction, while indirectly affecting the soil's chemical and biological properties, is referred to as a soil amendment. The main objective of this paper is to review the main effects of organic amendments on soil fertility and environmental quality. Organic amendment types could improve the physical, chemical and biological characteristics of soil and environmental quality in a dose dependent manner and frequency of application. A major challenge for agricultural sustainability is maintaining and enhancing agricultural product yield and nutrient quality while retaining soil quality, including the soil carbon reserve. Organic soil amendments (OSA) increase aggregate stability, bulk density, aeration, porosity, water-holding capacity, water flow, and nutrient cycling in soil. The use of suitable OSA, including green manure (GM), vermin compost (VM), farm yard manure(FYM), rice and other materials as a novel technique for increasing crop production and soil fertility has been investigated by several scientists. Organic amendments play a positive role in chemical characteristics of the soil including increase in organic carbon (up to 58% with 120 t ha-1 versus unfertilized soil) and organic nitrogen up to 90% depending on the type and the level applied. Compost is a stabilized kind of organic matter (OM), which enhances soil physical characteristics such as nutrient and water reserve, aggregation, macro-pores and micro-pores resistance to erosion, temperature insulation, and apparent density to the soil, chemical and biological characteristics such as microbial bio-mass population. However, organic amendments have more of long-term return rather than short-term positive effect and there is competition of organic materials for the purpose of fodder or fuel. As a result, additional measures such as physical and biological soil conservation measures should get due attention and it is better to use the combination of organic and inorganic fertilizers in order to sustain soil fertility and environmental quality.

Key Words: Natural farming system Organic Amendments, Soil Fertility, Environmental Quality, Compost, Farmyard Manure.

I INTRODUCTION

Since soil is the original source of the nutrients we utilize to develop crops, it is an essential component of successful agriculture. Human nutrition, ecosystem services, and good particular and pollutes the environment. Although mineral fertilizer makes nutrients easily accessible for plant growth, it has no effect on the physical, chemical, or biological conditions of the soil. On the other hand, organic matter inputs in the form of organic amendments not only provide nutrients but also enhance soil aggregation and promote microbial activity and diversity (Azarmi, R *et al.* 2008). The quality and health of the soil are affected by fertilizers used in agricultural management (Singh and Ryan 2015; Doran and Zeiss 2000). Soil fertility refers to a soil's ability to meet a plant's physico-chemical and biological requirements for growth, reproduction, and quality, while taking into account plant and soil type, land use, and climatic conditions (Abbott and Murphy 2007).

The world faces multiple challenges to food security including under-nutrition and over consumption, rising food prices, population growth, rapid diet transitions, threats to agricultural production, inefficient production practices and supply chains, and declining investment in food system research. In addition to causing widespread human suffering, food insecurity contributes to degradation and depletion of natural resources, migration to urban areas and across borders, and political and economic instability. The food system faces additional pressure as the global population grows to around 9 billion by 2050 (United Nations Population Division, 2011).

As global demand for food, fodder and bio-energy crops grows, many agricultural systems are depleting soil fertility, biodiversity and water resources. In many regions there are large gaps between potential and actual crop yields **(Foley *et al*. 2011).** Heavy use of chemicals in agriculture has weakened the ecological base in addition to degradation of soil, water resources and quality of the food. At this juncture, a keen awareness has sprung on the adoption of "organic farming" as a remedy to cure the ills of modern chemical agriculture **Kannaiyan (2000).** Organic fertility inputs, such as composted farmyard manure (FYMC) and green manure, improve the soil's physical properties by lowering bulk density, increasing water-holding capacity, and improving infiltration rates **(Tester 1990; Werner 1997; Petersen *et al.* 1999).** It is very much essential to develop a strong workable and compatible package of nutrient management through organic resources for various crops based on scientific facts, local conditions and economic viability. However, soils do pose serious limitations for plant growth too, at times. Presence of disease causing organisms and nematodes, unsuitable soil reaction, unfavorable soil compaction, poor drainage, degradation due to erosion etc. are some of them. In addition, conventional crop growing in soil (Open Field Agriculture) is somewhat difficult as it involves large space, lot of labour and large volume of water.

We are not discussing about threat to culture, but for their survival, their per capita income has to be enhanced and that too from agriculture. As per ancient era including the historically, Maharshi Vasishtha served the divine "Kamdhenu" Cow and Maharshi Dhanvantari offered to mankind a wonder medicine "Panchgavya" (a combination of cow urine, milk, dung, *ghee* and curd). In Sanskrit, all these five products are individually called "Gavya" and collectively termed as "Panchgavya". Panchgavya had reverence in the scripts of Vedas (divine scripts of Indian wisdom) and Vrkshyurveda (Vrksha means plants and Ayurveda means health system). Indian cow breeds are unique and distinct species, both in their appearance and characteristics. Cow is the backbone of Indian culture and rural economy, and sustains our life; represent cattle wealth and bio-diversity. Cowpathy has many beneficial implications in agriculture, organic farming as good quality natural manure and bio-pesticides and as alternate energy resources. However, scientific validation of cowpathy products is required for its worldwide acceptance and popularity in terms of agricultural, energy resource and nutritious applications so as to exploit the optimal power of cowpathy for the service of mankind.

The natural farming system with soil organic technology has to evaluate the efficiency and efficacy of some cowpathy and vedic krishi inputs, viz. Vrkshayurveda, Panchagavya, Kunapajala, Beejamrit, Jeevamirit, Compost tea, Matka khad, Vermiwash and Amrutpani with the objectives to enhance the biological efficiency of crop plants and food production for eco-friendly nutrient and disease management and improve soil health in organic farming.

Agricultural intensification was sustained through indiscriminate use of synthetic agrochemical, overuse of water and alteration of the soil ecosystem all at a considerable cost to the climate to increase crop output. Indeed, substituting external inputs for internal soil processes casual the soil fundamental properties such as its ability to self-regulate to deteriorate over time (Barthod *et al*., 2018).

Soil amendments are both inorganic and organic compounds blended into the soil to strengthen the soil constitution in terms of plant production. Soil amendments aimed to improve the root proliferation and plant growth environment, which includes improving water holding capacity (WHC), soil structure and nutrient accessibility, and the living conditions for microbes that are essential for plant growth.

As a result, Natural farming system and organic amendments (OAs) can be defined as any materials originated from plants and animals and added/or incorporated into the soil for the improvement and/or replacement of physical, chemical and biological properties of soil and in turn to make the environment suitable for production and productivity (Davis and Wilson, 2005) Pettygrove and Pettygrove (2010).

As a consequence, agricultural management practices by applying OAs mainly compost and farmyard manure (FYM) that enhance soil OM content are needed for preserving farming output and environmental quality (Diacono, M. and F. Montemurro, 2010). Mulching or the placement of materials on top of the source is not regarded as a soil amendment. Different substances are used with various soils and plants to optimize soil conditions. Because of its low production costs, Natural farming system and organic manures such as compost, is a common amendment for thousands of years, natural farming system and organic soil amendments has improved soil quality and fertility.

For any farming operations with livestock that relies on manure and for crop producers who have access to an economical supply of compost, there is a need to knowing and understanding about the effect of Natural farming system and organic amendment techniques on soil fertility and environmental quality. Therefore, the main objective of this paper is to review the major effects of Natural farming system and organic amendments on soil fertility parameters and other environmental quality.

(a) **Natural Faming System (Vedic Krishi):** As stated above the soil of Jharkhand is acidic in nature hence, the production of crops is very less because most of the cultivable items grow in slightly too alkaline soil. *Vedic Krishi* is natural agriculture free from all poisonous fertilizers, pesticides and herbicides, grown by farmers enjoying Vedic consciousness. The goal of Vedic *Krishi* is to re-enliven Natural Law in agriculture, bringing the farmer, the process of farming and the environment in complete harmony with each other. Natural Law is the unseen intelligence of nature that upholds and nourishes all life. *Vedic Krishi* will produce Vedic food, the purest, most nutritious and most vital food available anywhere. Vedic food is vibrant in the total potential of Natural Law. It brings the intelligence of nature directly into our human physiology to create a mind and body capable of living higher states of consciousness - the full potential of life. It is worth mentioning here that for any crop the composition and the properties of the soil has already been reported in literature.

S. No.	Name of the inputs	Ingredients used and their quantities	Method of preparations
1.	Panchagavya	Cow dung = I kg (fresh) Cow dung slurry = 4 kg Cow urine = 3L Cow milk = 2L (fresh) Curd = 2 kg Cow butter oil = 1 kg (ghee)	It is a blend of 5 product obtained from cow mainly its dung, urine, milk, curd and ghee. For making Panchagavya thoroughly mix the required quantities of ingredients and allow fermenting for 7 days with twice stirring per day.
2.	Vermiwash	Earthen pitcher = three of 20L capacity Cow dung = 12-15 kg Earthworms = 100-200 Nos. Rubber pipe = I mt long	Put some dry grass and a 15-20 cm layer of 2-3 weeks old cow dung along with 100-200 earthworms in a pitcher. Put on the cow dung and again covered with dry grass. Allow the

			water to fall drop by drop into the pitcher. Collect the liquid coming from the pitcher with the help of a pipe.
3.	Compost Tea	Vermicompost = 5 kg Bucket = 15L capacity Gunny bag = 1 no. Rope = 2-3 m length	A small gunny bags half filled (5 kg) with vermicompost is handed over a water tub/bucket filled ¾ with water in a way that vermicompost remained submerged in water. The nutrients in the vermicompost get dissolved in water within 24 hours, thus making its colour like tea.
4.	Matka Khad	Cow dung = 5 kg Cow urine = 5L Water = 5L Jaggary = 250 gm Earthen pitcher = 1 No. of 20L capacity	Thoroughly mix 5 kg of cow dung, 5 L cow urine, 5 L water and 250 gm jaggary and put in a pitcher of 20 L capacity. The pitcher is filled up to ¾ levels only, for effective fermentation. A lid is placed over the pitcher and buried in the soil for 7 to 10 days with its neck outside the soil.
5.	Beejmirit	Cow dung = 50 gm Cow urine = 50 ml Cow milk (fresh)= 50 ml Lime stone = 2-3 gm Water = 1L	Thoroughly mix all the ingredients preferably in plastic/glass jar and keep overnight.
6.	Jeevamirit	Cow dung = 5 kg Cow urine = 5L Jaggary = 1 kg Pulse flour = 1 kg Fertile soil = ½ kg Water = 50L	Mix all the ingredients in a drum with the help of a wooden stick. Shake the mixture 2-3 times per day regularly for 5to 7 days for proper fermentation.
7.	Amrutpani	Cow butter oil = 1/4 kg (ghee) Honey = ½ kg Cow dung = 10 kg Water = 200L	Thoroughly mix quarter kilo of ghee into 10 kilos of cow dung. Blend half kilo of honey into this mixture and add 200 litres of water stirring all the time. The mixture thus obtained is Amrutpani.

Source: NCOF, Ghaziabad

(b) Vrkshayurvedic Farming: Vrkshayurvedic farming is scientific reorientation of eco - friendly ancient system of Indian agriculture by looking back the traditional and natural ways of food production and adopting traditional and indigenous practices and methods for cultivation of crops; by utilizing trees, plants and animal products, by products, extracts and other means with the objective of enhancing the quality of food produce **(Swaminathan, 2012).**

(c) Anbukkarasi and Sadasakthi, (2011) indicated that basal application of *Albizia lebbeck* as green leaf manure along with seed treatment and foliar spray of *Annona squamosa* leaf extract recorded the highest yield parameters *viz.*, fruit length (21.55 cm), fruit girth (7.59 cm), number of seeds per fruits (59.20), fruit weight (18.33 g), yield (13.96 t ha-1) with a benefit cost ratio of 3.78 and also quality parameters *viz.*, lowest crude fibre (6.17 per cent), highest crude protein (14.27 per cent) and vitamin C (14.10 mg/100 g) of Bhindi.

(d) Yogic Agriculture: Yogic Agriculture or "sashwat yogic kheti" is a process that includes seed empowerment (through meditation), mind and heart development of the farmer (through meditation) and integrated organic farming (through cow products, crop rotation and integrated pest management). As farmers gain confidence, the impact they are able to have on their crops through meditation is enhanced. Yogic Agriculture has resulted in lower costs to farmers and reduced the pressure on the environment. Other benefits have been improvements in farmers' emotional well-being and enhanced community resilience.

