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2 Day National Level Seminar

Organized by

Department of Environmental Science

MSS's Arts, Science & Commerce College, Ambad, Dist. Jalna
(Maharashtra-India)

Held on 2-3 January 2026



Role of Artificial Intelligence in Sustainable Development & Environmental Challenges

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Published At

Plot No. 163, Shivaji Nagar, Mhada Colony,
Ambad Choufully, Jalna-431203 (Maharashtra-India)

Printed by

Mandar Offset & Printers,
Plot No. 43, Vrundavan Colony, Kacheri Road, Old Jalna,
Dist. Jalna-431203 (Maharashtra-India)

Special Issue Price: 400/-



Knowledge Flame is a Bi-Monthly, online and print, multilingual, multidisciplinary research journal from Jalna, Maharashtra (India). This academic journal publishes in Marathi, Hindi, and English. Its mission is to foster a healthy society by encouraging young researchers to conduct creative studies. The current publication has accomplished the goal of giving scholars a forum to voice their opinions by consistently introducing fresh concepts. Through publications, an effective effort is being made to expand knowledge by integrating a variety of topics related to social science, trade, commerce, science, and technology, as well as rural-urban civilization.

Journal particulars	
ISSN	3049-1541
Frequency	Bi-Monthly
Impact Factor	5.292
Editor in Chief	Dr. Ram Raunekar Professor & Head, Department of Marathi, MSS, Arts, Science & Commerce College, Ambad, Dist. Jalna, Maharashtra (India). dr.rbraunekar@mssambad.org , ramraunekar@gmail.com Mo. No. 9420221498
Editor	Mr. Krushna A. Nagwe Assistant Professor, Department of History, MSS, Arts, Science & Commerce College, Ambad Dist. Jalna, Maharashtra-India. knagwe@mssambad.org kanagwe@gmail.com 9923069260, 9309773762
Starting year	2024
Subject	Multidisciplinary Subject
Language	Multiple languages- English, Hindi, Marathi
Publication format	Online / Print
PRGI Reg. No.	MAHMUL/2024/89852
Mobile No.	9923069260, 9309773762
Publisher	Mr. Krushna A. Nagwe
E-mail	knagwe@mssambad.org kanagwe@gmail.com
Publication Address	Plot No. 163, Shivaji Nagar, Mhada Colony, Ambad Choufully, Jalna-431203.
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Editorial Message

The **Department of Environmental Science**, represents a landmark exploration into the **Role of Artificial Intelligence in Sustainable Development and Environmental Challenges**. As we stand at a global crossroads, the research compiled here demonstrates that the intersection of digital innovation and ecological stewardship is no longer a luxury, but a necessity. By leveraging Artificial Intelligence (AI), we are moving from traditional, reactive conservation methods toward proactive, data-driven solutions. From harnessing AI for precision plant identification and forest fire buffer zone mapping to developing complex mathematical frameworks for predictive modeling, these papers illustrate a future where technology acts as a powerful ally to nature.

While the focus is on cutting-edge innovation, this collection remains firmly anchored in the essential bedrock of empirical biological research. The transition to a "smart" environment is only possible through the rigorous field studies presented here—such as the phytoremediation of wastewater using *Lemna minor*, air quality assessments in Chhatrapati Sambhajnagar, and biodiversity surveys across the Jalna district. By combining the "brain" of AI with the "heart" of environmental chemistry and field biology, we ensure that our industrial growth and urban expansion remain within the safe boundaries of our ecosystem.

The significance of this subject extends deeply into the fabric of society and human life. For the general public, the integration of AI in environmental monitoring leads to direct benefits such as cleaner air, safer water, and enhanced public health through early-warning systems for pollutants. Furthermore, the inclusion of multidisciplinary studies—ranging from the legal accountability of AI to its role in mental health and the preservation of historical heritage—ensures that our technological journey is ethical, culturally sensitive, and human-centric.

For **students and researchers**, this volume opens a new frontier of professional growth. Students are equipped with "future-ready" skills that blend environmental science with digital literacy, preparing them for a modern workforce that demands cross-disciplinary expertise. For researchers, AI offers high-precision tools to process massive datasets and model complex environmental economics, bridging the gap between scientific discovery and government policy. Ultimately, this editorial collection serves as a call to action for all stakeholders to embrace a future where technology, law, and environmental ethics operate in total harmony for the benefit of all living beings.

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In

Volume- 03, Issue- 02 (Special Issue)

January- 2026



WRC-ICSSR

Sponsored

**2 - Day National Level
Seminar**

Organized by

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Held on 2-3 January 2026

Theme of the Seminar

**Role of Artificial Intelligence in Sustainable
Development & Environmental Challenges**



Harnessing the Power of Artificial Intelligence for Environmental Protection and Conservation

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Abstract:

Our planet is currently confronted with interconnected crises, including climate change, biodiversity loss, and pollution. Although human activity is the main contributor, Artificial Intelligence (AI) presents transformative potential as a means to understand, mitigate, and adapt to these intricate threats. This article delves into the diverse applications of AI in environmental protection, highlighting its role in the precise monitoring of ecosystems, optimizing renewable energy sources, combating wildlife crime, and managing pollution levels. It investigates AI's ability to analyze extensive and varied datasets—from satellite imagery to acoustic sensors—and convert them into actionable insights for conservationists, policymakers, and communities. Nevertheless, the implementation of AI is accompanied by significant ethical and practical challenges, such as its own carbon footprint, data inequities, algorithmic bias, and surveillance risks. The article posits that a responsible way forward necessitates a framework of "Ecological AI," a principled approach that emphasizes transparency, equity, sustainability, and collaboration between humans and AI. By leveraging AI's analytical capabilities within this ethical framework, we can expedite the transition to a more resilient and sustainable relationship with the natural environment, transforming data into decisive actions for the health of our planet.

Keywords: Artificial Intelligence, Environmental Monitoring, Conservation Technology, Climate Change Mitigation, Sustainable Development

1. Introduction: At the Intersection of Crisis and Innovation:

The 21st century presents a significant paradox: human creativity has facilitated extraordinary technological advancements, yet this progress, historically reliant on extractive and polluting industrial practices, has driven Earth's natural systems to critical limits. Climate change, accelerated biodiversity loss, ocean acidification, and widespread pollution are interlinked crises that require solutions of comparable scale, complexity, and ingenuity. Conventional approaches to environmental science and policy, while essential, are frequently hindered by data limitations, delayed analyses, and the vastness of the systems involved.

Enter Artificial Intelligence (AI). More than just a technological trend, AI—encompassing machine learning (ML), computer vision, natural language processing, and robotics—signifies a paradigm shift in our ability to perceive, interpret, and respond to information regarding our planet. At its essence, AI excels at identifying subtle patterns within



extensive, noisy datasets, making predictions from incomplete data, and automating intricate analytical tasks. From the microscopic examination of soil microbiomes to the macroscopic monitoring of atmospheric rivers, AI is emerging as an essential partner in the pursuit of environmental sustainability.

This article explores the transformative potential of AI across the range of environmental protection and conservation efforts. It goes beyond a mere listing of applications to investigate the underlying mechanisms, present real-world implementations, and, importantly, scrutinize the significant ethical and practical challenges that accompany this technological frontier. The central argument is that AI, when developed and utilized within a strong framework of ecological ethics and social equity, can be leveraged as a powerful force for planetary stewardship. It facilitates a crucial transition from passive observation to intelligent, timely, and effective action.

2. The Analytical Engine: Understanding How AI Interprets the Earth's Pulse:

To fully grasp the environmental applications of AI, it is essential to first comprehend its core capabilities. Environmental data is defined by the "4 Vs": Volume (terabytes of satellite images produced each day), Variety (including spectral bands, acoustic frequencies, genomic sequences, and text from social media), Velocity (real-time data from sensor networks), and Veracity (the differing quality and inherent noise). Conventional analytical techniques often find it challenging to cope with this overwhelming influx.

a. Machine Learning & Pattern Recognition:

Supervised machine learning algorithms, which are trained on labeled datasets (for instance, images depicting healthy versus bleached coral), are capable of accurately classifying new, previously unseen data. Unsupervised learning techniques reveal hidden clusters and relationships, such as identifying new animal behavioral patterns through movement telemetry. Reinforcement learning allows systems, such as a smart electrical grid, to discover optimal operational behaviors via iterative trial and error.

b. Computer Vision:

This area of study enables machines to 'see' and interpret visual information. By examining pixel-level data from drones, camera traps, and satellites, artificial intelligence can execute tasks like counting individual animals within a migrating herd, identifying tree species based on canopy structure, detecting the distinctive geometric scars indicative of illegal logging in forests, or identifying accumulations of plastic waste in river systems.

c. Natural Language Processing (NLP):

NLP has the capability to analyze millions of scientific articles, news reports, and social media content to monitor emerging environmental threats, assess public sentiment regarding conservation policies, or reveal patterns of illegal wildlife trade in online marketplaces.

d. Predictive Modeling: Sophisticated AI models, including deep neural networks, are adept at forecasting the behavior of complex, non-linear systems. They are employed to predict hurricane paths with enhanced accuracy, model the potential spread of invasive species under various climate conditions, or foresee regional crop failures based on soil health and



meteorological data. These capabilities come together to create a digital nervous system for the planet, converting raw, unstructured data into organized knowledge and, ultimately, into actionable insights for decision-makers.

3. AI for Planetary Health: Climate Change Mitigation and Adaptation:

Climate change is the archetypal "wicked problem," and AI is being utilized in both mitigation (reducing emissions) and adaptation (addressing impacts) efforts.

A. Intelligent Energy Systems:

The shift to renewable energy is fundamental to mitigation. AI plays a vital role in optimizing this transition:

a. Grid Management:

AI predicts wind and solar power generation with exceptional temporal and spatial accuracy, enabling grid operators to effectively balance supply and demand, incorporate larger shares of variable renewables, and lessen dependence on carbon-heavy "peaker" plants.

b. Smart Consumption:

AI technologies in buildings and industrial operations analyze usage patterns to reduce energy waste through automated modifications. When combined with dynamic pricing strategies, AI can encourage off-peak consumption, thereby smoothing demand curves.

c. Materials Discovery:

AI expedites the identification of new materials by simulating molecular interactions on a large scale, condensing years of laboratory experimentation into mere months or weeks. This is crucial for the advancement of next-generation batteries, efficient carbon capture materials, and higher-efficiency photovoltaic cells.

B. Emissions Tracking and Reduction:

AI improves the precision, detail, and responsibility of carbon accounting:

a. Satellite-Based Monitoring:

Initiatives such as Climate TRACE utilize AI to evaluate data from various satellite constellations, detecting and measuring point-source emissions like methane leaks from oil and gas facilities and CO₂ emissions from power generation plants. This offers independent, near-real-time verification that surpasses corporate self-reporting.

b. Supply Chain Optimization:

AI models scrutinize intricate logistics networks to identify the most fuel-efficient transportation routes, minimize material waste in production, and enhance the use of agricultural inputs (water, fertilizer), thus significantly reducing Scope 3 emissions.

C. Climate Resilience and Adaptation:

As the effects of climate change become more severe, AI supports preparedness and response efforts:

a. Extreme Weather Forecasting:

Advanced deep learning models are transforming numerical weather prediction, providing longer lead times and improved spatial accuracy for storms, floods, and heatwaves, which helps save lives and mitigate economic losses.



b. Precision Agriculture:

AI-powered tools combine data from soil moisture sensors, drone-based multispectral imagery, and localized weather forecasts to offer farmers tailored recommendations on planting, irrigation, and harvesting. This enhances crop resilience against droughts, pests, and changing growing seasons.

c. Disaster Response:

Following wildfires or floods, AI can swiftly analyze pre- and post-event satellite images to assess the extent of damage, prioritize areas for emergency assistance, and guide reconstruction efforts.

4. AI as a Guardian of Biodiversity and Ecosystems:

The loss of biodiversity represents a quiet crisis that is occurring on a global scale. AI serves as a significant enhancer for conservationists, bolstering often limited field initiatives.

A. Monitoring and Discovery:

a. Camera Traps & Acoustic Sensors:

Tools such as Wildlife Insights utilize AI to analyze millions of images from camera traps and thousands of hours of audio recordings, automating the identification of species, counting individuals, and monitoring behaviors at a scale that is unachievable for human researchers.

b. Bioacoustics:

AI algorithms are capable of recognizing the distinct calls of endangered species (for instance, the Puerto Rican parrot), identifying human-made sounds such as chainsaws or gunshots that may indicate poaching, and evaluating the health of marine ecosystems by examining the diversity of reef soundscapes.

c. Environmental DNA (eDNA) Analysis:

AI assists in interpreting intricate metagenomic data derived from water or soil samples, offering a non-invasive and thorough overview of the biodiversity present in a given area, including the identification of rare, elusive, or cryptic species.

B. Protection and Enforcement:

a. Anti-Poaching:

Predictive AI models, such as those employed by PAWS (Protection Assistant for Wildlife Security), assess historical poaching incident data, terrain characteristics, and animal movement patterns to predict poaching hotspots. This allows rangers to perform risk-based, strategic patrols. Drones outfitted with real-time AI vision can enhance this initiative, particularly during nighttime hours.

b. Combating Illegal Fishing:

AI evaluates integrated data from vessel tracking systems (AIS), satellite-based synthetic-aperture radar (SAR), and optical imagery to detect vessels exhibiting suspicious activities—such as disabling transponders or lingering in marine protected zones—prompting alerts to authorities across extensive oceanic jurisdictions.



c. Deforestation Alerts: Platforms like Global Forest Watch leverage near-real-time satellite imagery (e.g., from Sentinel-2) and AI algorithms to issue automated alerts upon the detection of new forest disturbances, facilitating swift ground verification and intervention.

C. Restoration and Habitat Management:

a. Rewilding Planning:

AI models are capable of simulating ecosystem dynamics and species interactions to pinpoint optimal sites for species reintroductions or the establishment of wildlife corridors, forecasting long-term ecological impacts.

b. Invasive Species Control:

Drones equipped with high-resolution cameras and AI can systematically chart the spread of invasive plant species across extensive, hard-to-reach areas, allowing for targeted and effective removal efforts before native ecosystems are compromised.

5. AI for Pollution Control and Circular Economies:

The battle against pollution, encompassing everything from plastics to airborne particulates, is being enhanced by the sensing and analytical capabilities of AI.

A. Air and Water Quality:

a. Hyperlocal Monitoring:

The deployment of networks of affordable IoT sensors in urban settings, in conjunction with AI, enables the creation of dynamic, street-level air pollution maps. These models can pinpoint temporary pollution sources (such as traffic congestion) and offer personalized health risk notifications to at-risk populations.

b. Pollution Source Attribution:

AI can simulate the spread of pollutants within a watershed or airshed, merging sensor data with meteorological models to trace contamination back to its likely origin, thereby reinforcing regulatory enforcement.

B. Plastic Waste and Marine Debris:

a. Remote Sensing:

AI algorithms that have been trained on spectral signatures are utilized to detect floating plastic debris in satellite and drone imagery, assisting in the mapping of significant accumulation areas in rivers and oceans and tracking waste pathways to their origins.

b. Smart Recycling:

Computer vision technologies in material recovery facilities (MRFs) can swiftly and accurately identify and sort waste streams, far surpassing human capabilities, which significantly enhances recycling purity rates and economic feasibility. Additionally, AI can guide product design to facilitate easier disassembly and recycling.

C. Facilitating the Circular Economy:

AI enhances the intricate logistics of reuse and remanufacturing, aligns industrial waste streams with prospective users in "industrial symbiosis" networks, and assists in the design of



products and systems that have extended lifespans and reduced environmental impacts from cradle to cradle.

6. The Shadow Side: Critical Challenges and Ethical Imperatives

The influence of AI is not solely beneficial. Its use in the environmental sector presents significant issues that require proactive measures to prevent unintended consequences.

A. The Carbon Cost of Computation:

Training advanced, large-scale AI models necessitates substantial computational resources, typically located in data centers that rely on fossil fuels. The contradiction of employing a carbon-heavy tool to combat climate change is striking. The industry must vigorously seek efficiency improvements through specialized hardware and "Green AI" algorithms, while also committing to utilizing renewable energy for computational power.

B. Data Inequity and Algorithmic Bias:

AI models are only as effective as the data used for training. If data is consistently lacking from the Global South or marginalized groups, the resulting models will exhibit bias and may underperform when applied in those environments. An "AI for conservation" model predominantly trained on data from North American temperate forests may struggle to accurately identify species or threats in the Amazon or Congo Basin, potentially resulting in misguided policies and the continuation of "digital neo-colonialism."

C. Surveillance and Privacy:

The sensor networks and computer vision technologies that are utilized for monitoring wildlife and tracking poachers can also be adapted to surveil indigenous communities, environmental activists, or local populations. The implementation of AI in sensitive socio-ecological environments must adhere to the principles of free, prior, and informed consent, while respecting land rights, data sovereignty, and cultural autonomy.

D. Technological Solutionism and Job Displacement:

A perilous narrative suggests that AI serves as a techno-fix silver bullet. It is vital to recognize that AI is merely a tool, not a replacement for political will, systemic economic reform, or the profound, localized knowledge of indigenous peoples. An excessive dependence on high-tech solutions can misallocate resources and focus away from community-based conservation efforts. Additionally, automation in sectors such as environmental monitoring could lead to the displacement of skilled workers if not approached with the principles of a 'just transition'.

E. Transparency and Accountability:

Numerous advanced AI models function as 'black boxes,' making decisions through mechanisms that are challenging even for their developers to decipher. If an AI system suggests denying a fishing permit, distributing limited water resources, or implementing redlining in a conservation area, stakeholders must have the ability to comprehend and challenge its rationale. Establishing clear accountability frameworks for AI-driven decisions is crucial for ensuring democratic governance.



7. Toward a Framework for "Ecological AI"

In order to address these challenges and responsibly leverage the potential of AI, it is essential to pursue an "Ecological AI"—a framework in which the development and implementation of technology are fundamentally aligned with the principles of ecological integrity and social justice. This framework is built upon several key pillars:

1. *Sustainability by Design:*

AI research should emphasize energy-efficient algorithms, operate on verifiably green infrastructure, and perform comprehensive lifecycle environmental cost-benefit analyses.

2. *Equity and Inclusion:*

The processes of data collection and model development must be participatory and co-creative, engaging local and indigenous communities as partners rather than mere subjects. There must be proactive efforts to enhance local capacity and ensure that benefits are distributed globally.

3. *Transparency and Explainability:*

In the context of environmental governance, where decisions affect both lives and ecosystems, AI systems should strive for maximum interpretability. The pursuit of Explainable AI (XAI) is vital for fostering public trust and facilitating informed scrutiny.

4. *Precaution and Human-in-the-Loop:*

Due to the inherent complexity and uncertainties of ecosystems, AI should primarily serve to enhance human expertise rather than replace it. Critical decisions, particularly those with significant social or ecological implications, must involve meaningful human oversight and judgment.

5. *Governance and Collaboration:*

There is an urgent need for robust, multi-stakeholder governance. This requires collaboration among governments, intergovernmental organizations, technology companies, NGOs, academia, and civil society to create strong standards, ethical guidelines, and regulatory frameworks for environmental AI.

8. Conclusion: Intelligence for a Living Planet

The environmental challenges we face are, in part, a reflection of the unintended repercussions of human industrial and technological intelligence functioning without a comprehensive understanding of Earth's interconnected systems. Paradoxically, Artificial Intelligence now provides us with a formidable tool to help rectify this trajectory. By enabling us to listen to the planet in real-time, comprehend the complex web of life with unparalleled depth, and optimize our own systems for harmony instead of extraction, AI can serve as a foundational element of a new, regenerative relationship with nature.

Nevertheless, this favorable outcome is not guaranteed; it is a conscious decision. The direction we choose fundamentally relies on whether we have the collective wisdom to instill in our machines the values of stewardship, equity, and humility. By intentionally developing AI within the "Ecological AI" framework, we can guide this powerful technology away from becoming a source of further disruption and towards evolving into a crucial ally in the



significant endeavor of protection, conservation, and healing. The ultimate aspiration is not a planet governed by cold, impersonal algorithms, but a flourishing Earth where advanced computational intelligence, in respectful collaboration with human wisdom and the insights of natural systems, nurtures a future where both technology and wilderness can thrive.

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From Soil Degradation to Soil Regeneration: A Global Review of Sustainable Practices

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Abstract:

Soil degradation impacts more than 33% of global land, challenging food security, biodiversity, climate regulation, and ecosystem services. This study compiles global research on the shift from degradation—caused by erosion, nutrient depletion, compaction, salinization, and intensive practices—to regeneration via sustainable and regenerative agriculture. Conservation tillage, cover cropping, crop rotation, organic amendments, decreased synthetic inputs, agroforestry, and integrated livestock management are among the most important methods. These treatments improve soil organic carbon (SOC), microbial diversity, water retention, and resilience. Meta-analyses and case studies conducted across continents demonstrate that yield stability or gains are associated with environmental co-benefits, but adoption hurdles (economic, knowledge, and policy) persist. The study emphasizes alignment with the UN SDGs (particularly 2, 13, and 15) and advocates for expanded implementation, long-term monitoring, and policy support to achieve land degradation neutrality by 2030.