Nutrient	Yogic	Chemical	Cost/Profit (INR)	Yogic	Chemical
Fat	0.11%	0.20%	Net cost/ Acre	6020.00	26740.00
Protein	1.13%	0.74%	Gross cost/Acre	13378.00	28147.00
Carbohydrate	5.36%	4.15%	Total crop/Acre	13667Kg	15158Kg
Energy	27.41Kcal/100g	19.5Kcal/100g	Market value/Acre	77446.00	85895.00
Vitamin -C	14.9mg/100 g	6.05mg/100 g	**Profit/Acre**	**64068.00**	**57778.00**

(e) Effect of cowpathy (*Panchagavya*) on crop yield and soil health: Balasubramanian *et al*. (2001) reported that dipping of rice seedlings in Panchagavya before transplanting enhanced the growth and yield. Rajasekaran and Balakrishanan, (2002) revealed that the *Abelmoschus esculentus* yield parameters were increased in 3% panchagavya spray when compared with control and other concentration. Similarly, in black gram and green gram (Brito and Girija, 2006) and groundnut (Ravikumar *et al.,* 2012). The photosynthetic pigments content such as chl. A, chl. B and carotenoid were increased in 3% panchagavya spray and decreased in control in *Arachis hypogaea* (Subramaniyan, 2005) and *Vigna radiate*, *Vigna mungo* and *Oryza sativa* (Tharmaraj, 2011).

Natarajan (2007) reported that the *panchagavya* contains macronutrients like N, P and K, essential micronutrients, many vitamins, essential amino acids, growth promoting factors like IAA, GA, which may provide nutrition to rhizosphere microorganisms and thus help to increase their population.

Mohanalakshmi and Vadivel, (2008) revealed that application of poultry manure (5 t ha-1) + Panchgavya (3%) in aswagandha exhibited significantly superior performance by registering the highest root yield of 1354.50 kg ha-1. Vennila and Jayanthi, (2008) revealed that application of 100 per cent recommended dose of fertilizer along with panchagavya spray (2%) significantly increased the number of fruits per plant, fruit weight g fruit-1 and fruit yield q ha-1 of okra.

Table 1
Changes in Physico-chemical and biological properties of Panchagavya with time.

Sl. No.	Available nutrient status				Physical properties			Microbial load (Population = X cfu ml-1)		
	N	p	K	Ca	Mg	EC (dSm-1)	pH	Bacteria (106)	Fungi (104)	Actinomycetes (103)
0th day	0.18	0.02	0.24	0.54	0.81	0.62	6.47	10	4	8
7th day	0.32	0.13	0.41	1.01	1.16	0.73	6.53	21	9	16
14th day	0.62	0.12	0.53	1.15	1.13	0.98	6.72	38	14	18
21st day	0.97	0.28	0.65	1.31	1.63	1.20	6.83	110	25	21
28 th day	0.77	0.18	0.45	1.24	1.28	1.78	6.92	68	22	20

***Values represent mean of three replications**
***Source:* Suchitra Rakesh *et al*., (2017).**

Table 2
Effect of application of liquid traditional inputs in Knol-khol, Onion, Pea, French bean and Paddy crops yield (q/ha) and against stalk rot (*Sclerotinia sclerotiorum*) of Cauliflower in sick soil.

Traditional inputs	Knol-khol	Onion	Pea	French bean	Paddy	Pre-emergence infection (%)	% Disease control	Post-emergence infection (%)	% Disease control
-	Marketable yield	Bulb yield	Seed yield	Seed yield	Grain yield	-	-	-	-
Jeevamtri	159.61	182.20	15.8	12.10	25.40	56.4	43.6	14.3	85.7
Beejamtri	161.67	182.58	16.5	14.50	25.90	61.1	38.9	22.2	77.8
Panchagavya	168.89	184.10	18.9	16.50	30.86	11.1	88.9	11.1	88.9
Matka Khad	157.5	180.61	18.2	14.30	28.50	44.4	55.6	22.2	77.8
Compost tea	178.61	178.35	17.5	15.80	29.68	72.2	27.8	22.2	77.8
Vermiwash	211.67	177.81	16.3	14.50	28.45	44.5	55.5	22.2	77.8
Nadep Compost	162.65	182.60	18.3	14.90	26.87	70.2	29.8	22.2	77.8
Control	128.06	167.34	14.2	10.40	24.50	100	00	-	-
C D (5%)	19.77	9.34	2.7	1.19	3.26	2.83	13.8	1.64	1.19

(f) Effect of Natural Farming System (Vedic Krishi) on Soil Health: Mulching of soil surface with organic materials renders the soil soft, pulverized, and humid that ultimately creates a congenial environment for beneficial microbes to maintain bulk density and porosity in the soil (Naeini *et al*., 2000). The improvement of soil physical properties due to organic farming has spatio-temporal dimension also. Lotter *et al.* (2003) reported that organic farming is better in areas having extreme rainfall because of the higher absorption and less run-off of water in the field. Application of good quality FYM improves the total nitrogen (Bhradwaj and Guar, 1985) and organic matter in the soil, which is "an important substrate of cationic exchange and the warehouse of most of the available nitrogen, phosphorus, and sulphur; the main energy source for microorganisms; and is a key determinant of soil structure" (Ewel, 1986). It is undoubtedly an important controlling factor for C: N ratio, total and available N, N mineralization, soil moisture, microbial activity, and soil texture (Agehara and Warncke, 2005; Cabrera *et al*., 2005). Significant differences and higher values of soil organic carbon, carbon stocks, and carbon sequestration rate were observed in organically managed plots compared to non-organic plots Gattinger *et al*. (2011). Application of organic fertilizer not only provides nutrient to the standing crop but also to the succeeding crop (Jannoura *et al*., 2014). Papadopoulos *et al.* (2014) notice that organic management can improve soil structure, organic matter content, and porosity in soil.

II MAJOR ORGANIC SOURCES AND TRANSFORMATIONS

Carbon present in soil is in the form of organic matter. The organic materials most commonly used to improve soil conditions and fertility include farm yard manure (FYM), animal wastes, crop residues, urban organic wastes (either as such or composted), green manures, bio-gas spent slurry, microbial preparations, vermicompost and biodynamic preparations. Sewage sludge and some of the industrial wastes also find application in agriculture.

(a) General Overview of Organic Amendments: A soil amendment is a material that can improve soil physically and/or chemically, making it more suitable for plant growth (Pettygrove, S. and B. W. Pettygrove, 2010). According to Davis and Wilson (2005), Organic Amendments come from something that was alive and include wood chips, grass clippings, straw, compost, manure, biosolids, sawdust and wood ash. However, this review focuses on compost and farmyard manure.

Aggregate stability is a basic factor in questions of soil physical fertility and could enhance by means of an appropriate management of OAs involving the incorporation of compost and FYM into soils, which can maintain an appropriate soil structure (Diacono, M. and F. Montemurro, 2010) Bipfubusa *et al.* (2008) also concluded that adding fresh and composted organic substrates usually have beneficial effects on soil aggregate stability, humification and microbial activity. Amlinger *et al.* (2003) has confirmed the throughout positive effects of compost on soil structure and other soil physical properties (e.g. pore volume, soil density, water capacity, hydraulic conductivity and infiltration rate, etc.). Generally, many research results revealed that organic materials help nutrients to remain in the agricultural production system. However, the gathering, storage and application of organic materials are usually labor-intensive tasks, requiring the availability of sufficient workers (Schöning, A., 2010).

Organic matter (OM) with a low C: N ratio should also be composed to avoid the release of apid NH3/NH $^{+}$ gas and toxicity. Organic Soil Amendment such as compost and animal manure are the most common now days, but peat moss, wood chips, straw, sewage sludge, and sawdust stare still used. Some of the alternative sources of OSA available in the country are listed below.

(b) **Animal Manure:** Manure is a mixture of faces, urine, and animal bedding that has been stacked and keep turning until it has been composted to a certain extent. It's made from beef, dairy, pork, poultry, and turkey, and the composition varies depending on where it's made, how urine and faces are excreted and mixed, and how long it sits before being added to soil. Manure not only feeds crops, but it also adds organic matter to the soil, making it more fertile (Goss et al., 2013).

(c) **Cover Crops:** Cover crops include plants that are planted for positive turning of physical, chemical, or biological properties, minimizing erosion or increasing soil fertility i.e., for in-between periods when the principal cash crops are produced (where the soil would otherwise be left blank) other than harvest for direct commercial value. Cover crops may also be used to fill in short periods of non-cultivation in crop rotations to protect soils, prepare the soil f or a perennial crop, or provide animal feed. Cereal crops supply straw that remains after harvest.

(d) **Compost:** Composting is a long-term method of converting organic wastes into OSA, useful as potting media or soil conditioners (Barthodetal.,2018). Composting is an aerobic method that can be done on a large scale in wind Rows or piles(Hobsonetal.,2005) or on a small rescale a home composter(Andersenetal.,2011).

(e) **Aquatic Weed Biomass:** Aquatic weeds such as *Eichhorniacrassipes* (water hyacinth), *Salviniamolesta*, Chara spp., Nitella spp., and algal scum can be found in large areas of India's northern region, including Kerla (Varshney et al., 2008).

(f) **Biosolids (Municipal Solid Waste):** Solid waste includes garbage, refuse, and discarded products from mining, farming activities, manufacturing, community events, and consolidated materials from a wastewater and water treatment plant (Singh *et al*., 2021).

(g) **Vermi compost:** Composting or breaking down organic materials supplemented with earthworms produces vermin compost. Vermi composting is an environmentally sustainable and efficient method of transforming agricultural waste (such as crop residues, cow dung, tree leaves biomass, fruit and vegetable waste, kitchen waste, weeds, and so on) into nutrient-rich produce with the help of earthworms (Nedgwa and Thompson 2001). It is high in essential plant nutrients and has the potential to improve the soil's condition and quality (Mahmud et al., 2018).

(h) **Green Manuring:** Green manuring (GM) is a method of enhancing the physical, chemical, and biological properties of soil by turning undecomposed plant material beneath the soil, which provides organic material and nutrients to the soil and an alternate source of soil amendments (Fageria 2007).

Table
Average nutrient content of bulky manure

Manure	**Percentage content**		
	N	**P_2O5**	**K_2O**
Animal refuse	0.3-0.4	0.1-0.2	0.1-0.3
Cattle dung, fresh	0.4-0.5	0.3-0.4	0.3-0.4
Horse dung, fresh	0.5-0.5	0.4-0.6	0.3-1.0
Poultry manure, fresh	1.0-1.8	1.4-1.8	0.8-0.9
Sewage sludge, dry	2.0-3.5	1.0-5.0	0.2-0.5
Sewage sludge, activate dry	4.0-7.0	2.1-4.2	0.5-0.7
Cattle urine	0.9-1.2	trace	0.5-1.0
Horse urine	1.2-1.5	trace	1.3-1.5
Human urine	0.6-1.0	0.1-0.2	0.2-0.3
Sheep urine	1.5-1.7	trace	1.8-2.0

Ash, coal	0.73	0.45	0.53
Ash, household	0.5-1.9	1.6-4.2	2.3-12.0
Ash, wood	0.1-0.2	0.8-5.9	1.5-36.0
Rural compost, dry	0.5-1.0	0.4-0.8	0.8-1.2
Urban compost, dry	0.7-2.0	0.9-3.0	1.0-2.0
Farm yard manure, dry	0.4-1.5	0.3-0.9	0.3-1.9
Filter-press cake	1.0-1.5	4.0-5.0	2.0-7.0
Ricehulls	0.3-0.5	0.2-0.5	0.3-0.5
Ground nut husks	1.6-1.8	0.3-0.5	1.1-1.7
Banana, dry	0.61	0.12	1.00
Cotton	0.44	0.10	0.66

Source: Organic Farming for Sustainable Agriculture by A. K. Dhama, 1996 Agro Beneficial Publishers (India).

III EFFECTS OF ORGANIC AMENDMENTS ON SOIL PHYSICAL PROPERTIES

(a) **Aggregate Stability and Bulk Density:** Concerning the physical soil properties, aggregate stability seems to be the most important parameter of all and contrary to many other parameters, it is easily measured. Many studies have addressed the effects of composts and FYM on aggregate stability. As an example, Zelalem B., (2012) highlighted that organic materials including compost and FYM have a positive effect on improvement of the soil structure and Bouajila and Sanaa (2011) showed that the addition of OA was associated with a significant ($p<0.05$) improvement of the structural stability of the soil. Such behavior might be the result of elevated OM content and improved microbial activities.