Keywords: Soil Health, Regenerative Agriculture, Sustainable Practices, Land Degradation Neutrality, climate mitigation.

1. Introduction

Soil is a scarce resource, and regeneration rates are orders of magnitude slower than current deterioration (Amundson et al., 2015). Globally, ~24 billion tons of rich topsoil are lost annually due to erosion and mismanagement. If current trends continue, land degradation is projected to exceed 90% by 2050 (UNCCD, 2017, as noted in recent studies). Degradation processes such as water/wind erosion, salinization, acidification, compaction, nutrient mining, and organic matter loss impair agricultural productivity, biodiversity, and carbon storage, aggravating climate change and food insecurity (Shokri et al., 2025). On evolutionary timescales, soil is a non-renewable resource, with formation rates ranging from 0.01 to 1 mm per century, contrasted to erosion losses that can be 10-100 times greater under poor management. According to recent estimations, 33-52% of global land is deteriorated to some extent, with forecasts indicating that up to 95% of Earth's land would be damaged by 2050 if no action is taken. Annual topsoil loss is estimated at 24-75 billion tons, resulting in economic losses of hundreds of billions of dollars due to diminished productivity and ecosystem services. Degradation worsens climate change by releasing stored carbon (agricultural soils have lost around 133 Pg SOC since farming began) and decreasing susceptibility to droughts, floods, and nutrient deficits (Lal, 2020).

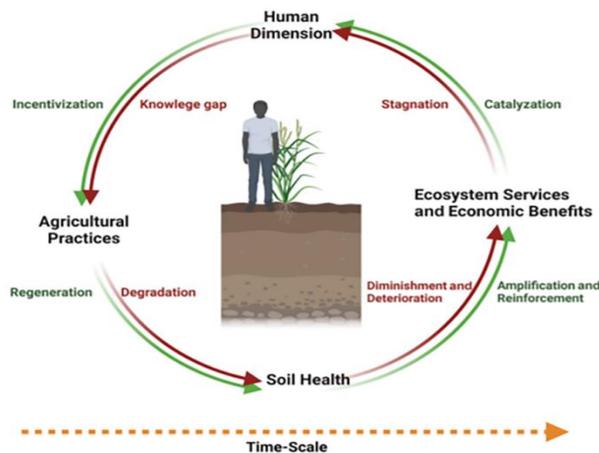


Figure 1. Soil Health Cycle (adopted by Maharjan et al., 2024)

This figure 1 depicts a closed-loop soil health cycle, emphasizing the movement from degradation (e.g., erosion, low SOC) to regeneration via methods such as cover cropping and reduced disturbance, hence generating virtuous feedback for ecosystem recovery.

Regenerative agriculture has arisen as a proactive paradigm that moves beyond "sustainability" (maintaining the status quo) to active repair (Newton et al., 2020; Khangura et al., 2023). The core concepts include limiting disturbance, maximizing live roots/cover, boosting variety, integrating animals, and lowering synthetics (Regeneration International 2017). This review looks at worldwide evidence of these strategies reversing deterioration, focusing on meta-analyses, regional syntheses, and field research (2020-2025).

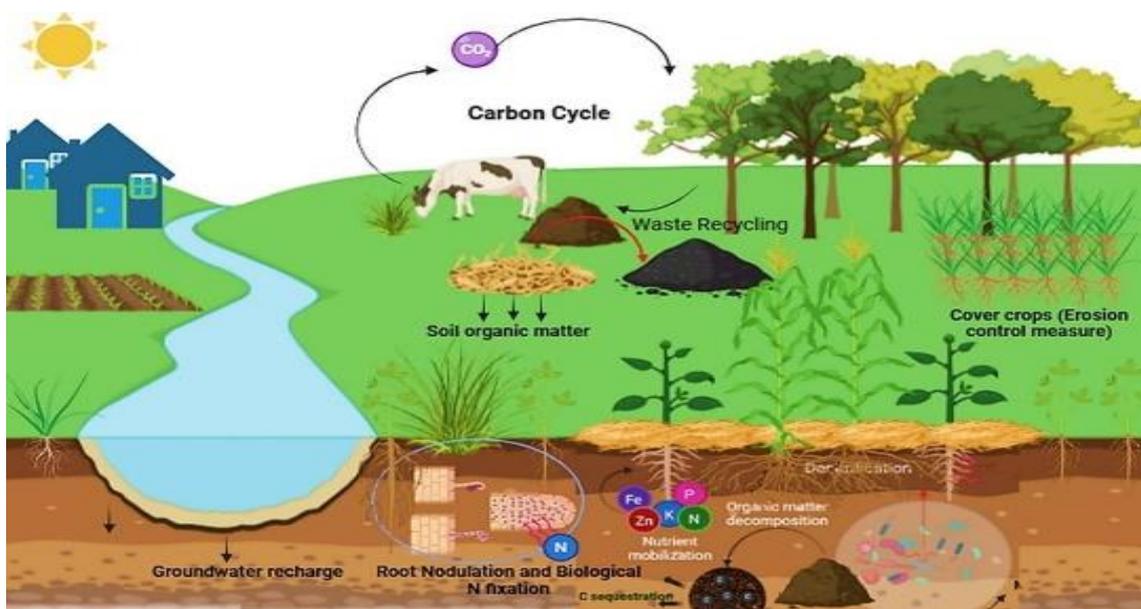


Figure 2. Regenerative pathways in rural ecosystems (Adopted by Das et al., 2025)



Figure 2, graphical representation of regenerative pathways in rural ecosystems, with arrows representing feedback from practices (cover crops and no-till) to soil repair.

2. Global Extent and Drivers of Soil Degradation:

Global degradation affects approximately 2 billion hectares, primarily in Asia and Africa (Shokri et al., 2025)

Major drivers include:

Intensive tillage and monoculture lead to erosion and loss of SOC.

Excessive use of synthetic fertilizers and pesticides leads to acidification and reduced biodiversity.

Deforestation and overgrazing lead to soil compaction and nutrient export. Climate change exacerbates these problems through extremes (droughts and floods) (IPCC-linked reports; Kopittke et al., 2025).

Degradation affects about 2-5.1 billion hectares, with substantial consequences in drylands (Africa, Asia) and highly farmed regions (Europe, North America). Water/wind erosion affects 1,100-1,500 million hectares, whereas salinization affects 300-400 million ha. Nutrient depletion is prevalent on around 33% of croplands. Recent revisions indicate that climate change will accelerate trends.

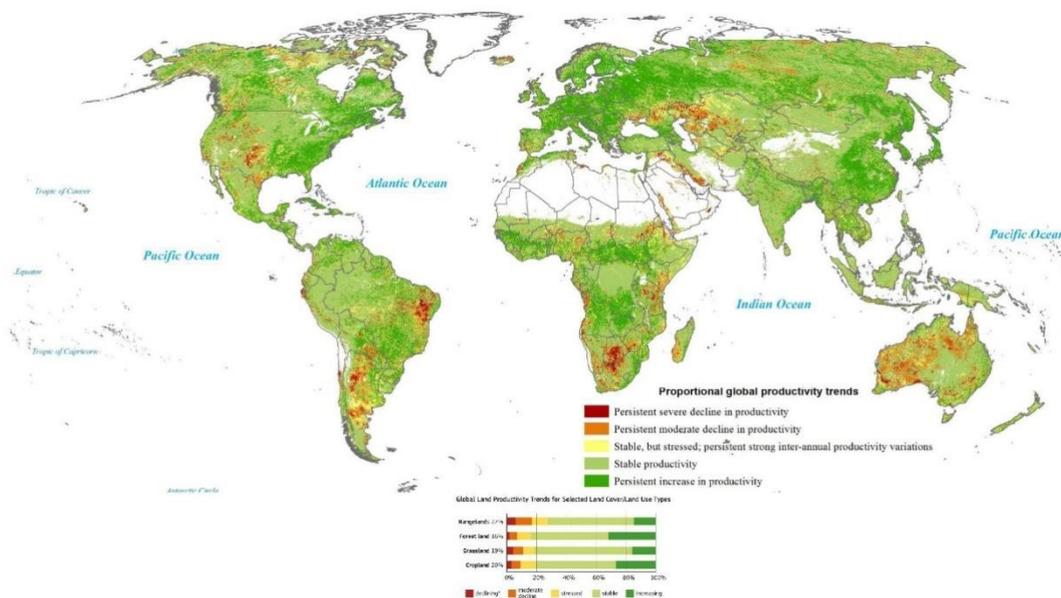


Figure 3, Land Degradation (IPCC, 2019)

Table 1. Major Soil Degradation Processes and Global Extent

Process	Primary Cause(s)	Global Affected Area (million ha)	Key Impacts	References
Water/wind erosion	Tillage, bare soil, overgrazing	1,100–1,500	Topsoil loss, reduced fertility, sedimentation	Borrelli et al., 2021; UNCCD, 2017
Salinization	Poor irrigation, sea-level rise	300–400	Osmotic stress, yield declines	Shokri et al., 2025



Nutrient depletion	Monoculture, export without return	~33% croplands	Lower productivity, increased GHG emissions	Lal, 2020
Compaction	Heavy machinery	Widespread in mechanized areas	Reduced infiltration, root restriction	UNCCD, 2017
Organic matter loss	Intensive practices	20–30% decline in many soils	Reduced water/carbon storage, biodiversity loss	Khangura et al., 2023; Patil et al., 2025

3. Pathways to Soil Regeneration: Key Sustainable Practices

Soil health restoration is being more acknowledged as an important method for mitigating climate change and ensuring sustainable food production. Conventional agricultural techniques, which include intense tillage and synthetic inputs, have resulted in the loss of up to 50-70% of the original SOC pool in many soils (Lal, 2020). Regenerative pathways aim to counteract this tendency by focusing on the soil's biological environment.