(b) **Water Holding Capacity:** As soil fertility status is strongly related to water availability; regarding the effect of compost and FYM on physical properties of the soils, it is essential to underline that the effect of amendments on soil water content and water holding capacity (WHC). Addition of compost and FYM to the soil increases the WHC, because adhesive and cohesive forces within the soil hold water and an increase in the pore space will lead to an increase in WHC of the soil (Reicosky, D., 2003).

(c) **Organic Matter and Soil Reaction (pH):** Organic amendments increase soil OM content depending on the amounts and quality of the materials added. The literature review of McConnell *et al.* (1993) shows that compost applied at a rates, varying from 18 to 146 t ha-1, produced a 6 to 163% increase in soil OM content. Manure amendments add OM to the soil, primarily in the form of OC and the amount of OC present in a soil reflects the long-term balance between additions of OC and losses through different pathways. The addition of manure typically shifts this balance and increases soil OM. Vitosh *et al.* (1973)

(d) Primary Nutrients (N, P and K): Organic amendments mainly composts and FYM have great contributions for nutrient availability to plants Hue, N. V. and J. A. Silva, (2000). There is a common understanding that many microorganisms convert organic N into inorganic N forms by mineralization. Both C and N potentially mine realizable pools and basal respiration were higher in soils treated with OA than in soils treated with mineral fertilizers (Canali *et al.* 2004)

(e) Challenges in Application of Organic Amendments: Competition of organic materials for the purpose of fodder or fuel, land scarcity, the cost intensive activities of organic materials gathering, storage and application are some of the constraints in utilization of OAs to improve soil fertility (Agyarko, K. and W. Adomako, 2007, Odhiambo, J. and N. Magandini, 2008; Negasi *et al.,* 2013). Due to those factors and since it is a practice with high labor and low yield, and only rich population will afford, application of OAs can't be result sustainable agriculture particularly in developing countries. In addition to this, OAs has more of long-term return rather than short-term positive effect (Miller D. and W. Miller, 2000). As a result, other alternative measures such as physical and biological soil conservation measures should be given more attention/emphasis and it is better to use the combination of the organic and inorganic fertilizers.

(f) Effects of Organic Amendments on Environmental Quality: Modern and sustainable agricultural systems through application of OA aim at developing new farming practices that are safe and do not degrade the environment. With regard to environmental concern, OA as compost and FYM can prevent water and air contamination that would result from erosion and leaching problem. Composting stabilizes some of the nutrients in wastes so that they may not as readily leach out. This decreases the potential for ground and surface water contamination (Diacono, M. and F. Montemurro, 2010). The use of compost on low OM soils results in improved moisture and nutrient retention, decreased soil erosion, reduced surface crusting, suppression of plant diseases and improved soil tilth. Composting of organic wastes kills weed seeds, pathogenic bacteria and viruses. There is also an increasing positive evidence of the impact that composts and FYM can have on soil carbon sequestration. Van-Camp *et al.* (2004) highlighted that when organic materials, such as compost and manure are added to soil; at least a share of their OC is decomposed and producing CO2, while another part is sequestered in the soil.

(g) Challenges in Application of Organic Amendments: Competition of organic materials for the purpose of fodder or fuel, land scarcity, the cost intensive activities of organic materials gathering, storage and application are some of the constraints in utilization of OAs to improve soil fertility (Agyarko, K. and W. Adomako, 2007, Odhiambo, J. and N. Magandini, 2008; Negasi *et al.,* 2013). Due to those factors and since it is a practice with high labor and low yield, and only rich population will afford, application of OAs can't be result sustainable agriculture particularly in developing countries. In addition to this, OAs has more of long-term return rather than short-term positive effect (Miller D. and W. Miller, 2000). As a result, other alternative measures such as physical and biological soil conservation measures should be given more attention/emphasis and it is better to use the combination of the organic and inorganic fertilizers. In fact, if the compost and FYM has not been sufficiently stabilized, its application increases ammonia volatilization, decreases the soil oxygen concentration, produces some phyto -toxic compounds and immobilizes soil mineral N. This could affect air and water quality.

IV CONCLUSION

Natural farming system and Soil amendments provide an alternate source of nutrients while improving soil fertility and crop sustainability. Organic amendment application can play a positive role in climate change mitigation by soil carbon sequestration, which in turn can reverse the process of soil degradation and environmental pollution. However, the presence of competition of organic materials for different purposes, the cost intensive activities of natural based farming and organic materials (gathering, storage and application) and since it has more of long-term return rather than short-term positive effect, application of organic amendments can't be result sustainable agriculture particularly in developing country. The most efficient methods for transforming biomass from alternative organic amendment sources into plant-nutrient-rich products are composting and vermin composting. Therefore, compost and organic matter additions have been emphasized as an essentials source for improving soil quality needed for improved crop production and yield.

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A Study on Ecology and Behaviour of Budgerigar (Melopsittacus Undulatus) Under Tirhut Region, Bihar

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ABSTRACT
Budgerigars (Melopsittacus undulatus) rank as the third most favored pet globally, following domestic dogs and cats, owing to their compact size, affordability, and capacity to imitate human speech. Budgerigars are raised in captivity featuring colors of blue, white, yellow, gray, greenish hues, and have small crests. The study of budgerigar ecology and behavior was conducted in captivity at Dr. C.V. Raman University, Bhagwanpur in Vaishali district, Bihar. The research from 06/03/2025 to 15/06/2025. The research was funded by AGU-CRIG which is aimed to understand the behavioral shifts during feeding, breeding, different color variations and their genetics; nest selection and cage upkeep. For investigating nest selection, territory, and seasonal changes in breeding, a primary cage measuring 1m x 1m x 1m constructed from plastic-coated iron wire mesh was utilized. Four test cages measuring 30 cm × 30 cm × 30 cm were utilized to determine the optimal feed for them. A discussion was conducted with budgerigar breeders and veterinarians to gather information on color variations, ailments, parasites, and their treatments. A survey was carried out among pet shop owners selling budgerigars who were breeding them to gather information on their popularity, variety selection, and quality.

Keywords: Ecology, Behaviour, Captivity, Budgerigars

I INTRODUCTION

Budgerigars are very social and swift-flying birds. They are inexpensive companions and simple to maintain. It ranks among the tiniest parrot species globally, and their sex is quite simple to identify. The colour of the cere can be used to distinguish between male and female budgies. The male budgerigar has a blue cere, whereas the female budgerigar's cere is brown. An unusual instance is seen in albino and lutino budgerigars, as males possess pink ceres while females exhibit white or cream (Adajar, 2001). The budgerigars (Melopsittacus undulatus) belong to the class: Aves and order: Psittaciformes. It is widely referred to as a pet parakeet or shell parakeet, which are small parrots with long tails that eat seeds. They are frequently located in Australia. This sociable species was identified in 1805 by George Shaw and has now become the third most popular pet globally. The English zoologist Dr. George Shaw (1751-1813) recorded the species in 1794, but comprehensive research on budgerigars couldn't be conducted as they were still found in their natural habitat. Shaw was the initial person to characterize the small parrot called, "Psittacus undulatus" (undulated grass parakeet). The English ornithologist John Gould (1804-1881) was evidently captivated by these tiny birds, calling them the liveliest, joyful little beings. Gould managed to bring home a few budgies. In 1840, he released the initial comprehensive study on budgerigar behavior in his book 'Birds of Australia.' He was also the person who coined the current scientific name, Melopsittacus undulatus (melodious parrot, but also signifying the finest of all grass parakeets). Budgerigars are excellent instances of monogamy.

It is the most basic type of mating system where each adult individual pairs exclusively with one member of the opposite sex for their entire life. They primarily communicate through vocal sounds, and the budgie's song is fairly loud. Budgerigars communicate with each other using their voices, as they are highly social birds (Eda Fujiwara et al. 2011). A typical budgerigar measures 18cm in length, weighs 30-

40 grams, and has an average wingspan of 30cm. They display sexual dimorphism. Below are definitions for some of the essential terms.

- Ecology: encompass all ecological facets associated with the cage; both biotic and abiotic elements.
- Behavior: refers to changes in behavior during breeding, feeding, and territory maintenance in Budgerigars.
- Captivity: refers to a condition in which animals are restricted to a specific area and are unable to escape or move freely. Here, the cage contains budgerigars.

II MATERIALS AND METHODS

The research took place in captivity at Dr. C.V. Raman University, located in Bhagwanpur of Vaishali district, Bihar, from 06/03/2025 to 30/05/2025. Different techniques were employed to examine various aspects associated with behavior, enclosure management, color variations, reproduction, nutrition, territorial interactions, as well as prevalent diseases, parasites, and their management. Observations are conducted directly, and photos are captured using a Nicon 1300 D, vivo dual camera, and Redmi Note 4 camera. The primary cage measured 1m x 1m x 1m (Plate 1) and was made of plastic-coated wire mesh. Furthermore, four testing cages measuring 30cm×30cm×30cm (Plate 2) were constructed using the same material. Various foods and supplements were provided to budgies in four test cages to assess the effect of diet on breeding. The weights of budgies were documented each month using an electronic scale. Their typical weight was assessed.

Average weight of budgerigars = sum of weight measured monthly / number of weight measured monthly Number of eggs, clutch size, fledging size and clutch gap were calculated by direct observation. Average number of eggs in clutch was calculated.

Average number of eggs in clutch of budgerigars= sum of number of eggs in each clutches /number of clutches measured

Average fledging size of chicks were calculated, Average fledging size of budgerigar chicks = sum of number of chicks fledged / number of fledge size measured

Two clay nest pots were positioned in each of the four experimental cages. For the analysis of nest selection, clay and plastic nest pots were positioned in the primary cage. Birds' preferences for nests were observed in relation to the size, hole dimensions of the nest pot, and the distance between the wire mesh and the nest pot. A preference for the location of the nest—top, bottom, and middle—was also observed. The clutch gap is the time between the date the first egg of the first clutch is laid and the date the first egg of the second clutch is laid. The parental care from the day of chick hatching to the fledging of the chick was documented. The nest underwent daily inspections throughout the nestling stage transitions. The clutch initiation date was established either through direct observation of egg deposition or by calculations based on known hatching dates and average developmental times. Clutch size, defined as the total count of eggs deposited and the length of the developmental phase, was determined through a visual examination of the nests.

A study was carried out to determine whether there were variations in clutch size, fledging size, hatching size, and the number of incubation days across the summer, rainy, spring, and winter seasons. To determine the hatching day of the eggs, a new technique was implemented, known as the egg marking method. Using a marker pen, the eggs were labeled according to the sequence they were laid. The eggs' weights were determined using an electronic balance, and their sizes were measured with thread and a ruler; consequently, morphology was examined through morphometric analysis. The cage was observed daily in the morning (05:00 am to 06:00 am) and in the evening (05:00 pm to 06:00 pm). During holidays (06.00am to 05.00pm), the time was split into four segments (06.00am to 09.00am, 09.00am to 12.00pm, 12.00pm to 03.00pm, 03.00pm to 06.00pm). A nest with at least one fledged young bird was deemed successful. Discussions were held with budgerigar breeders and veterinarians to gather information on colour variations of budgerigars, ailments, parasites, and their treatments. The investigator performs a survey with pet shop owners who breed budgerigars. A survey covers different elements such as popularity, preferred varieties, quality choices, reasons for selecting budgies as pets, information on varieties, dietary needs, common diseases, preventative measures and treatments for illnesses, parasitic infestations, and cage selection. The sample size comprised 30, and a duplicate of the questionnaire can be found in the Appendix. Following the survey with a sample size of 30, the data was analyzed and several conclusions were drawn.

Morphometry of Budgerigar

- **Colour Varieties and Genetics -** The different color variations include normal, spangle (single factor spangle & double factor spangle budgerigar), opaline, pinnamon, albino, lutino, creamino, latewing, fallow, clearwing, greywing, pied (recessive pied, dominant pied (single factor dominant & double factor dominant), clear flight pied, mottled pied), crusted, and rainbow budgerigar.

Table no: 1 – table showing the list of various foods given to budgerigars

Seeds	*Vegetables*	*Fruits*	*Minerals(suppliments)*	*Leaves*
Setaria italica (foxtail millet)	*Daucus carota(carrot)*	*Malus domestica (apple)*	*Internal skelton of cuttle fish(calcium)*	*Spinacia oleracea (spinach)*
Triticium	*Solanum lycopersicum*	*Magnifera indica*	*Agrimin fort(mineral mixture)*	*Centalla asiatica*
Vigna radiata		*Psidium guajava*	*Plaster of paris*	*Ocimum tenuiflorium*
Zea mays (maize)			*Egg shells*	*Capsicum annum*
Coconut dried cake			*Lugols iodine*	*Moringa oleifera*
Peanut cake			*Groviplex(liquid supplement)*	*Solanum lycopersicum*
Wheat bran, maize bran			*Osomin+vimeral(liquid supplements)*	*Coriandrum sativum*

They were fed very actively in the early morning and evening. However, budgerigars have young ones in the nest, and the parents bring food each time. Breeding pairs also eat more than non-breeding pairs. The female consumed a greater quantity of food than the male. However, during the incubation period, females eat very little food. Typically, males regurgitate seeds to females during incubation. During the breeding season, the female eats mineral blocks similar to cuttlefish. They additionally ingest eggshell and whitewash on the wall. Young birds also consume mineral blocks for calcium, which aids in trimming or sharpening their beaks. Their preferred foods include foxtail millet and Ocimum tenuiflorium leaves. They also exhibit neophobia, which is a condition occurring when they are presented with a new type of food. They ascended and watched the new nourishment. Once one of them sampled it, the rest were motivated and began to partake. They can be bred over the years when they receive a consistent and ample supply of food at all times. When a featherless young chick falls from the nest, the other budgerigars begin to eat it. This results in the chick's death. In the wild, budgerigars consume different seeds and herbs.

III EXPERIMENT TO FIND MOST NUTRITIOUS FOOD FOR BUDGERIGARS

We carried out a study to determine which food is more beneficial for budgerigars. Four pairs of adult budgerigars of the same age were selected and placed into four individual cages measuring 30cm×30cm×30cm. Four enclosures were designated as test cage 1, test cage 2, test cage 3, and test cage 4. Foxtail millet, water, cuttlefish internal skeleton, and leaves were provided to test cage 1. Foxtail millet, hydrated wheat, water, the internal structure of cuttlefish, and leaves were provided to test cage 2. Foxtail millet, a dehydrated concentrated feed powder (composed of wheat powder, wheat bran, maize powder, maize bran, coconut cake, peanut cake, and second-quality gram powder) excluded the agrimin forte mixture, along with the internal skeleton of cuttlefish, leaves, and water, were provided to test cage 3. Foxtail millet, dried concentrated feed powder with agrimin forte mineral mixture (vitamin A, zinc, magnesium, manganese, iron, iodine, vitamin E, methionine, cobalt, potassium, sodium), internal cuttlefish skeleton, leaves, fruits, vegetables, sprouted grams (twice weekly), boiled egg (once weekly), water, groviplex (2 ml mixed with 250 ml of water containing calcium, phosphorus, cobalt chloride, vitamin D3, vitamin B12), ostovet forte (calcium, phosphorus, vitamin D3, vitamin B12, carbohydrate) + vimeral (vitamin A, vitamin D3, vitamin E, vitamin B12) (2 ml mixed with 250 ml of water) were provided to test cage 4. Table no: 2 lists different foods provided to budgerigars in four test cages. Various diets for budgerigars.

Table 2
Table Showing the List of Different Foods Given to Budgerigars in Four Test Cages

Number of cage	Food materials
Cage 1	Foxtail millet, water, internal skeleton of cuttlefish, leaves
Cage 2	Foxtail millet, wetted wheat, water, internal skeleton of cuttlefish, leaves
Cage 3	Foxtail millet, dried concentrated feed powder(wheat powder + wheat bran + maize powder + maize bran + coconut cake + peanut cake + second quality gram powder) without agrimin forte mixture, internal skeleton of cuttlefish, leaves and water
Cage 4	Foxtail millet, dried concentrated feed powder with agrimin forte mineral mixture(vitamin A, zinc, magnesium, manganese, iron, iodine, vitamin E, methionine, cobalt, potassium, sodium), internal skeleton of cuttlefish, leaves, fruits, vegetables, sprouted grams (twice in a week), boiled egg(once in a week), water, groviplex (2 ml mixed with 250 ml 0f water containing calcium, phosphorus, cobalt chloride, vitamin D3, vitamin B12), ostovet forte(calcium, phosphorus, vitamin D3, vitamin B12, carbohydrate) + vimeral(vitamin A, vitamin D3, vitamin E, vitamin B12) (2ml mixed with 250 ml of water)

Table 3
Showing Comparison Between Clutch Size and Weight of Budgerigars in Four Test Cages.

Number of cage	Cage1	Cage2	Cage3	Cage4
Average number of chicks weaned	(2,2,1) 1.6	(2,2,2) 2	(3,3,4) 3.9	(4, 4, 5) 4.3
Average number of days taken for weaning	36.2	35.8	33.2	30
Number of days between clutch 1 and 2	75	70	60	55
Number of days between clutch2 and 3	72	73	61	56

The findings from this experiment (Table no:3 & 4) indicate that the food resources in cage four are more beneficial for the growth and breeding of budgies. In comparison to the first cage, the fourth demonstrated the most significant growth. When comparing the first and fourth cage, the chicks were initially weaned from the fourth cage. The development of chicks in cage 1 was extremely inadequate. The chicks in the initial cage were weaned after 36 days, whereas those in the fourth cage were weaned after just 30 days. In the first, second, and third cages, females lay eggs with a one-day interval. However, in cage four, they also lay eggs every other day, but occasionally they lay eggs daily without any interval. The gap in the clutch is elevated in cages one and two. However, for cages three and four, the level is quite low.

Table 4
Table Showing Comparison Between Fledge Size, Clutch Gaps and Number of Days Taken for Weaning of Budgerigars in Four Test Cages

Number of cage	**Cage 1**	**Cage 1**	**Cage 3**	**Cage 4**
Average weight of male	28g	28g	33g	36g
Average weight of female	26g	27g	30 g	33g
Number of eggs in clutch-1	6	6	8	6
Number of eggs in clutch-2	7	7	9	9
Number of eggs in clutch-3	6	7	9	12

Number of days taken for laying first egg in first clutch after introducing them in four test cages were18,15,13 and 10 in cage 1, cage 2, cage 3 and cage 4 respectively.

(a) **Comparison of the number of successfully weaned chicks in four test cages -** In mate selection, the responsibility falls to the males. Males stayed near the female and consistently attempted to pursue her. She has no interest in this activity and flew off. The male pursues the female and he bobs his head up and down displaying his feathers to her. He darted from one corner of the cage to the opposite corner and continued the head bobbing to entice the female. This task might continue for several hours and potentially for days. She persuaded him with the activity and sat near him. The male caresses the female's beak and nods his head repeatedly; this can happen multiple times. Following that, they sit closely and eat together. This indicates the formation of pairs. She ultimately embraces the male, and the duo formed a connection. Once the male is paired, he begins to dance by bobbing his head, rubbing his beak against the female, and hopping between twigs while making a chirping sound, displaying his excitement. Following this, the female might accompany the male; they can be observed sitting together, eating together, and engaging in both auto-preening and allo-preening behaviors.

(b) **Courtship behavior-** Different courtship behaviors include courtship feeding/regurgitation, proximity, preening, and grooming

IV MATING PROCESS

The male budgerigar produces a noise resembling 'click click kli' and circles the female. He is dancing a lot. He nods his head repeatedly while looking at women. She drew attention and began to sit in an arched posture. He placed his foot on her wings and held on to climb onto her back. She sits in an arched position and raises her tail to facilitate comfort during mating. The female spreads her wing to stabilize his weight. The male climbed onto the female and positioned himself down her tail to maintain the mating process. During that period, the male vibrates and twists his body, producing a cracking sound resembling 'cra cre cra'. The procedure takes just 2 minutes, but occurs multiple times daily. The highest mating activity occurs during the early morning and evening. The brightness of cere colour in males amplifies during mating. During mating, the eye rings are more pronounced in both genders. The females will exhibit a distinct alteration in cere color. The light cream shade of the cere transformed into a deep chocolate brown.

V NEST SELECTION

The choice of nest pot is made solely by the female. For a new pair, the choice of nest site begins two days following the mating. In the case of an old pair, they choose a single nesting site for their entire life, cleaning their nest after the previous brood has been weaned. The nest pots were set in a line with an average spacing of 20cm, and additional nest pots were positioned at the bottom and middle of the cage. The space from the upper to the middle nest pot is 33cm, and the gap between the middle and lower one is also 33cm. Following mating, she begins to concentrate on choosing a nest site. Fourteen pots are provided in the main cage. Females consistently enter every nest pot, and they seem somewhat puzzled. All of them declined the plastic pots, and most chose the upper nest pots while rejecting the nest pots positioned in the center of the cage. They likewise decline nest pots lacking a top cover. The female required three to four days to choose the nesting location.

Table 5
Table Showing Various Measurements, Positions and Nature of Nest Pots (NP) In Main Cage for Budgerigars

Nest pot number	Nature of NP	Circumference of NP (cm)	Height of NP (cm)	Hole size of NP (cm)	Distance from side wall of cage to NP (cm)	Position of NP on cage (cm)	Presence of Upper Covering in NP	Selected (/rejected)
NP-1	Clay	54 cm	15 cm	17cm	10cm	Top	Yes	Selected
NP-2	Clay	54.5 cm	15 cm	16cm	11cm	Top	No	Rejected
NP-3	Clay	53 cm	14 cm	17cm	8.6cm	Top	Yes	Selected
NP-4	Clay	54 cm	13 cm	17cm	9.4cm	Top	Yes	Selected
NP-5	plastic	34 cm	13.cm	18.3 cm	3 cm	Top	Yes	Rejected
NP-6	Clay	87 cm	15 cm	18.6 cm	14.cm	Bottom	Yes	Rejected
NP-7	Clay	33.2 cm	10 cm	16 cm	10 cm	Top	Yes	Selected
NP-8	Clay	54 cm	15. cm	17.6 cm	12 cm	Middle	No	Rejected
NP-9	Clay	77 cm	14 cm	16 cm	8cm	Middle	Yes	Rejected
NP-10	Clay	54.6 cm	12.4 cm	13.2 cm	7cm	Bottom	Yes	Rejected
NP-11	Clay	67 cm	14 cm	13 cm	12.8 cm	Middle	No	Rejected
NP-12	Clay	54.4 cm	15cm	17.1 cm	6 cm	Middle	Yes	Selected
NP-13	Plastic	37 cm	15cm	19 cm	8.9 cm	Middle	Yes	Rejected
NP-14	Plastic	34.8cm	16.3 cm	16.5 cm	9 cm	Bottom	Yes	Rejected

Budgerigars

Table no: 5 indicate the factors affecting the nest site selection in captivity are hole size, medium sized pot, easiness to enter, less distance from the cage side walls to the nest pot hole, nest pot with upper covering, nature of nest pot.

Table 6
Table Showing Nest Site Selection Factors of Budgerigars

Factors	Inference
Circumference of nest pot	Medium sized
Height of nest pot	Medium sized
Hole size of nest pot	Medium sized
Distance from side wall to nest pot hole	Less
Easiness to enter	They prefer easiness
Position of nest pot	Top
Upper covering of nest pot	Having upper covering

Various nest selection factors are listed in table no: 6

When the initial chick was weaned, the mother began her second clutch. She mated repeatedly. When the final chick takes longer to fledge, she becomes somewhat confused and looks for another nest close to the previous one. When the final chick left the nest early, the mother stopped looking for additional nesting sites. Research indicates that 90% of females lay eggs following the departure of the last chick from the nest. In research, females choose a single nest for their entire life.

- **Nesting Behaviour -** Typically, budgerigars produce eggs in a simple nest without any nesting materials. A study was carried out to examine nesting behavior by adding paper strips, wooden chips, and coconut fiber into the nest pot. All the females dismiss these nesting materials. They tidied their nest using their beak and legs. She dedicates additional time in the nest for cleaning. She selects dried feces from the last brood and discards them. It was incredible to witness. She carefully cleans the nest and leaves it bare. The male is positioned near the nest. The female began consuming the internal skeleton of the cuttlefish and scratched the whitewashed wall to obtain calcium. Cuttlefish bone served in beak trimming and provided calcium and minerals. She grows increasingly aggressive. She granted permission solely to her partner to sit close to their nest. She got ready for the egg-laying process. She spends additional time in the nest. The male consistently trails the female and relays the food after digestion. When she emerged from the nest. Courtship behavior might be observed. Reproduction also takes place consistently. She lays down her abdominal feathers and uses them as nesting material.
- **Egg Laying -** It was observed that the female's belly was distended, the vent appeared red, and the droppings increased in size. She constantly shakes her tail. The hindquarters become inflated, and her cloaca turns very red and enlarged. She appears very lovely right now and also seems quite plump and occupied. Honestly, she resembles a woman expecting a baby. She utilizes greater calcium supplies. Mating persisted and occupied more time in the nesting area.