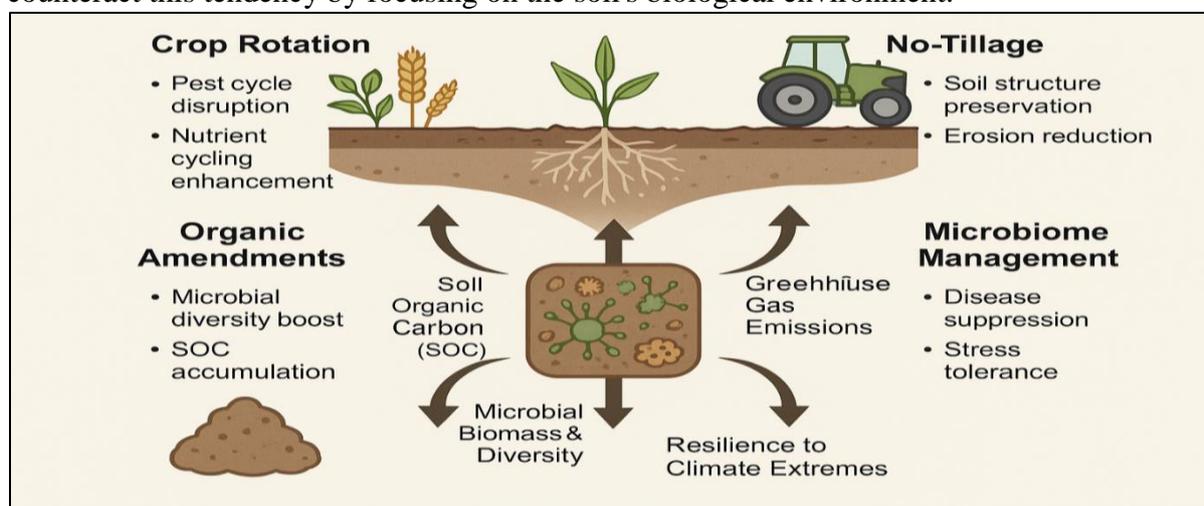


Figure 4, Integrated Management Practices Foster Soil Health, Productivity, and Ecosystem Resilience (Adopted by Liang et al., 2025)

The integrated management cycle demonstrates how activities promote soil health, production, and storage of carbon through reinforcing loops.

3.1 Minimizing Soil Disturbance (No-Till/Reduced Tillage):

Mechanical tillage disturbs the soil's structural integrity, causing aggregates to break down and organic matter to oxidize more quickly. Land managers who use no-till or reduced-tillage systems retain soil pore space and safeguard symbiotic fungus networks (mycorrhizae), which are necessary for nutrient absorption. These systems increase macrofauna activity, including earthworm populations, resulting in projected SOC benefits of 0.3 to 1.0 t/ha/yr (Lal, 2020; Montgomery, 2017).

3.2 Increasing Biodiversity (Crop Rotation and Diversification):

The transition from monocultures to complex polycultures and diverse crop rotations disrupts disease and insect life cycles, minimizing the need for chemical intervention.



Diversified systems use distinct root designs to obtain nutrients at different soil depths, increasing total nutrient efficiency. According to meta-analyses, increasing plant variety can result in SOC benefits ranging from 0.2 to 0.8 t/ha/year by offering a wider range of organic inputs (Lal, 2020; Paustian et al., 2016).

3.3 Organic Amendments (Compost, Manure, and Biochar):

The judicious use of organic amendments accelerates the regeneration of deteriorated soils. While farmyard manure (FYM) and compost give rapid nitrogen and microbial inoculation, biochar serves as a long-term carbon sink. Biochar's porous structure allows for long-term carbon storage and pollutant remediation, with sequestration rates ranging from 0.5 to 2.0 t/ha/year (Lehmann and Joseph, 2015; Rhodes, 2017).

3.4 Integrating Livestock and Agro forestry:

Integrated systems replicate the complexity of natural ecosystems. Managed rotational grazing (or "mob grazing") involves high-density, short-duration grazing to stimulate plant growth and cycle nutrients through manure. In addition, agroforestry incorporates perennial woody vegetation, which offers deep-root stability and long-term woody biomass storage. These methods have a synergistic impact, increasing the soil's water infiltration and storage capacity.

3.5 Evidence from Global Case Studies and Meta-Analyses:

Meta-analyses consistently show that regenerative techniques improve SOC, with rates changing according to integration level, climate, and duration. Temperate systems frequently demonstrate improvements without yield penalties, whereas tropical/subtropical locations have larger relative gains but greater unpredictability due to rapid decomposition and erosion concerns. Long-term (>10-20 year) deployment has the greatest impact, since POC (particulate organic carbon) accumulates initially and MAOC (mineral-associated organic carbon) stabilizes with time.

Table 2: Comparative Impacts from Recent Meta-Analyses

Practice	SOC Change (t/ha/yr or % increase)	Yield Impact	Other Benefits	Key Sources
No-till + cover crops	+0.3 to +1.0 t/ha/yr	Neutral to +10% (long-term)	↑ microbes, ↓ erosion, improved resilience	Khangura et al. 2023; Patil et al., 2025
Biochar application	+0.5 to +2.0 t/ha/yr; up to +37.7% in some systems	+11–19% (often in acidic soils)	Remediation, drought resistance, ↓ GHG	Ye et al., 2020
Diversified rotations	+0.2 to +0.8 t/ha/yr	Stable to + (yield stability ↑)	Pest control, biodiversity, nutrient cycling	Various 2023–2025 meta-analyses
Organic amendments (e.g., FYM, compost)	Highest gains (e.g., +6–13% in long-term)	Variable to +	Nutrient cycling, microbial recovery	Patil et al., 2025
Integrated systems (multiple practices)	+0.4 to +1.5 t/ha/yr	Often stable/+ long-term	Resilience, balanced POC/MAOC, ↓ GWP	Villat and Nicholas, 2024

4 Regional Evidence:

Regional results are influenced by the local climate, soil type, and socioeconomic background. Practices are particularly successful in areas with significant deterioration and big yield gaps.



4.1 India

A meta-analysis of 147 research spanning agro-ecological zones reveals that farmyard manure (FYM), green manure, and compost provide the maximum SOC improvements (e.g., effect sizes of 6.48-6.56 in 20-40 year studies). Integrated nutrient management and crop diversification improve microbial biomass and long-term stability, especially in tropical and subtropical soils with low baseline SOC. Long-duration tests (>20 years) demonstrate the highest regeneration, which is consistent with India's various climates and heavy cropping pressures (Patil et al., 2025).

4.2 Australia/Southeast Asia

In drylands (semi-arid Mediterranean climates), no-till coupled with residue retention and cover crops efficiently increases soil organic carbon and water-holding capacity, which is crucial in drought-prone regions. Studies in Western Australia have found site-specific improvements in coarse-textured soils, such as reduced wind erosion and improved microbial function under conservation tillage. These approaches promote yield stability in low-rainfall areas, while initial transitions must be carefully managed to minimize short-term declines (Khangura et al., 2023).

4.3 Europe/North America

Biochar mixed with decreased tillage improves yield stability and SOC sequestration, particularly in temperate soils prone to compaction and acidity. According to meta-analyses, biochar increases yields by 11-19% in nutrient-poor or polluted soils, with additional advantages such as heavy metal cleanup and enhanced water retention. Long-term studies show neutral to positive yield responses with no significant GHG trade-offs, enabling implementation in automated systems (Ye et al., 2020; Villat and Nicholas, 2024).

4.4 Africa/South America

Agroforestry and rotational (holistic) grazing are effective erosion control and regeneration strategies in drylands and savannas. In Sub-Saharan Africa, agroforestry is expected to minimize soil loss by up to 30% by 2040, while rotational grazing enhances rangeland health, fodder quality, and animal output by allowing for recovery periods. Silvopastoral systems in South America improve biodiversity and nutrient cycling, with high potential in degraded pastures. Success is dependent on community involvement and context-specific design (e.g., Zambia/Tanzania examples; Abegunde et al., 2020).

5. Yield and Co-Benefits:

Many long-term research (>10 years) reveal that regenerative systems produce neutral or positive yields with improved stability under extremes (e.g., droughts). Meta-analyses suggest that initial drops are probable, but that recovery will be achieved through better resilience, nutrient efficiency, and biodiversity. Co-benefits such as decreased erosion, increased microbial diversity, and improved water/nutrient retention outweigh short-term trade-offs in varied systems.

5.1 Co-Benefits and Alignment with Global Goals:

Regenerative methods have the ability to trap carbon on a global scale, with estimates for improved agricultural management ranging from 0.4 to 1.0 Gt C/yr (in line with "4 per 1000" and contemporary forecasts). This contributes to climate mitigation (negative emissions equivalent to a reforestation at ~160 USD/t CO₂e by 2050, primarily in the Global South). Co-benefits include increased biodiversity (microbial and above-ground variety), better water security (infiltration/retention), nutrient cycle efficiency, and reduced erosion/salinization. These are closely aligned with the UN SDGs: SDG 2 (zero hunger via resilient yields), SDG



13 (climate action through sequestration and GHG reduction), SDG 15 (life on land via ecosystem restoration), and LDN aims by reversing degradation and improving soil health.

6. Barriers, Gaps, and Recommendations:

6.1 Adoption Barriers

Economic barriers include transition expenses (e.g., no-till equipment, first modifications) and short-term yield hazards. Knowledge gaps among farmer's/extension services, policy misalignment (subsidies favoring synthetics), and scale difficulties (labor for varied systems) all hinder acceptance, especially in resource-constrained areas.

6.2 Research Gaps

Long-term (>10-20 year) research are limited, particularly in tropical/subtropical zones with high decomposition rates and significant degrading pressures. Quantifying complete life-cycle GHG trade-offs (e.g., N₂O emissions from legume cover crops or manure transport), social equity elements (e.g., gender, smallholder/indigenous access, community impacts), and integrated system effects (combining different techniques) remains a challenge. Standardized measures for SOC sequestration verification, biodiversity recovery, and economic assessment are insufficient, impeding carbon credit markets and policy scaling. Perennial systems, rangelands, and climate extreme resilience in various agroecosystems are all topics that have received little research. More randomized controlled trials and participatory farmer-led research are required to bridge the process-versus-outcome divide and enhance context-specific bundles.

6.3 Recommendations

6.3.1 Financial Incentives and De-risking

Redirect subsidies from conventional inputs to regenerative transitions (e.g., repurposing some of the global ~700 billion yearly agricultural/fossil fuel subsidies). Expand programs like the USDA's 2025 Regenerative Pilot Program (700 million through EQIP/CSP for whole-farm planning, cover crops, and soil health), EU pesticide reduction objectives, and efforts like California's Healthy Soils Program and Brazil's Low Carbon Agriculture Program. Scale carbon/biodiversity credits (e.g., through blended financing, premiums for regeneratively generated items) and transition assistance (e.g., compensation for initial yield drops, low-interest loans, risk-sharing insurance). Prioritize integrated public-private methods to reduce investment risk, with a focus on small and medium-sized farms in the Global South.

6.3.2 Knowledge and Extension System

Enhance farmer-led extension through participatory monitoring, digital technologies (soil health analytics, precision agriculture), and advisory councils (e.g., the USDA's Chief's Regenerative Agriculture Advisory Council). Invest in regional training, demonstration farms, and peer networks to increase technical capacity and confidence. Increase consumer education and demand for regenerative products to generate market pull.