The initial egg was laid, typically occurring nine to ten days post-mating. The egg was oval-shaped and white in hue with no decorations. Following the laying of her first egg, she began to lose her feathers quickly.

A one-day gap will occur between egg laying, which also depends on food availability. As she emerged from the nest, the male positioned himself nearby the female, and they engaged in allo-preening. Feeding and reproduction will be observed frequently. After laying the second egg, she devoted more time to the nest, possibly because she began incubating the eggs.

Table 7
Indicates Various Characteristics of Budgerigar's Egg.

Egg colour	Egg colour Average egg weight	Average egg	Shape of egg
White	1.34gram	5.3cm	oval

In females, the cere's color deepens to a dark chocolate brown. The frequency of mating gradually diminishes, as she invests a lot of time in the nest. She provided calcium sources and consumes a lot of food. This study found that after 15 days of incubation, they cease mating. When she leaves the nest, the male regurgitates food and provides it to the female. She quickly grooms her body and then abruptly returns to the nest pot. Upon entering the nest, one might hear the soft rolling sound of the eggs.

- **Incubation -** Incubation is ongoing. Only the female incubates the eggs. She began the incubation process after the second or third egg was deposited. The eggs developed over 18 days of incubation. However, because of the alternating egg-laying, she continues her incubation even after the first egg hatches. The incubation period for females extends to 25 - 28 days. During incubation, the female eats a minimal quantity of food provided by the male. Once the first egg hatched, she began to consume a greater quantity of food from the male. The female provided the correct temperature for the recently hatched chicks. Following 25 days of incubation, females become increasingly proactive in seeking food from the males. The female relies on the male for food while also searching for food independently. During incubation, she is quite diligent in ensuring appropriate humidity levels, so she bathes in water to keep the humidity regulated. During incubation, there is a high opportunity for ectoparasites. Therefore, when she emerged from the nest pot, she rubbed her body with 'ocimum leaves ('thulasi' leaves). While incubating, she emerged from the nest pot two or three times each day for mating, ingests calcium, cleans herself with 'ocimum' leaves, takes water baths, and feeds.
- **Egg Hatching and Parental Care -** The eggs of budgerigars hatched at the same time. The first egg hatched following 18 days of incubation. Of the nine eggs, five successfully hatched, indicating a hatching success rate of 55%. The remaining four eggs failed to hatch because of elder chicks moving, lack of fertilization, or embryo death. The baby creature had a clear and swollen belly. The body is skin-toned and they emerge blind and bare (featherless). The diet consists of partially broken down seeds from the female's crop. The female feeds the hatchling by regurgitating into its beak. Female given additional food caused crop to bulge. Maintaining the nest was an ongoing task. In this research, a female never cleans her nest pot, resulting in droppings sticking to the chicks' beaks and feet, drying out, and occasionally covering the cere, which can lead to suffocation and death of the chicks. When the female arrives at the nest, the chicks loudly cry out and plead for food. The male provides food to the chicks after six to seven days, following the hatching of the first chick. Parents provide food for the chicks, while the females tidy the nest each day. In this research, it was noted that chicks began to open their eyes on the seventh or eighth day after hatching. The primary or pin feathers begin to develop on the seventh day after hatching. Chicks left the nest 30 days (depending on food) after hatching.
- **Vocalization -** Syrinx is a skeletal formation located at the base of the trachea. Syrmechanism. Budgie melodies developed via sexual selection and experimentation. It indicates that the quality of bird song is an effective measure of fitness. During mating or breeding, the male produces a distinctive sound like 'click click kli' that attracts the female, making her ready to mate. When a threat arises or a predator appears, they produce a loud noise similar to 'cralk cralk klki'. When the couple has chicks, the female emits a 'ki ki ki' sound to signal her need for food, which the male then provides. She continuously produces a 'ki ki ki' sound while taking regurgitated food from the male's beak. A female claims her territory and permits only her partner to enter her area. She emits a 'cri cri' alert noise when people

enter her space. Perform an experiment that isolated a budgerigar couple at a distance of approximately 100 meters. They are arranged in a manner that prevents them from seeing one another. The female produces a noise when the male emits a sound from another cage. Thus, they convey messages via sound. They never choose different partners. After 30 days, they were put back in the same cage. They were matched once more, making vocalization crucial for connection.

- **Territorial Behaviour -** Territorial behavior is a means of defense for food supplies, nesting areas, or other resources against individuals of the same species. Budgerigars are social creatures. During their mating season, they exhibit territorial behavior. To test their territorial behavior, I select a pair and, after 10 days, add some budgies to their cage. When anyone sits close to their nest, the female becomes very aggressive, makes loud noises, and starts to attack. The mating pair views their nest and several spots around it as their territory. Females are more proactive in defending their territory. She grants consent solely to her partner. A territory is a protected section of a habitat inhabited by a mating couple. Territoriality refers to the behavior pattern employed to recognize, set up, and protect a territory. Budgerigars possess very limited territories, measuring only a few squares Aureole 2020 107 meters. This occurs because they utilize the area solely for reproduction, and they are generally outside the territory for feeding. It is regarded as a home range. They bite the nets and twigs close to their nest to signal their territory.

(a) **Nutrient Deficiency Disorders -** Information regarding nutritional deficiencies, parasites, and diseases caused by bacteria, viruses, protozoa, and fungi was gathered from interviews with veterinarians and breeders.

(b) **Parasites Ectoparasites -** The primary ectoparasites found in budgies are mallophaga (budgie lice), scaly leg and face mite (Cnemidocoptes mutans), and red mites (Dermanyssus gallinae).

(c) **Prophylaxis for ectoparasites**

- Apply avian insect liquidator, poron, and clear ticks spray to the corners of cages and nesting pots.
- Using turmeric powder and dried neem leaves to smoke the cage.
- Suspend tobacco leaves in the enclosure.
- Provide clean drinking water
- Once a week, clean the cage and the nesting pots.
- Provide ocimum leaves for consumption and they used it on their plumage.
- Incorporate ocimum and neem leaves
- Remove to the bath water

(d) **Endoparasites**

- The main endoparasites seen in budgerigars are roundworm, tapeworm and Sternostoma tracheacolerum.
- Therapy for endoparasites
- Deworm the budgerigars at consistent intervals.
- Add aloe vera gel to the water for drinking.
- Provide extracts from neem and ocimum leaves.
- Administer ivermectin via oral and injectable forms.

Key deworming medications include fenbendazole, albendazole, fentasplus. SIGNIFICANT BACTERIAL, VIRAL, PROTOZOAN, AND FUNGAL ILLNESSES include Budgerigar candidiasis, budgerigar sneezing, Parrot fever (psittacosis), budgerigar fledgling disorders, French molt, Budgerigar beak and feather syndrome, Coccidiosis, conjunctivitis, and avian influenza.

VI DISCUSSION

From the perspective of animal welfare, humans are allowed to breed and utilize pets for their needs, but animals' 'interests must be met', encompassing their health and overall welfare (Gruen-2011). Currently, raising pets is becoming popular. Budgies have gained commercial popularity as pets due to their attractiveness and high reproductive capacity. However, in confined enclosures they do not receive enough nutrients. Simultaneously, they are not provided with cozy enclosures. An additional crucial aspect is ensuring a proper cage is set up. The cage must be built outdoors, where there is light and wind. Sunlight plays a crucial part in their reproduction. This research allows for the creation of a high-nutrient feed. It enhances their efficiency and strengthens their immune defenses. Vegetables, fruits, boiled eggs, greens, cereal blends, oil meals, maize, calcium blocks, and additives enhance their production rate. Ullray et al. (1991) assessed the nutritional composition of seeds frequently found in commercial bird diets against the estimated needs of psittacine birds, concluding that they generally lack sufficient amounts of amino acids, calcium, phosphorus, sodium, manganese, zinc, iron, vitamins A, D, E, and B12, riboflavin, pantothenic acid, choline, and niacin. Complete diets typically consist of ground grains like corn for energy, along with ground grains such as soybean meal or peanut meal for protein, vitamins, minerals, vegetable oil, and purified amino acids added in suitable amounts to address deficiencies in the grain and protein sources (Elizabath A. Koutos, Kevin D Matson et al. 2001).

Another crucial task with food is to create their nesting pots. This research revealed that they select the nests that are most appropriate for the environment. They opt for the clay pot while steering clear of the plastic nesting pots. They aim to place their eggs in the highest nest pots. They choose a nest pot of medium size. They opt to place eggs in a nest pot that was simple to access and no nesting materials were utilized. They select a nesting pot only once in their lives, which will be utilized during their entire time in captivity. However, if the chicks fail to emerge from the nest pot on schedule, they will deposit their eggs in another nest pot close to the prior one. Overpopulation is a significant issue. It results in intense rivalry for territory preservation and causes the demise of females. The territory is upheld by the females. Females expend more energy nurturing their chicks compared to males. With these females, we achieve high yields and high-quality chicks. The outcome of overpopulation is inbreeding, which adversely impacts the quality of the next generation. The cessation of inbreeding leads to increased productivity and quality. Choose to pair them and put them in a different cage before they mature. Once paired, place them into the main cage. This will avoid inbreeding. Coccidioidomycosis and conjunctivitis are the prevalent ailments that impact them. Therefore, clean the cage once or twice each day. Aim to incorporate ocimum, muringa, spinach, centella, and Plectranthus barbatus leaves into their everyday diet. Scaly leg and face mites are the most prevalent ectoparasites found in budgerigars. The common treatments for these parasites are ivermectin in pill form and ivermectin via injection. Ascabiol is a cream that is used on the dried sores. They frequently rubbed the feathers with ocimum leaves to eliminate the mites. Incorporate ocimum and neem extracts into their bathing water to manage the mites and ticks. Endoparasites such as roundworms and tapeworms also cause various health problems in budgies. The newly arrived budgies are quarantined and dewormed only when there are no other parasites and diseases present. Ensure you deworm the budgies consistently at set intervals. In the laboratory, it has been established that female and male budgerigars can identify one another after a separation period of 70 days (Felicity Muth-2011). In the research, females identify the sound of their separated partner. When he makes a sound, she replies with a loud noise. 114 Aureole 2020 is combined, and then they form pairs once more. They practice monogamy and primarily communicate via vocal sounds. The survey revealed that the albino budgerigar variety (53.3%) was in highest demand, followed by spangle (20%) as the second priority. There is significant demand for rainbow budgies, yet their population is quite limited in Kerala, and not many individuals are familiar with them. The demand for the Pied variety was minimal at 2%. The features of albinos, such as white feathers, red eyes, pink cere, and pink feet, make them very sought after.

Determine the gender in advance to avoid inbreeding. The cere of male chicks is a pale pink shade, while female chicks have a lighter white or bluish hue. They need to be kept apart and permitted to pair with other budgies that are not related by blood. Otherwise, it could result in disabilities, diminished productivity, hindered growth, unchecked growth of beak and nails, and early death. In the research, the breeding season for budgerigars in Kerala occurs between September and November. As they are held in captivity, they mate and hatch chicks all year round. However, a large number of chicks fledged between September and November, which is springtime in Kerala. Fewer babies were fledged from December to February, which is winter in Kerala. While the rainy season doesn't yield as much in the spring, its productivity remains high compared to other seasons (June-August). The egg breaks open at the beginning of summer. Typically, the incubation period for eggs lasts 18 days. However, during summer, it hatches after 17 days of incubation. However, during the winter season, it's too late for the egg to hatch, as it requires 19 days of incubation. The majority of eggs get harmed in winter and summer. Maybe extreme heat and extreme cold contribute to the harm of eggs.

Budgerigar offspring are underdeveloped at birth. The female deposits eggs every other day, allowing them to hatch on alternate days. The first chick to hatch is quite strong, making it very simple for them to obtain food from the mother. The final hatchling is quite tiny and unable to vie with the other chicks, resulting in its death from insufficient food. Out of eight laid eggs, five will successfully hatch, while the other three were damaged because of the erratic movements of older chicks. In the research, 95% of the last chicks died. Because of being held in captivity, they are unable to survive beyond the cage. In the research, it was observed that their release from the cage was due to negligence, allowing crows and other birds to capture and kill them. The chicks acquire all survival lessons from their parents, a behavior that is learned. When the baby birds are ready to leave the nest, the father will stay nearby and shield the chicks more than the mother. He also gives the chicks appropriate food. Sadly, if chicks happen to land on the ground prior to fledging, the other adults/juveniles will eliminate the chicks. They consumed the meat and blood of chicks. It is a behavior that involves cannibalism. Therefore, steer clear of congestion. They fear what is unfamiliar to them; this condition is known as neophobia. Their conservation status is of least concern, which is why they rank as the third most popular pet globally. Budgies are very responsive to threats from predators. They provide a specific type of voice and guide others. As a result, everyone is vigilant. The primary issues in captivity involved attacks by dogs, cats, civets, rats Aureole 2020 115, and snakes. Therefore, attempt to maintain the cage at a higher level.

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VII CONCLUSION

The research titled "A STUDY ON ECOLOGY AND BEHAVIOUR OF BUDGERIGAR (Melopsittacus undulatus) IN CAPTIVITY AT DR. C.V. RAMAN UNIVERSITY, BHAGWANPUR, VAISHALI DISTRICT, BIHAR" was conducted 06/03/2025 to 30/05/2025. Different factors such as morphometry, behavior alterations during breeding, feeding habits, territory maintenance, fledge size comparison across seasons in Kerala, color variations and their genetic basis; nest choice; diseases, parasites and their management, as well as cage upkeep were examined. The colour of a budgerigar's cere allows us to determine its sex. The male displays a bluish cere, while the female's cere appears light cream, except for albino and lutino variations. The cere of males is pink, while the cere of females is light cream or whitish. Thus, they exhibit sexual dimorphism. Courtship behaviors encompass courtship feeding, proximity, preening, and grooming. While mating, the female's cere color will undergo a distinct change. The light cream-colored cere transformed into a deep chocolate brown shade.

The most demanded budgerigars variety is albino (53.3%). Nutritious feed also enhances the productivity. Coccidiosis, conjunctivitis (eye infections) are the major diseases that affect them. Keep the cage hygiene. Don't forget to include ocimum leaves, muringa leaves, centalla leaves are in their daily feed, as this will give the immunity. Overcrowding is a main problem in captive breeding, which leads to inbreeding. Accomadate only a maximum of 10 pairs in a one meter squared cage. They should be dewormed at regular intervals. 90% of last hatchlings were died. Budgies prefer clay pots for laying eggs and the nest pots on the top and select less distanced hole from the mesh for easy entering. Eggs are more damaged during summer and winter season. Normally the egg incubation days is 18 days, but in summer it hatches in 17th days of incubation. But in winter season it is too late to hatch the egg, it reaches in 19th days of incubation. Now a days pet rearing is becoming a commercially popular pet, because of their beauty, productivity and easy to care. Nutritious food will increases the productivity. The nutritious feed, spring season, stress free environment and cage with fewer pairs will favour the fledge size. The albino variety of budgerigars is the most sought after (53.3%). Nutrient-rich feed also boosts productivity. Coccidiosis and conjunctivitis (eye infections) are the primary illnesses that impact them. Maintain the cleanliness of the cage. Remember to add ocimum leaves, moringa leaves, and centella leaves to their daily feed, as this will boost their immunity. Overpopulation is a primary issue in captive breeding, resulting in inbreeding. Only a maximum of 10 pairs can be housed in a one square meter cage. They need to be dewormed periodically. 90% of the recent hatchlings perished. Budgies favor clay pots for egg-laying and choose nest pots located higher up, picking holes that are closer to the mesh for easier access. Eggs sustain more damage in the summer and winter months. Typically, the incubation period for eggs is 18 days, but during summer, they hatch on the 17th day of incubation. However, during the winter season, it is too late for the egg to hatch, as it reaches 19 days of incubation. Currently, raising pets is gaining popularity as a business due to their attractiveness, productivity, and ease of care. Nutritious food boosts productivity. The healthy feed, springtime, relaxed surroundings, and cage with fewer pairs will benefit the fledge size.

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Environmental Implications of Solar Drying Systems: A Comprehensive Review

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ABSTRACT
With the increasing urgency to combat climate change and promote sustainable practices, solar drying is evolving as an efficient and environmentally sustainable technique for the preservation of food, medicinal plants, and other natural resources. In Solar drying system, mainly three types of analysis can be performed: (1) thermal performance, (2) economic analysis, and (3) environmental analysis (sustainable analysis). Therefore, this comprehensive review paper mainly aims to evaluate the benefits of environmental analysis of various types of solar drying systems. Different equations related to environmental analysis of solar drying systems are presented. This study evaluates the reduction in carbon dioxide (CO_2) emission, carbon mitigation strategies, and the environmental benefits of transitioning from conventional drying methods to solar drying systems. The review points out that solar dryers greatly minimize greenhouse gas emissions as they replace electricity or fuel-powered drying. They also assist in decreasing post-harvest losses, enhancing food security, and minimizing environmental pollution. The scope of these systems to be used in carbon credit generation and the adoption of circular economy principles is touched upon. Furthermore, the economic benefits of carbon credits are analysed in order to bring forth the extra benefits of employing solar drying techniques. These results promote solar drying as an eco-efficient technology that works towards global climate objectives as well as clean and sustainable food processing techniques.

Keywords: Solar Dryer, Solar energy, CO_2 emission, Carbon mitigation, Carbon Credit.

Nomenclture

AISD Active indirect solar dryer
EE Embodied energy
EI Environmental impact
EPBT Energy Payback Time
GHG Greenhouse gas
GSD Greenhouse solar dryer
HPD Heat pump dryer
HSD Hybrid solar dryer
ISD Indirect solar dryer
PISD Passive indirect solar dryer
PVT Photovoltaic Thermal

Symbols

E_{aout} annual energy output (kWh/ yr)
E_{in} embodied energy (kWh)
L life time in years

I INTRODUCTION

Solar drying systems have emerged as a viable alternative to conventional drying techniques in various industries, including agriculture, food processing, and textiles. [1] Traditional drying methods often rely on fossil fuels, contributing to high energy consumption and significant greenhouse gas emissions, particularly CO_2. [2] This growing environmental concern has motivated the exploration of renewable energy-based solutions such as solar drying, which offers a sustainable way to preserve agricultural products, reduce energy usage, and mitigate climate change. [3]

Solar drying systems use solar energy as a clean and renewable source of energy to dry products. Solar dryers differ from conventional methods, where there is the emission of carbon through the combustion of fossil fuels. Solar dryers minimize the environmental aspect of the drying process. [4] Solar dryers can also produce carbon credits, providing financial benefits for lessening greenhouse gas emissions.

This paper would seek to analyse the environmental aspects of different solar drying systems, including energy conservation, reduction of CO_2 emissions, and carbon credit earning possibilities. It would attempt to offer an in-depth analysis of how different solar drying technologies can help achieve sustainability objectives across different industries, and eventually reduce climate change and encourage green practices.

(a) Types of Solar Dryers

Solar dryers are devices that utilize solar energy to dry food, marine, & agricultural crops, thus enhancing their quality and storage life. Solar dryers are broadly classified into three categories: direct, indirect, and mixed-mode solar dryers. Fig. 1 shows classification of solar dryer. In direct solar dryers, the products are exposed in an enclosed chamber with transparent lids, where they are exposed to direct sunlight. This technique is straightforward but can expose products to too much heat and UV radiation. Indirect solar dryers isolate the process of heating from the drying chamber [5]. Solar energy is used to heat air in a collector, and hot air flows through the chamber, not exposing products to direct sunlight but providing superior temperature control. Mixed-mode solar dryers incorporate both approaches by subjecting products to heat from direct sunlight as well as hot air from a solar collector. Solar dryers may also be used in passive or active mode, based on airflow systems. They present a sustainable, cost-effective answer to food preservation and post-harvest loss minimization [6].

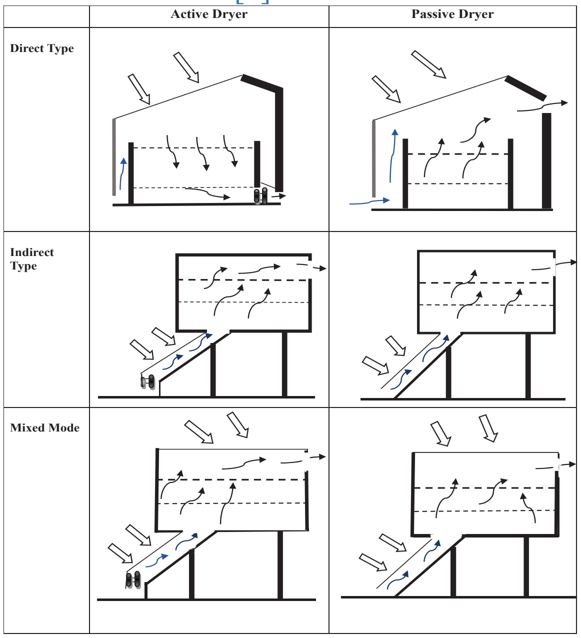

Fig. 1: Classification of Solar Dryer

II ENVIRONMENTAL ANALYSIS PARAMETERS

The assessment of the environmental impact (EI) of solar drying systems includes the following key parameters: [7]

(a) Embodied energy (EE): The cumulative energy necessary for the production, transportation, & maintenance of a dryer across its whole existence. For solar drying systems, it includes energy used in manufacturing components, transportation, installation, maintenance, and eventual disposal. It helps assess the full EI of the system beyond its operational energy savings. Fig. 2 shows the EE distribution. [8]

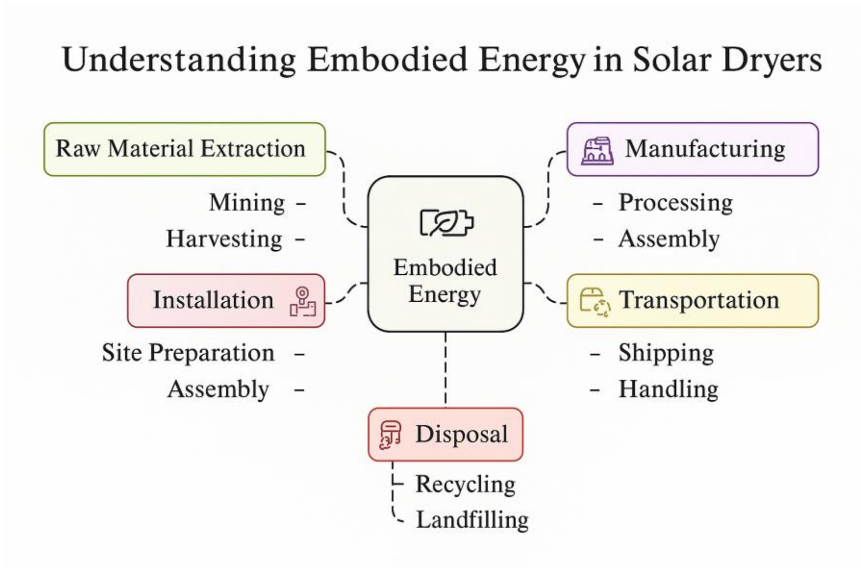

Fig. 2: Detail of Embodied Energy

(b) Energy Payback Time (EPBT): This measures the time it takings for the energy savings from a solar drying system to equal the energy invested in its construction and operation. The formula used to calculate EPBT is: [9, 10, 11]

$$EPBT = \frac{Embodied\ energy\ (kWh)}{Annual\ energy\ output\ (\frac{kWh}{yr})} \quad (1)$$

(c) CO_2 Emissions Reduction: This parameter quantifies the decrease in CO_2 emissions resulting from the switch to solar drying. The reduction is calculated by comparison of CO_2 emissions by traditional drying methods with those of solar drying systems. The general formula for calculating CO_2 savings is: [9, 10, 11]

$$CO_2Emission/year = \frac{Embodied\ energy\ (kWh) \times 2.042\ kg}{Life\ time\ (yr)} \quad (2)$$

(d) Carbon Mitigation: Solar dryers provide climate change mitigation by decreasing GHG. The potential for carbon mitigation is estimated by assessing the energy saved and CO_2 emissions avoided through the adoption of solar drying systems. [9, 10,11]

$$CO_2Mitigation = (E_{aout} \times L - E_{in}) \times 2.042\ kg \quad (3)$$

The value 2.042 is the value of total loss, due to domestic appliances losses, and transmission losses.