6.3.3 Policy and Institutional Reforms

Incorporate regenerative concepts into national policies that are consistent with UN SDGs, LDN objectives, and NDCs (e.g., through UNCCD's LDN Target Setting Programme 2.0 and synergies with NAPs/climate adaptation). Create flexible, outcome-based standards (drawing on the work of the Regenerative Organic Alliance and the Savory Institute) while avoiding unduly restrictive certification. Encourage intra-agency collaboration (e.g., USDA-NRCS) and landscape-scale methods (e.g., regenerating entire agriculture landscapes to improve supply chain resilience).



6.3.4 Research and Monitoring Priorities

Long-term, multi-site trials in underrepresented regions should be funded; SOC/biodiversity measures should be standardised; and equity-focused research should be prioritized. To establish genuine carbon markets, support worldwide platforms for data exchange and verification (such as the FAO worldwide Soil Partnership and the 4 per 1000 Initiative).

7 Conclusions

Regenerative practices—such as no-till with cover crops, diversified rotations, organic amendments, integrated livestock, and agroforestry—effectively reverse soil degradation, sequester SOC at meaningful rates (typically 0.3–2.0 t C/ha/yr, with integrated systems strongest), and improve agroecosystem resilience to climate extremes, according to solid, mounting evidence from global meta-analyses, regional syntheses, and 2020–2025 field studies. With significant co-benefits like better water retention, nutrient cycling, biodiversity recovery, decreased erosion/salinization, and alignment with global goals (UN SDGs 2, 13, 15; LDN targets; "4 per 1000" initiative), long-term implementations frequently produce neutral to positive productivity outcomes. Although sequestration potentials differ by region (higher in degraded croplands with yield gaps), realistic global estimates from improved cropland management range from 0.28 to 0.68 Gt C/yr (or up to 0.7 to 2.5 GtCO₂e/yr from key practices), meaningfully mitigating climate change without compromising food security when context-adapted.

Despite these benefits, economic risks, knowledge gaps, policy distortions, and structural impediments continue to impede adoption; these issues are being addressed more and more by 2025 efforts including blended financing, large-scale pilot funding, and subsidy redirection. In order to reverse degradation trends, create resilient food systems, and secure soils in the face of escalating climate pressures, governments, the private sector, and communities must prioritize de-risked incentives, farmer-centered extension, standardized monitoring, and landscape-level integration. Regenerative agriculture provides a proven, comprehensive road to land degradation neutrality, improved human and planetary health, and sustainable wealth for future generations with focused effort.

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Performance Evaluation of an Industrial Effluent Treatment Plant for Pollution Reduction: A Case Study of Karmayogi Ankushrao Tope Samarth Sahakari Sakhar Karkhana (KATSSSK), Jalna

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Abstract:

This study evaluates the performance of the industrial effluent treatment plant (ETP) at Karmayogi Ankushrao Tope Samarth Sahakari Sakhar Karkhana (KATSSSK), Jalna, focusing on pollution reduction efficiency. Monitoring was conducted over a 25-day period, assessing key physico-chemical parameters including pH, chemical oxygen demand (COD), total dissolved solids (TDS), chlorides, and temperature. A unit-wise analysis was performed across the various treatment stages to quantify pollutant removal efficiency. All analyses followed standard procedures outlined by the APHA guidelines. The treated effluent quality was benchmarked against regulatory discharge standards prescribed by the Maharashtra Pollution Control Board (MPCB). Results demonstrate a progressive decrease in pollutant concentrations through successive treatment units, with final effluent parameters largely within permissible limits. The findings underscore the efficacy of the existing treatment system and highlight the importance of detailed unit-wise performance evaluations for enhancing environmental management practices in sugar industries.

Keywords: Effluent Treatment Plant, Sugar Industry, Pollution Reduction, Unit-wise Performance, Industrial Wastewater

Introduction:

The sugar industry plays an important role in agro-industrial development, particularly in regions where sugarcane cultivation forms a major part of the rural economy. Along with economic benefits, sugar manufacturing activities generate considerable quantities of wastewater containing high concentrations of organic matter, dissolved solids, and process-related contaminants. The characteristics of this waste water vary with production stages and operational practices, making its management a critical environmental challenge. Wastewater produced during sugar processing originates from operations such as cane washing, Juice extraction, evaporation, and equipment cleaning. If discharged without adequate treatment, such effluent can adversely affect surface water bodies and surrounding soil by increasing organic load and altering physicochemical conditions.

To prevent environmental degradation and comply with regulatory requirements,



sugar industries employ effluent treatment plants (ETPs) designed to reduce pollutant concentrations prior to discharge. Wastewater produced during sugar processing originates from operations such as cane washing, juice extraction, evaporation, and equipment cleaning. If discharged without adequate treatment, such effluent can adversely affect surface water bodies and surrounding soil by increasing organic load and altering physicochemical conditions. To prevent environmental degradation and comply with regulatory requirements, sugar industries employ effluent treatment plants (ETPs) designed to reduce pollutant concentrations prior to discharge.

An industrial ETP typically consists of a series of treatment units that function collectively to achieve pollution reduction. The effectiveness of each unit depends on wastewater characteristics, operational stability, and process efficiency. While compliance monitoring generally focuses on final treated effluent quality, evaluating performance at individual treatment units provides a clearer understanding of pollutant removal mechanisms and system efficiency. Unit-wise assessment is therefore essential for identifying critical treatment stages and optimizing overall ETP performance.

Although several studies have reported treated effluent quality of sugar industry wastewater, limited research has emphasized unit-wise performance evaluation based on continuous field data. In this context, the present study focuses on the performance evaluation of the industrial effluent treatment plant at Karmayogi Ankushrao Tope Samarth Sahakari Sakhar Karkhana (KATSSSK), Jalna. The study uses 25 days of monitoring data for physicochemical parameters to assess pollution reduction efficiency across different treatment units and to evaluate compliance with prescribed discharge standards.

Materials and Methods:

1. Study Area

The study was conducted at the effluent treatment plant of Karmayogi Ankushrao Tope Samarth Sahakari Sakhar Karkhana (KATSSSK), located in Jalna district, Maharashtra, India. The ETP treats wastewater generated from various sugar manufacturing operations before discharge. The treatment system comprises multiple units designed to progressively reduce pollutant concentrations.

2. Sampling and Monitoring

Effluent samples were collected from different treatment units of the ETP over a monitoring period of 25 days. Sampling locations varied depending on the relevance of the parameter and the monitoring practices followed at the industry. Unit-wise sampling enabled assessment of pollutant reduction across individual treatment stages. Grab samples were collected and analyzed on the same day to avoid changes in water quality.

3. Analytical Methods

The collected samples were analysed for selected physicochemical parameters



including pH, chemical oxygen demand (COD), total dissolved solids (TDS), chlorides, and temperature. All analyses were carried out following standard procedures recommended in Standard Methods for the Examination of Water and Wastewater (APHA). The observed treated effluent values were compared with discharge standards prescribed by MPCB.

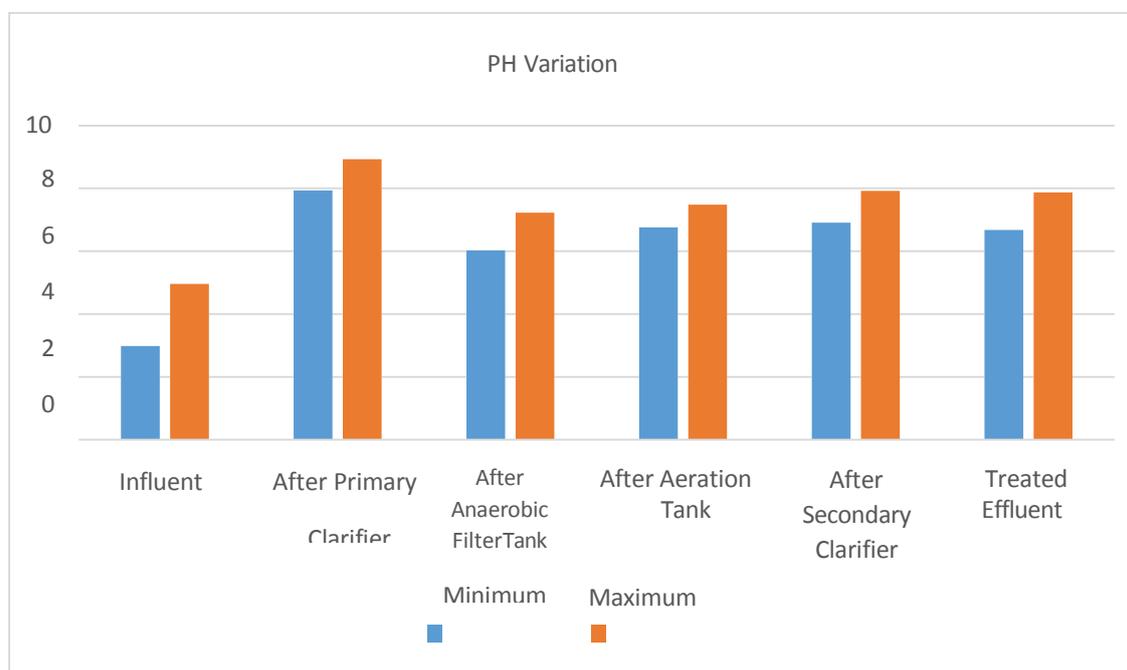
Result and Discussion:

Table1: Average reading of 25 days

Sr. No.	Parameters	Raw Effluent	Treated Effluent	Limiting conc. Not to exceed in mg/l, except for pH
1	pH	2.98-4.96	6.67-7.88	5.5-9
2	COD	6368	312	250
3	Chloride	323.2	261.6	600
4	TDS	1610	1424	2100
5	Temperature	29.4	23.9	NA

1. pH Variation

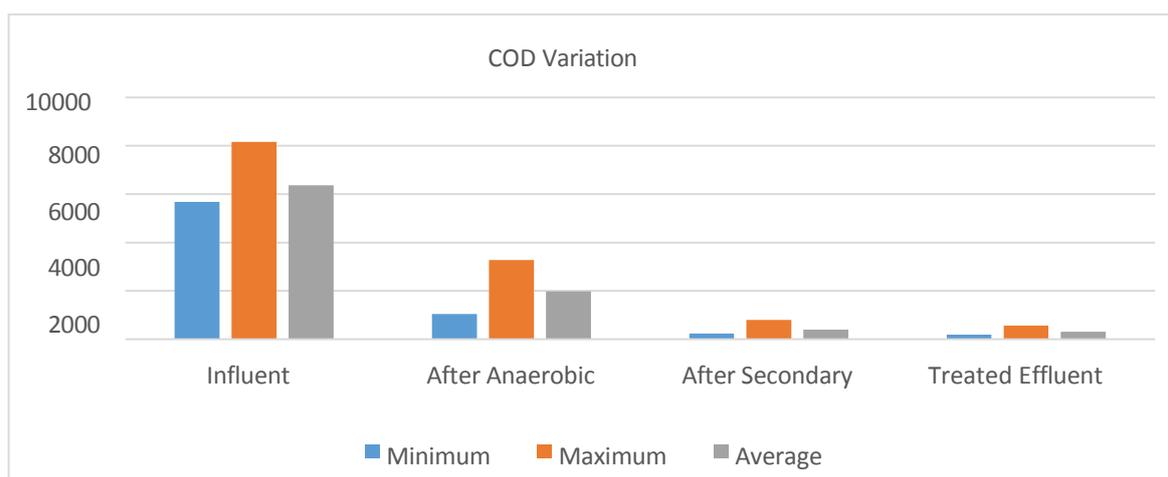
The pH values observed across different treatment units indicated relatively stable conditions throughout the monitoring period. Minor fluctuations were observed between units due to biological activity and treatment processes. The pH of the treated effluent remained within the permissible limits specified by regulatory authorities, in dictating effective buffering capacity of the treatment system. Stable pH conditions are essential for optimal biological treatment performance.