Where, E_{aout} = annual energy output (kWh/ yr)

E_{in} = embodied energy (kWh)

L = life time in years

(e) Carbon Credits Earned: Carbon credits are earned by reducing emissions below a baseline level. The calculation of carbon credits is based on the amount of CO_2 saved: [9, 10, 11]

$$Earned\ Carbon\ Credit = net\ mitigation\ of\ CO_2 in\ life\ time \times Price\ per\ ton\ of\ CO_2\ mitigation \quad (4)$$

III ENVIRONMENTAL STUDY ON VARIOUS TYPE OF SOLAR DRYER

To provide a clearer understanding of the several studies on solar drying systems and their environmental implications, the following table summarizes key research findings on CO_2 emission reductions, energy savings, and carbon credits. These studies help demonstrate the possibilities of solar dryers in reducing EI across different applications. Table 1 shows some literature related to environmental analysis.

Table 1
Literature review on environmental assessment of solar dryer

Solar Dryer Type	Year	Drying Product	Findings	Ref.
Hybrid photovoltaic/thermal (PV/T) greenhouse dryer	2008	----	The dryer earns approximately Rs. 46,853 in carbon credits over its 30-year lifespan. The EPBT is about 3-5 years, indicating efficient energy recovery relative to its 30-year life.	[12]
Heat pump dryer (HPD)	2013	----	This system exhibit 20.4–34.1% lower GHG emissions compared to conventional HPD systems, depending on the electricity generation resources used. Integrating solar thermal systems adds an additional 32 g CO_2/kWh due to their lifecycle impacts.	[13]
PVT mixed- mode GSD	2016	----	EPBT for solar dryer found to be 1.23 years & 10 years respectively; these less than those of other current systems based on energy and exergy respectively. Environment sustainability benefits from CO_2 reducing and carbon credit earning for 25 years of solar dryers found to be 81.75 tons & $817.50 respectively.	[14]
Direct & indirect solar dryer	2017	----	17.6% reduction in the per unit cost of fossil fuel-generated electricity when utilizing solar drying systems, highlighting the economic benefits of adopting solar energy for drying processes. A net mitigation of CO_2 emissions amounting to 38.06 tons/ year for the solar dryer, with	[15]

			potential carbon credits earned ranging from INR 12,561.70 to 50,245.49.	
Greenhouse solar dryer (GSD)	2018	Coconut	A passive GSD coupled with a back-up biomass heater with a mean thermal efficiency of 24%, the dryer conserved 64% of drying time in summer and 70% in winter. The energy study of the drier found low CO_2 emissions of 1518 kg year, EE of 18,302 kWh, and net CO_2 mitigating effect of 678 tons. It also picked up a $18,645 carbon credit.	[16]
North wall insulated GSD	2018	Bitter gourd slice	The EPBT of dryer is 2.35 years, while its passive mode has a 1.68-year payback. These systems are more eco-friendly than solar drying systems.	[17]
Hybrid solar-electrical dryer	2021	Wood	The implementation of a PVT air collector in traditional wood dryers can substantially decrease energy usage, achieving savings of 86.5% in summer and 73.5% in winter, while also drastically lowering CO_2 emissions by 78.5%.	[18]
Indirect Solar Dryer	2022	Cocoa bean	The solar drying of cocoa beans demonstrates that achieving equilibrium moisture content through natural convection drying is challenging under certain climatic conditions. The integration of induced & passive mode during the night yields a final moisture content of 0.15 kg/kg after 32 hours. The solar dryer reduces CO_2 emissions by 15 to 25 grams per kilogram of evaporated water, with a EPBT of 2.19 years.	[19]
Active & Passive ISD	2022	Guava Slices	Over the operational lifespan of the dryer, which spans from 5 to 35 years, the CO_2 mitigation and total carbon credits generated ranged from 4.23 to 36.02 tons & $84.55 to $720.43 in PMISD. In AMISD, these figures were 4.29 to 41.05 tons & $85.78 to $820.90, respectively. The environmental analysis revealed an increase in CO_2 levels in AMISD; however, CO_2 emissions were mitigated, and the carbon credits obtained were reduced in PMISD.	[20]
Solar dryer	2023	Tomato slices	The HPD system exhibited the shortest EPBT at 2.98 years, positioning it as the most viable option in comparison to the SD & SCD systems. The measured CO_2 emissions were 36.6 kg/year, 100.05 kg/year, & 43.68	[21]

			kg/year, while the net CO_2 mitigation achieved was 9.21, 25.18, & 10.99 ton/year for the SD, SCD, & HPD Systems, respectively. The HPD system was regarded as superior and environmentally sustainable because of its minimal electricity costs associated with operating the heat pump.	
Indirect Solar Dryer	2023	Wheat seeds	The EPBT for solar dryers is 1.35 years, which is relatively short. The lifespan of a solar dryer ranges from 5 to 25 years, with annual CO_2 emissions identified as 36.63 to 7.32 kg and the CO_2 mitigation effect quantified between 1.03 and 6.67 tons. Over the 25-year lifespan of the dryer, the total carbon credit accrued for trading at $80 per credit will amount to Rs. 40,029.37.	[22]
Indirect Solar dryer with PVT operated tracking	2024	Tomato slices	The solar dryer emitted 137.11 tons of CO_2, with CO_2 mitigation over its lifespan amounting to 5334.9, 5822.8, & 6795.4 tons for FCM, and 6323.3, 6305.7, & 7366.9 tons for TCM. The solar dryer combined with FCM and TCM achieved minimum carbon credits of 26,674, 29,114, & 33,977 dollars, as well as 31,616, 31,528, & 36,834 dollars respectively.	[23]
GSD	2024	Medicinal Ocimum sanctum leaves (Tulsi leaves)	By 50%-60%, the GSD drastically lowers drying time; it improves the quality of Ocimum sanctum leaves; and it provides an EPBT of 0.78 years, so defining a sustainable and affordable way to preserve medicinal herbs.	[24]
PVT Solar dryer	2025	Habanero chili	The investment costs for Solar Mode (SM), Hybrid Mode (HM), and Conventional Mode (CM) configuration equipment were calculated at USD 6560.16, USD 9595.90, and USD 4961.20. Using solar energy SM and HM save 26,258.70 USD and 6717.74 USD, respectively, in 20 years. For the SM, HM, and CM modes, the EE and EPBT were estimated at 15935.03 kWh (1.22 years), 16312.29 (1.25 years), and 3186.88 kWh.	[25]
Solar -Biomass Hybrid Solar dryer	2025	Eryngium Foetidum	Emissions and mitigation of CO2 ranged from 511 to 128.5 kg annually and 9.86 to 47.61 tons, respectively. The EPBT was 1.02 years. Over a 20-year period, the projected carbon credits for the suggested model ranged from 238.8 to 955.2 USD.	[26]

IV RESULTS AND DISCUSSION

Solar dryers, particularly hybrid models, can significantly reduce CO_2 emissions and energy consumption in food processing. By implementing thermal energy storage, these systems enhance energy efficiency and decrease CO_2 emissions. Different designs earn higher carbon credits due to efficiency and lower waste emissions. Solar drying systems also generate carbon credits, providing financial returns and promoting sustainable agricultural practices. The economic analysis shows favourable payback periods for some systems, and their efficiency in various environmental conditions can improve stakeholder livelihoods.

V CONCLUSION

Solar dryers play a crucial role in carbon mitigation by replacing energy-intensive, fossil fuel-based drying methods with renewable solar energy. This transition directly reduces CO_2 emissions, significantly lowering the carbon footprint of industries like agriculture, food processing, and textiles. By minimizing reliance on electricity and fossil fuels, solar dryers align with global efforts to mitigate climate change. Adopting solar drying systems also offers financial incentives through carbon credits, making them a practical choice for businesses aiming to meet sustainability goals. As a key strategy for carbon mitigation, solar dryers support a greener future while reducing EI.

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Soil Fertility Mapping of Macro and Micro Nutrients in Adopted Village of Hazaribag (Jharkhand) and distribution of Soil Health Card

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ABSTRACT
This study was carried out in village Tarwa, Maheshra, Harli, Dandai and Kawalu of Hutpa, Jinga, Harli, Amnariand Ramdeokharika Panchayatof Hazaribag district of Jharkhand to know the fertility status of land of fifty farmers of each village towards soil testing. It is well known to us that the soil testing is an important measure about soil health and to avoid excess use of fertilizer. The excess use of fertilizers is harmful for soil and also effect the pocket of the farmers. So, in this age soil testing and distribution of soil health card is important among the farmers of adopted village of Hazaribag district because maximum number of small and marginal farmers found in this area. The AISECT University, Hazaribag, the Department of Agriculture always encourage farmers to apply recommended doze of fertilizer on the basis of Soil Health Card recommendation to protect soil health and healthy crop production.

Keywords: - Soil fertility, Soil testing, Soil health, Fertilizer usage, Soil Health Card

I INTRODUCTION

Soil analysis is important tool for determines the exact input required for efficient and economical production to meet the needs of the society. It is important that soil sampling technique is correct the result of fertility status will correct. The ideal time of soil sampling is after harvesting of the crops. Fertility refers to the soil ability to supply essential nutrients to plant in adequate amounts and proper balance. It has been already observed that nutrients depletion due to intensive cultivation, chemical use and proper management practice has rendered large tracts of agriculture land deficient in both macro (N, P, K) and micro (Zn,Fe,Mn,Cu,B) nutrients.

To address this, the Government of India launched Soil Health Card Scheme in 2015. This scheme under National Mission for Sustainable Agriculture (NMSA). The Soil Health Card Gives the information about the soil nutrient status of crop fields and advice on optimum doze of fertilizer for different crop along with soil amendment to maintain soil health in long run. Soil Health Care prepared based on the soil test result for which the soil samples are collected. This research leverage SHC data to generate soil fertility map and offering a detail understanding of nutrient variability.

II METHODOLOGY

(a) **Collection and preparation of soil samples:** For present study, high surface (0- 15 cm) soil samples were collected from farmer's field in all adopted village of Hazaribag. Representatives soil samples were collected by using khurpi, placed in properly labeled polythene bags and transported to soil testing laboratory, where they were air – dried, crushed and sieved a 2mm plastic sieve. The details of soil samples from different villages are mentioned in table no. 1.

III OBSERVATION

pH: The pH was determined by using electrode in 1:2 soil water suspension, following method by Piper (1967).

(a) Electrical Conductivity: The soil water suspension used for pH determination was allowed to settle and measured by conductivity meter.

(b) Organic Carbon: Organic Carbon content was estimated by using Walkely & Black method (1934).

(c) Available Nitrogen: Available Nitrogen was determined by alkaline permanganate method (Subbiah & Asija, 1956) by the help of semi-automatic Kjeldahal Nitrogen Analyzer Distillation Apparatus.

(d) Available Phosphorus: Available Phosphorus was determined by Bray method (1945) by the help of Spectro photo meter.

(e) Available Potassium: Available Potassium in soil determined by flame photometer.

Available Zinc, Iron Copper, Manganese: Available Zinc, Iron Copper, Manganese was determined (DTPA - Extractable) with Atomic Absorption Spectro Meter.
Available Sulphur: Available Sulphur was determined by Turbidimetric Method.

Table 1
Details of soil samples collected from adopted villages

S.No.	Village Name	No. of soil sample collected
1	Tarwa	50
2	Maheshra	50
3	Harli	50
4	Dandai	50
5	Kawalu	50
Grand Total		250

Table 2
Limits of different nutrients for classification

S.No.	Constituents	Limit for different Categories		
		Low	Medium	High
1	Av.N(Kg/ha)	<250	250-500	>500
2	Av.P(Kg/ha)	<25	25-50	>50
3	Av.K(Kg/ha)	<125	125-300	>300
4	Organic Carbon %	<0.5	0.5-0.75	>0.75
		Normal	Critical	Above Critical
5	pH	6.5-7.5	7.5-8.5	>8.5
6	E.C (dS/m)	<0.5	0.5-1.0	>1.0
		Deficient		Sufficient
7	Sulphur (PPM)	<10		>10
	Av. Micro Nutrient	Deficient		Sufficient
8	Zinc	<0.78		>0.78
9	Boron	<0.50		>0.50
10	Fe	<7.0		>7.0
11	Cu	<0.60		>0.60
12	Mn	<3.0		>3.0

IV CONCLUSION

The study highlights the critical need for promoting soil testing and the distribution of Soil Health Cards among farmers in the adopted villages of Hazaribag district. With a predominance of small and marginal farmers in the region, proper nutrient management based on scientific analysis is essential for sustainable agriculture. The findings reaffirm that awareness and implementation of soil health practices not only improve crop productivity but also help in conserving soil fertility and reducing the economic burden on farmers caused by indiscriminate fertilizer use. Institutions like AISECT University and the Department of Agriculture play a vital role in educating farmers and ensuring that soil health-based farming becomes a foundation for long-term agricultural sustainability in Jharkhand.

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The Role of Spirituality in Positive Youth Development: Implications for Pharmaceutical Sciences

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ABSTRACT
This review explores the correlation of spirituality and pharmaceutical science in fostering positive youth development (PYD). As spirituality enhances mental well-being, helps you to find meaning and purpose of life, provide connection with surrounding, experiencing sympathy and apathy for others, inner calm, peace and ethical values, pharmaceutical chemistry focuses on physiological health through drug discovery from plants and isolating it to create new medicinal drug and its formulation, its quality testing, its production through environmentally healthy way through Green Chemistry (GC) synthesis and therapy. Integrating these disciplines offers a holistic approach to youth health, emphasizing mental, emotional, and physical well-being. This paper reviews existing literature, highlighting the biological impacts of spiritual practices, their role in medication compliance, stress reduction, and ethical considerations in pharmaceutical research.

Keywords: Positive Youth Development (PYD), Green Chemistry (GC), Hypothalamic-pituitary-adrenal(HPA)

I INTRODUCTION

Positive youth development (PYD) emphasizes the cultivation of skills, positive relationships competencies, and values that empower youth to reach up to their full potential by building self-confidence among young individuals to thrive. Spirituality, defined as the search for meaning, purpose, and connection of life has emerged as a critical factor in mental and emotional health. Simultaneously, pharmaceutical chemistry contributes significantly to physical health through drug designing that how a drug formulates and what the mode of action and its efficacy. Understanding the symbiosis between these fields can lead to comprehensive strategies for youth development. Positive Youth development emphasizes on 6 C (Competence, Confidence, Connection, Character, Caring, Contribution.)

II LITERATURE REVIEW

(a) **Spirituality and Mental Health** - Research indicates that spiritual practices such as mindfulness, meditation, and prayer can significantly reduce symptoms of anxiety, depression, and stress among youth it acts as coping mechanism for mental health. (Smith et al., 2020). These practices promote emotional regulation, emotional intelligence improve ability to manage emotions, and resilience, essential components of PYD.

(b) **Biological Impact of Spiritual Practices** - Spiritual practices influence the hypothalamic-pituitary-adrenal (HPA) axis, reducing cortisol levels and mitigating stress-related health issues, improved immune system, lowered blood pressure reduces risk of cardiovascular disease by providing relaxation, decrease anxiety and depression and increase pain tolerance by promoting a focused mindset and positive coping mechanism. (Johnson & Lee, 2019). Neuroimaging studies have shown that meditation enhances brain regions associated with attention, self-awareness, and emotional regulation. For example, substances like psilocybin (found in certain mushrooms) have been researched for their potential to induce profound spiritual experiences that may have therapeutic benefits for mental health.

(c) Pharmaceutical Chemistry and Youth Health- As advancement and research in pharmaceutical chemistry led to development of new drugs and therapies that improve the quality of life in rare disease condition, genetic disorders and autoimmune disease pharmaceutical chemistry play a significant role in combating substance abuse which is challenge among youths for addiction treatment, cure to opioid dependence and Narcotics managing mental health disorders, among youth. However, medication adherence remains a challenge, Anti-depressants, and Anti-Anxiety medication and Psychotropic medications this treatment along with spirituality and psychological support can manage emotional state and often influenced by psychological and social factors.

III DISCUSSION

(a) Enhancing Medication Adherence Through Spirituality - Youth engaged in spiritual practices exhibit higher self-discipline and purpose, improving adherence to medical regimens. Studies suggest that integrating spiritual counselling with pharmaceutical care enhances treatment outcomes (Garcia et al., 2021).

(b) Stress Reduction and Complementary Therapies - Combining pharmacological treatments with mindfulness-based stress reduction (MBSR) programs has shown promising results in managing anxiety and depression, reducing the need for high-dose medications (Brown et al., 2018).

(c) Moral Decision-Making in Pharmaceutical Science - Spirituality fosters ethical values crucial for young professionals in pharmaceutical research and practice. Ethical frameworks rooted in compassion, integrity, and social responsibility can guide drug development and patient care. A pharmacist respects the autonomy and dignity of each patient and promotes the right of self-determination and recognizes individual self-worth by encouraging patients to participate in decisions about their health.

IV IMPLICATIONS FOR RESEARCH AND PRACTICE

(a) Interdisciplinary Programs and Clinical Trials: Developing educational programs that integrate spirituality and pharmaceutical science can promote holistic youth development. Further research is needed to explore the efficacy of combining spiritual practices with pharmacological treatments such as spirituality practices like yoga and meditation helps to influence neurotransmitters in brain and increase happy hormones and regulating mood swings, Different cultures and religion performs different spiritual practices example: In Hinduism, practices such as puja (worship), mantra recitation, and yoga are common. In Buddhism, meditation, chanting, and mindfulness practices are commonly practiced. In Christianity, prayer, communion, and Bible study are important practices.

V CONCLUSION

Integrating spirituality with pharmaceutical sciences provides a holistic framework for positive youth development. By addressing mental, emotional, and physical health, this approach can enhance adaptability, moral decision-making, empathy, self-regulation, and overall well-being in young individuals.

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From Lab to Landscape: The Role of Analytical Chemistry in Modern Ecology

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ABSTRACT
Analytical chemistry plays a critical role in advancing ecological research by providing powerful tools for identifying, quantifying, and understanding environmental processes at molecular, chemical, and ecological scales. This paper explores the applications of analytical chemistry in modern ecology, focusing on environmental monitoring, pollution detection, soil and water chemistry, and biogeochemical cycles. The integration of advanced techniques such as chromatography, spectroscopy, and mass spectrometry enables a more nuanced understanding of the interactions between chemical substances and ecological systems, contributing to better environmental management and sustainability.

Keywords: Analytical chemistry, environmental monitoring, pollution detection, soil chemistry, water chemistry, biogeochemical cycles, mass spectrometry, chromatography, ecological systems.

I INTRODUCTION

Modern ecology, at its core, investigates the intricate relationships between organisms and their environments. As environmental challenges grow in complexity, understanding the chemical underpinnings of ecological processes is crucial. Analytical chemistry, the science of identifying and quantifying chemical substances, has emerged as a key tool in ecological research. It allows scientists to monitor pollutants, study nutrient cycles, assess biodiversity, and track the effects of climate change. By linking laboratory techniques with real-world ecological data, analytical chemistry provides an essential bridge between theory and application in environmental science.

II THE ROLE OF ANALYTICAL CHEMISTRY IN ECOLOGICAL RESEARCH

Analytical chemistry has various applications in ecology, ranging from **monitoring environmental contaminants** to understanding the **chemical dynamics of ecosystems**. Below, we explore some of the most relevant contributions of analytical chemistry to modern ecological studies:

(a) Environmental Pollution and Toxicology
Environmental pollution, particularly through chemical contaminants, poses significant risks to ecosystems and human health. Analytical chemistry allows researchers to:

- **Identify contaminants** such as heavy metals (e.g., lead, mercury), pesticides, and pharmaceutical residues in air, water, and soil.
- **Quantify concentrations** of pollutants to assess the level of contamination and predict the impact on flora and fauna.
- **Monitor toxicological effects**, such as bioaccumulation in organisms and ecosystems, using chemical markers and biomarkers.

Techniques like **gas chromatography-mass spectrometry (GC-MS)** and **high-performance liquid chromatography (HPLC)** are essential in detecting trace contaminants, even at minute concentrations.

(b) Soil and Water Chemistry

Soil and water are critical components of terrestrial ecosystems, and their chemical composition directly influences the health of the environment. Analytical chemistry provides insights into:

- **Nutrient cycling** in soils, such as nitrogen, phosphorus, and carbon, which are essential for plant growth and ecosystem productivity.
- **Soil quality assessment**, including testing for acidity (pH), salinity, and the presence of toxins that might affect plant and microbial life.
- **Water quality monitoring**, including the analysis of dissolved oxygen, turbidity, and contaminants such as nitrates, phosphates, and heavy metals.

Using **ion chromatography** and **atomic absorption spectroscopy (AAS)**, scientists can measure the concentration of ions and trace metals in soil and water samples to assess ecosystem health.

(c) Biodiversity and Ecological Health

Understanding biodiversity and ecological health requires analyzing the chemical composition of various species and their habitats. Analytical chemistry aids in:

- **Examining biochemical markers** in plants and animals to track health, stress responses, and species interactions.
- **Studying ecosystem shifts** caused by environmental stressors, such as pollution or climate change, by analyzing changes in chemical signatures in ecosystems.

Mass spectrometry and **NMR spectroscopy** are used to detect and quantify the molecular compounds produced by organisms, which provide insights into their interactions within ecosystems.

(d) Climate Change and Greenhouse Gases

Analytical chemistry is critical for understanding the **role of greenhouse gases (GHGs)**, such as carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O), in driving climate change. The monitoring of these gases in ecosystems helps:

- **Track atmospheric concentrations** of GHGs, which are pivotal for understanding global warming.
- **Study soil carbon sequestration** and the role of forests and wetlands in mitigating climate change.

Advanced techniques like **gas chromatography (GC)** and **Fourier-transform infrared spectroscopy (FTIR)** are used to measure atmospheric gases, enabling scientists to track emissions and assess the effectiveness of carbon-capture initiatives.

III TECHNIQUES OF ANALYTICAL CHEMISTRY IN ECOLOGY

Modern analytical chemistry utilizes several sophisticated techniques to enhance ecological research. These include:

- **Chromatography (GC, HPLC, Ion Chromatography)**: Techniques for separating and analyzing complex mixtures of compounds in environmental samples.
- **Mass Spectrometry (MS)**: Used to identify and quantify chemical compounds in various media (air, water, soil, organisms).
- **Spectroscopy (UV-Vis, FTIR, NMR)**: Methods for analyzing chemical bonds, structures, and concentrations of compounds in ecological samples.

- **Atomic Absorption Spectroscopy (AAS)**: A technique for detecting and quantifying metal concentrations in soil and water samples.
- **Isotope Ratio Mass Spectrometry (IRMS)**: Used for studying biogeochemical cycles, including nitrogen and carbon isotopes, to track nutrient flow in ecosystems.

These techniques allow for high-resolution analysis of environmental samples, enabling the detection of both common and trace chemicals that influence ecological systems.

IV BRIDGING THE GAP BETWEEN LAB AND LANDSCAPE

While laboratory techniques provide critical data, their real-world applicability hinges on effective **field sampling** and **data integration**. The challenge lies in translating **laboratory results** into meaningful **landscape-scale** insights. This is achieved through:

- **Field-based chemical sampling**, which collects data from diverse ecosystems, ensuring the data is representative of real-world conditions.
- **Geospatial analysis** that integrates chemical data with environmental variables (e.g., land use, climate data) to better understand the complex relationships in ecosystems.
- **Modeling ecological processes** using chemical data to simulate nutrient cycling, pollutant dispersion, and climate change scenarios at larger scales.

V CHALLENGES AND FUTURE DIRECTIONS

While analytical chemistry offers powerful tools for ecological research, there are several challenges that need to be addressed:

- **Sampling limitations**: Ecological systems are highly heterogeneous, and obtaining representative samples can be challenging.
- **Cost and accessibility**: Advanced analytical techniques can be expensive and may not be accessible in all regions, limiting global collaboration.
- **Data integration**: Combining chemical data with ecological models requires sophisticated computational tools and interdisciplinary expertise.

The future of analytical chemistry in ecology lies in **advancements in sensor technology**, **portable field equipment**, and **automated data collection** systems. Additionally, the increasing integration of **artificial intelligence (AI)** and **machine learning (ML)** in data analysis will enable more efficient processing of large datasets and better predictions of ecological changes.

VI CONCLUSION

Analytical chemistry is essential for modern ecological research, offering invaluable insights into environmental health, pollution control, and ecosystem dynamics. By linking laboratory analysis with field data, scientists are now able to make more informed decisions about environmental conservation and sustainability. The integration of advanced analytical techniques in ecology not only enhances our understanding of environmental processes but also enables the development of innovative solutions to tackle pressing global challenges like climate change and biodiversity loss. As technology evolves, the role of analytical chemistry in shaping the future of ecological science will only continue to grow, offering new avenues for preserving and protecting our planet.

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