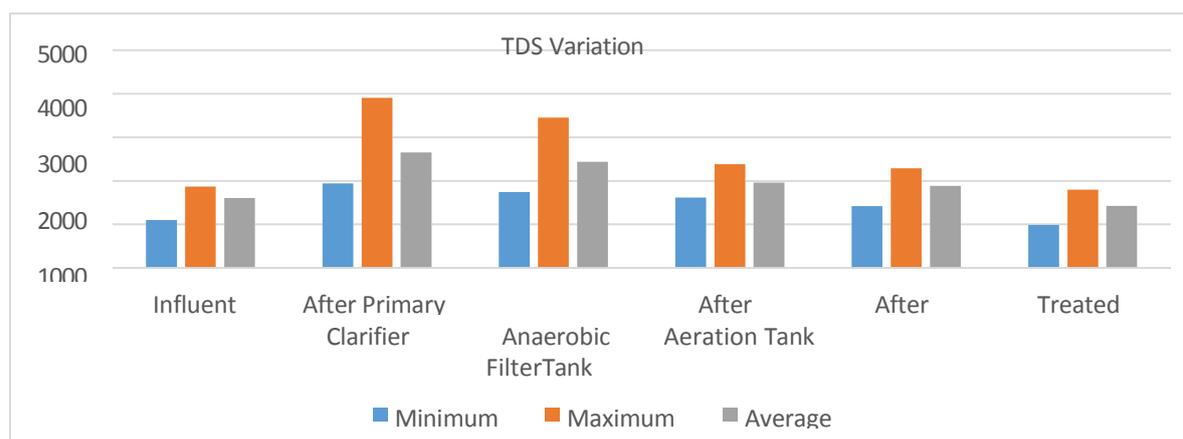
2. COD Reduction Performance:

Chemical Oxygen Demand (COD) is a key indicator of organic pollution strength in sugar industry wastewater. Unit-wise analysis revealed a progressive reduction in COD concentration across the treatment units. Significant COD removal was observed during biological treatment stages, highlighting the effectiveness of anaerobic and aerobic processes in degrading organic matter. The final treated effluent COD values showed substantial reduction compared to upstream units and largely complied with prescribed discharge standards. These results are consistent with findings reported in earlier studies on sugar industry ETP performance.



3. TDS Variation

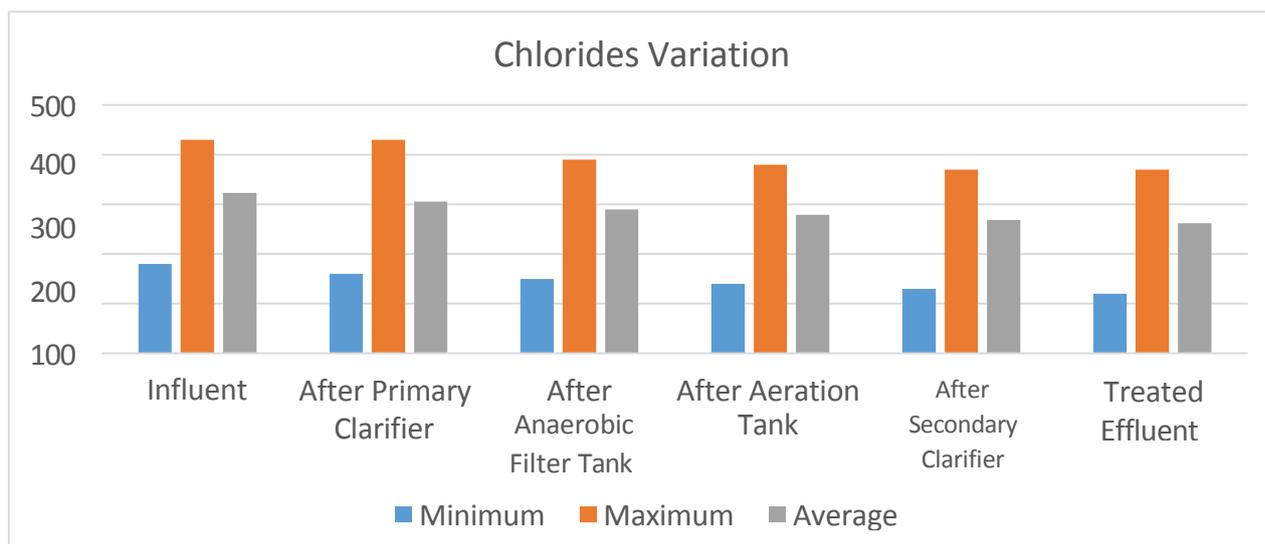
Total Dissolved Solids (TDS) values exhibited comparatively smaller variation across treatment units. Limited reduction in TDS concentration was observed, which is expected since conventional biological treatment processes are not specifically designed for dissolved solids removal. The treated effluent TDS values were influenced by process water characteristics and chemical usage. Despite limited removal, the final effluent values remained within acceptable discharge limits.





4. Chloride Concentration

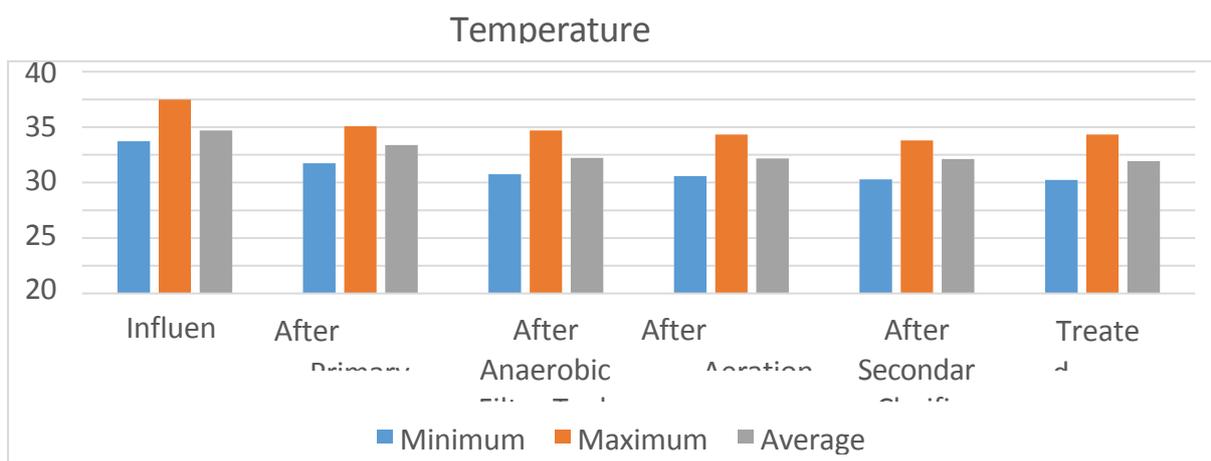
Chloride concentration showed conservative behavior across treatment units, with minimal reduction observed. Chlorides are generally not removed effectively through biological treatment and tend to remain stable throughout the process. The observed trends reflect the inherent nature of chloride ions and are in agreement with literature findings. The treated effluent chloride levels were within permissible limits, indicating no adverse environmental risk from salinity perspective.



5. Temperature Variation

Temperature measurements showed minor variation across treatment units, primarily influenced by ambient conditions and process operations. The treated effluent temperature complied with regulatory discharger requirements. Maintaining appropriated temperature is important for sustaining biological activity and overall ETP performance.

Conclusion:





The present study evaluated the performance of an industrial effluent treatment plant at Karmayogi Ankushrao Tope Samarth Sahakari Sakhar Karkhana (KATSSSK), Jalna, through unit-wise analysis of key physicochemical parameters over a 25-day monitoring period. The results clearly demonstrated effective pollution reduction, particularly in terms of organic load removal. The overall COD removal efficiency of the ETP was observed to be 95%, indicating excellent performance of the treatment system.

Unit-wise COD analysis revealed that the anaerobic treatment unit contributed significantly, achieving a COD reduction of 68.84%, followed by further removal in the secondary treatment unit (79.77%). The final polishing and treated effluent stage contributed an additional 22.25% reduction, ensuring compliance with prescribed discharge standards. This progressive reduction highlights the critical role of biological treatment processes in the effective degradation of organic pollutants in sugar industry wastewater.

In contrast, TDS and chloride removal efficiencies were comparatively lower, with overall reductions of 11.55% and 19%, respectively. This behavior is expected, as conventional biological treatment processes are not specifically designed for the removal of dissolved inorganic constituents. Nevertheless, the treated effluent concentrations of TDS and chlorides remained within permissible regulatory limits, indicating acceptable environmental performance.

Overall, the unit-wise performance evaluation provided valuable insight into the pollutant removal mechanisms operating within the ETP. The study confirms that the existing treatment system at KATSSSK is effective in achieving substantial pollution reduction and regulatory compliance. The findings emphasize the importance of continuous monitoring and unit-wise assessment to optimize treatment efficiency and support sustainable wastewater management in sugar industries.

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Integrated GIS-Based Assessment of Drainage Networks and Forest Fire Buffer Zones in Painganga Wildlife Sanctuary.

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Abstract

Forest fires pose a significant ecological threat to the dry deciduous landscapes of central India. Painganga Wildlife Sanctuary (PWS), located in Maharashtra, experiences recurrent fire incidents due to its dense litter load, dry climate, and anthropogenic activities. This study integrates Remote Sensing and GIS to map forest fire buffer zones and drainage networks within the sanctuary for the period 2020–2023. Using satellite-derived forest fire points and hydrological data, a comprehensive drainage–fire interaction map was generated. Results indicate a total burnt area of **183.708 hectares**, with major fire occurrences concentrated along secondary and tertiary drainage lines. Proximity analysis suggests that 68–75% of fire hotspots lie within ecologically sensitive zones where moisture availability fluctuates seasonally

Keywords: Hydrological Network, Fire Hotspot Mapping, Dendritic Drainage Pattern, Forest Fire Vulnerability, Spatial Analysis, Watershed-based Management, Fire Risk Assessment

Introduction

Forest fire is a recurring environmental hazard in dry deciduous ecosystems of India, causing biodiversity loss, soil degradation, carbon emission, and disturbance to wildlife habitats. Painganga Wildlife Sanctuary, part of the Deccan plateau landscape, is highly vulnerable due to its open canopy, dry summer conditions, and fuel load consisting mainly of leaf litter and grass.

Drainage systems play a crucial role in influencing fire behavior by modifying moisture regimes, controlling vegetation growth patterns, and acting as natural firebreaks. Understanding the spatial relationship between forest fire hotspots and drainage lines is important for planning fire mitigation strategies.

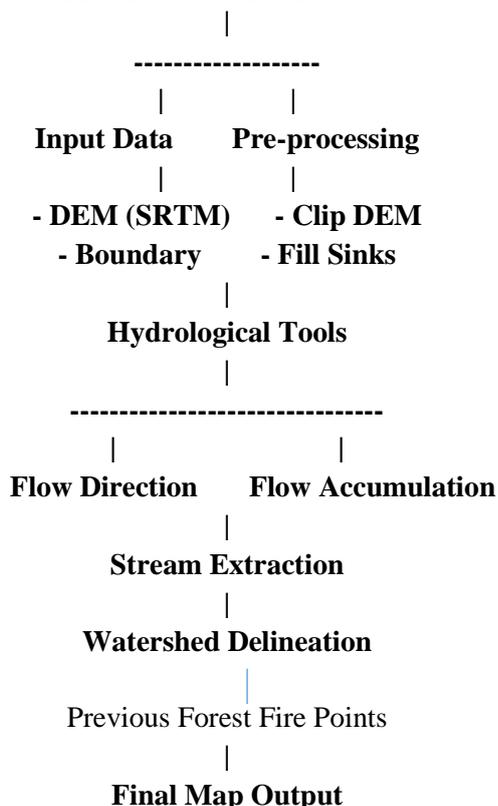


GIS and Remote Sensing provide reliable tools for: Mapping burnt areas, Identifying high-risk zones, Understanding fire–drainage interaction, supporting forest disaster management

This study focuses on generating an integrated Drainage and Forest Fire Buffer Map for PWS using GIS-based overlay and buffering techniques.

Methodology:

Watershed Mapping of Painganga Wildlife Sanctuary



Result and Discussion:

The integrated drainage and forest fire buffer analysis of Painganga Wildlife Sanctuary for the period 2020–2023 reveals a clear spatial relationship between fire occurrences and the sanctuary’s hydrological network. The drainage map shows a dominant dendritic pattern with numerous first- and second-order streams flowing throughout the region, indicating uniform geological structure and seasonal hydrological behavior. Forest fire hotspots, identified from multi-year fire records, are scattered across the sanctuary but show prominent clustering in the central, western, and southern dry deciduous zones. The total burnt area is estimated at **183.708 hectares**, highlighting the recurring severity of forest fire incidents.

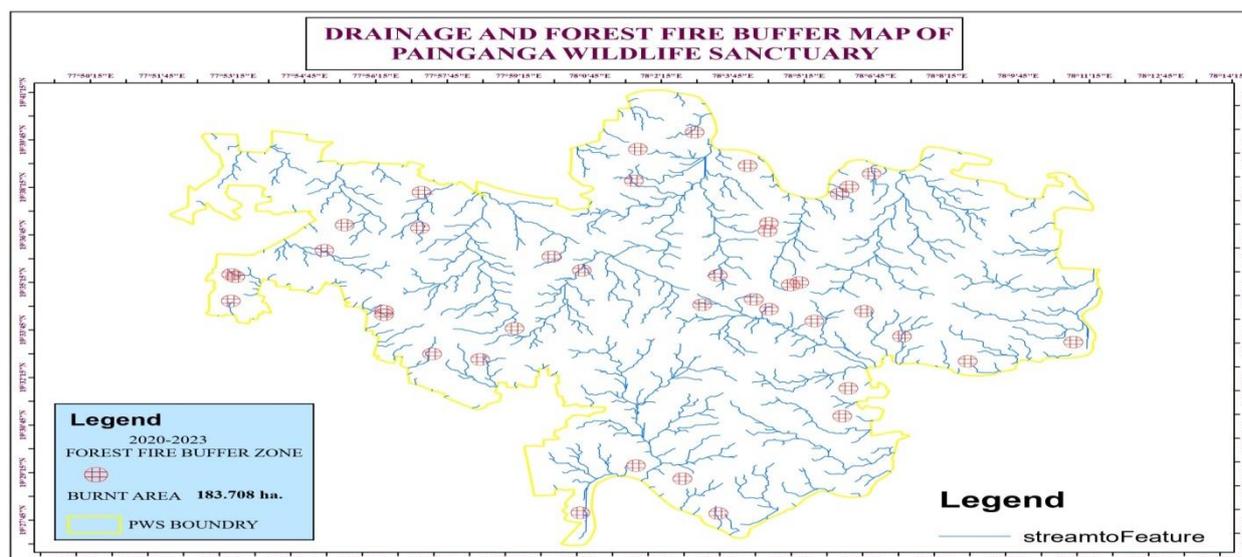


Fig. No.1: Drainage and Forest Fire Buffer Map

A significant observation is that most fire points lie within **500–800 meters** of drainage lines, particularly around seasonal streams where moisture levels drop rapidly during the dry summer months, resulting in high fuel load accumulation from leaf litter and grass. These transitional riparian belts become highly vulnerable due to fluctuating soil moisture and dense undergrowth, enabling the rapid ignition and spread of fires. In addition, fire clusters near human-accessible drainage corridors suggest an influence of anthropogenic pressures such as cattle movement, fuelwood collection, and accidental fires. The combined spatial overlay of drainage and fire buffers highlights ecologically sensitive fire-prone pockets, providing valuable insights for forest managers. Strengthening seasonal streams as natural firebreaks, improving patrolling near high-risk riparian zones, and integrating GIS-based hotspot analysis into early-warning systems can significantly reduce future fire damage. Overall, the study demonstrates that geospatial tools are effective for understanding fire–hydrology interactions and can support more targeted, watershed-based fire prevention and management strategies in Painganga Wildlife Sanctuary.

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AI and Its Use in Environment Conservation

Dr. Gajar T. D.

Research Guide

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Mr. Ganesh Khalekar

Research Research

**Matsyodari College,
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Introduction:

Artificial Intelligence (AI) is one of the most significant technological advancements of the present century. It refers to the ability of machines and computer systems to imitate human intelligence such as learning, reasoning, problem-solving, and decision-making. In recent years, environmental problems like climate change, deforestation, pollution, biodiversity loss, and natural disasters have increased rapidly across the world. These challenges are complex and interconnected, and traditional methods of environmental protection are often slow, costly, and less effective. AI provides advanced tools to collect, process, and analyze large volumes of environmental data within a short period of time.

Through satellites, sensors, and digital platforms, AI enables real-time monitoring of environmental changes. It helps scientists and policymakers to predict environmental risks more accurately. AI-based technologies reduce human effort and improve efficiency in conservation activities. They support sustainable use of natural resources and help maintain ecological balance. AI also assists governments and organizations in formulating data-driven environmental policies. Early detection of environmental threats through AI can reduce damage to ecosystems and human life. Thus, AI has emerged as a powerful support system for environmental conservation and sustainable development.

Concept of Artificial Intelligence (AI):

Artificial Intelligence is a branch of computer science that focuses on developing intelligent machines capable of performing tasks that normally require human intelligence. AI systems work through algorithms, data, and computational models that allow machines to learn from experience.

Machine Learning and Deep Learning are important components of AI that enable systems to identify patterns and improve performance over time. AI can process both structured and unstructured data efficiently and accurately. Unlike traditional computer programs, AI systems can adapt to new situations without continuous human instructions. AI technology is widely used in various fields such as healthcare, agriculture, education, industry, and environmental management. It performs complex and repetitive tasks faster than humans and minimizes errors. AI also helps in predictive



analysis, forecasting future trends based on past data. Due to these capabilities, AI has become an essential tool for solving large-scale environmental problems.

Degradation of Environment:

Environmental degradation refers to the deterioration of natural surroundings due to human activities and natural causes. Deforestation is one of the major causes of environmental degradation, leading to loss of forest cover, soil erosion, and destruction of wildlife habitats. Air pollution caused by industrial emissions and vehicles increases harmful gases in the atmosphere, affecting human health and contributing to climate change. Water pollution from industrial waste, sewage, and agricultural runoff contaminates rivers and lakes, making water unsafe for drinking and harming aquatic life. Soil degradation results from excessive use of chemical fertilizers and pesticides, reducing soil fertility and agricultural productivity.

Climate change has become a serious global issue due to rising greenhouse gas emissions, causing global warming, melting glaciers, and rising sea levels. Biodiversity loss occurs when natural habitats are destroyed, leading to extinction of plant and animal species. Rapid urbanization reduces green spaces and increases waste generation, putting pressure on natural resources. Industrialization consumes large amounts of energy and produces toxic waste, leading to environmental imbalance. Overpopulation increases demand for land, water, and food, resulting in overexploitation of resources. Plastic pollution has become a major threat to land and marine ecosystems as plastics take hundreds of years to decompose. Noise pollution affects both humans and wildlife by causing stress and behavioral changes. Electronic waste releases toxic substances into soil and water, creating serious health hazards. Overexploitation of natural resources such as mining and drilling depletes reserves faster than they can be renewed. Agricultural pollution damages ecosystems through chemical contamination. Frequent natural disasters such as floods and droughts are also linked to environmental degradation.

Need for Environment Conservation:

Environmental conservation is essential for ensuring the survival and well-being of present and future generations. Natural resources such as water, forests, and minerals are limited, and their overuse can lead to scarcity. Conservation helps maintain ecological balance by protecting ecosystems that support life on Earth. It plays a crucial role in preserving biodiversity, which is necessary for stable food chains and natural processes. Conservation efforts help reduce the impact of climate change by controlling carbon emissions and protecting forests that absorb carbon dioxide. Clean air and water, which are vital for human health, can only be ensured through proper environmental protection. Environmental conservation supports sustainable development by



promoting responsible use of resources without harming nature. It also reduces the risk of natural disasters, as forests and wetlands act as natural barriers against floods and storms. Conservation improves agricultural productivity by maintaining soil health and water availability. It encourages the use of renewable energy sources, reducing dependence on fossil fuels. Overall, environmental conservation enhances the quality of life by creating healthy and sustainable living conditions.

AI for Environment Conservation:

Artificial Intelligence plays a significant role in environmental conservation by providing advanced technological solutions. AI helps monitor climate change by analyzing large climate datasets and predicting future environmental conditions. It supports disaster management systems by forecasting floods, cyclones, and earthquakes, allowing early warnings and reducing loss of life. AI-based satellite monitoring helps track deforestation and detect illegal logging activities. Wildlife conservation benefits from AI through tracking animal movements and preventing poaching. AI assists in efficient water resource management by detecting leaks and analyzing consumption patterns. It helps control air pollution by identifying pollution sources and monitoring air quality in real time. In agriculture, AI promotes sustainable practices by monitoring crop health and optimizing fertilizer and water use. AI-based waste management systems improve waste segregation and recycling processes. Renewable energy systems benefit from AI through better prediction of energy demand and improved efficiency of solar and wind power. AI also supports environmental policy-making by providing accurate data analysis, helping governments and organizations achieve sustainability goals.

Conclusion:

Environmental degradation has become one of the most serious challenges faced by humanity today. Conservation of the environment is essential for maintaining ecological balance and ensuring sustainable development. Traditional conservation methods alone are not sufficient to address modern environmental challenges. Artificial Intelligence offers innovative and effective tools for environmental protection. It improves data collection, monitoring, and prediction of environmental changes. AI reduces costs, saves time, and enhances decision-making processes. It supports sustainable resource management and strengthens environmental governance. Developing countries can greatly benefit from AI-based environmental solutions. However, responsible and ethical use of AI is necessary to ensure accuracy, transparency, and data security. Human supervision remains important in AI applications. When used wisely, AI can significantly contribute to environmental



conservation. Thus, Artificial Intelligence is a powerful and promising tool for protecting the environment and ensuring a sustainable future.

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Relevance of Artificial Intelligence for Environmental Conservation

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Introduction

Environmental degradation has emerged as one of the most critical challenges of the twenty-first century. Rapid industrialization, population growth, urban expansion, and unsustainable consumption of natural resources have severely affected ecosystems. Climate change, deforestation, pollution, biodiversity loss, and water scarcity threaten both present and future generations. Traditional conservation methods, though valuable, are often limited by human capacity, time, and resources. In this context, Artificial Intelligence (AI) has gained global attention as a powerful technological tool. AI enables faster data processing, accurate prediction, and real-time monitoring of environmental changes. Governments, researchers, and environmental organizations are increasingly integrating AI into conservation strategies. AI-based systems support informed decision-making and efficient resource management. By enhancing precision and reducing human error, AI contributes significantly to sustainable environmental practices. Thus, understanding the relevance of AI for environmental conservation is essential in today's digital age.

Concept of Artificial Intelligence (AI)

Artificial Intelligence refers to the ability of machines to simulate human intelligence. It involves designing systems that can learn, reason, analyze data, and make decisions. AI operates through algorithms, machine learning, deep learning, and neural networks. These technologies allow computers to identify patterns from large datasets. AI systems improve their performance over time through experience. Unlike traditional computing, AI can handle complex and unstructured information. AI applications include image recognition, speech processing, prediction models, and automation. In environmental studies, AI processes satellite images and sensor data. It supports predictive analysis and risk assessment. AI reduces dependence on manual observation and field surveys. Hence, AI represents an advanced fusion of computer science and intelligent decision-making.

Need of Environmental Conservation

1. Protection of Biodiversity

Environmental conservation is essential to protect diverse plant and animal species. Loss of biodiversity disrupts ecological balance. Conservation ensures the survival of endangered species.



2. **Climate Change Mitigation**

Rising global temperatures demand urgent conservation measures. Forests and oceans act as carbon sinks. Conserving them helps reduce greenhouse gas emissions.

3. **Sustainable Use of Natural Resources**

Natural resources are finite and rapidly depleting. Conservation promotes their responsible and sustainable use. It ensures availability for future generations.

4. **Protection of Forest Ecosystems**

Forests regulate climate and support livelihoods. Deforestation causes soil erosion and habitat loss. Conservation maintains ecological stability.

5. **Water Resource Management**

Freshwater resources are under severe stress. Conservation helps prevent water pollution and wastage. It ensures clean water availability.

6. **Control of Air Pollution**

Industrial emissions and urbanization degrade air quality. Conservation encourages cleaner energy use. It improves human and environmental health.

7. **Soil Conservation**

Soil degradation reduces agricultural productivity. Conservation prevents erosion and nutrient loss. Healthy soil supports food security.

8. **Marine Ecosystem Protection**

Oceans support biodiversity and climate regulation. Overfishing and pollution threaten marine life. Conservation preserves oceanic balance.

9. **Disaster Risk Reduction**

Environmental degradation increases natural disasters. Conservation strengthens ecosystem resilience. It minimizes flood and drought impacts.

10. **Public Health Protection**

Environmental pollution causes serious health issues. Conservation reduces exposure to harmful substances. It promotes healthier living conditions.

11. **Economic Sustainability**

Natural resources support agriculture, tourism, and industry. Conservation ensures long-term economic stability. It prevents resource exhaustion.

12. **Intergenerational Equity**

Future generations have a right to natural resources. Conservation preserves environmental heritage. It ensures fairness across generations.

13. **Urban Environmental Balance**

Rapid urban growth strains natural systems. Conservation improves green spaces and air quality. It enhances urban sustainability.

14. **Preservation of Ecosystem Services**

Ecosystems provide food, water, and climate regulation. Conservation maintains these services. It supports human survival.



15. Ethical Responsibility

Humans have moral responsibility toward nature. Conservation reflects environmental ethics. It promotes harmony with nature.

Relevance of AI for Environmental Conservation

1. Climate Change Prediction

AI analyzes climate data to predict temperature and rainfall changes. It improves climate modeling accuracy. This helps in early planning and mitigation.

2. Wildlife Monitoring

AI-powered cameras track animal movement and population. It helps identify endangered species. This supports effective wildlife protection.

3. Deforestation Detection

AI processes satellite images to detect illegal deforestation. It provides real-time alerts. Authorities can take immediate action.

4. Disaster Management

AI predicts floods, cyclones, and droughts using historical data. It improves early warning systems. This reduces loss of life and property.

5. Air Quality Monitoring

AI analyzes pollution levels continuously. It predicts pollution trends. This supports effective environmental regulation.

6. Water Resource Management

AI detects water leaks and pollution patterns. It optimizes water usage. This ensures sustainable water management.

7. Waste Management

AI improves waste segregation and recycling. It identifies waste patterns. This reduces environmental pollution.

8. Renewable Energy Optimization

AI enhances efficiency of solar and wind energy systems. It predicts energy demand and supply. This promotes clean energy use.

9. Agricultural Sustainability

AI supports precision farming and soil analysis. It reduces chemical usage. This protects ecosystems and biodiversity.

10. Ocean Monitoring

AI tracks ocean temperature and pollution. It supports marine conservation. This protects marine biodiversity.

11. Urban Planning

AI assists in sustainable city planning. It analyzes traffic and pollution data. This improves urban environmental quality.



12. Environmental Policy Support

AI provides data-driven insights for policymakers. It improves decision-making accuracy. This strengthens conservation policies.

Conclusion:

Artificial Intelligence has emerged as a transformative tool for environmental conservation. It enhances the capacity to analyze complex environmental data accurately and efficiently. AI bridges the gap between environmental challenges and technological solutions. Through predictive modeling, AI supports proactive conservation measures. It enables real-time monitoring of ecosystems and natural resources. AI reduces human error and improves decision-making. It supports sustainable development goals at local, national, and global levels. However, ethical use and responsible deployment of AI are essential. Technological solutions must complement traditional conservation practices. Capacity building and data transparency are crucial for success. Governments and institutions must invest in AI-based environmental research. Public awareness and policy integration are equally important. AI cannot replace nature but can protect it. Thus, AI plays a vital role in ensuring environmental sustainability. Its relevance will continue to grow in the future. Environmental conservation through AI represents hope for ecological balance. Sustainable coexistence of technology and nature is achievable. Responsible innovation will define the success of AI-driven conservation.

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The Role of Artificial Intelligence in Enhancing Agricultural Productivity

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Abstract:

Artificial Intelligence (AI) has emerged as a significant technological advancement in modern agriculture, supporting farmers in improving productivity, efficiency, and sustainability. AI integrates machine learning, automation, data analytics, and smart sensing technologies to enable informed decision-making across agricultural operations. These technologies assist in optimizing crop management, reducing input costs, and enhancing yield outcomes. As noted by Basa (2024), "Artificial Intelligence has emerged as a transformative force in agriculture by enabling data-driven decision making that enhances productivity while reducing environmental stress." This study critically examines the role of AI in enhancing agricultural productivity through a comprehensive review of recent research.

Keywords: Artificial Intelligence, Agricultural Productivity, Precision Farming, Automation, Sustainable Agriculture

Introduction:

Agriculture remains a fundamental sector for ensuring food security, rural employment, and economic development. However, contemporary agriculture faces challenges such as climate change, declining soil fertility, labor shortages, and inefficient resource utilization. Traditional farming approaches are often inadequate to address these multifaceted problems. Artificial Intelligence offers innovative solutions by enabling real-time data analysis and predictive decision-making. Singh et al. (2024) emphasize that "the increasing complexity of agricultural challenges necessitates intelligent systems capable of learning, adapting, and supporting farmers beyond traditional methods." Thus, AI has become a critical component in the modernization of agricultural systems.

Review of Literature:

Several studies highlight the transformative role of AI in precision agriculture. AI-powered tools utilize satellite imagery, sensors, and drones to monitor crop health and soil conditions with high accuracy. Basa (2024) states that "precision agriculture powered by AI integrates sensors, satellite imagery, and machine learning algorithms to optimize farm inputs at a micro-level." Similarly, Padhiary et al. (2025) note that "AI-based precision farming systems significantly improve resource efficiency by ensuring site-specific crop management practices."



Machine learning techniques have also been widely applied for crop yield prediction and disease detection. According to Turgut et al. (2024), “machine learning models enable accurate crop yield prediction by analyzing complex interactions between soil, climate, and crop genotype data.” Such predictive capabilities reduce uncertainty and improve farm planning efficiency.

In the area of automation, AI-driven agricultural robotics have gained prominence. Anap et al. (2025) assert that “agricultural robotics driven by artificial intelligence has reduced dependency on manual labor while increasing operational precision and efficiency.” Despite these advancements, adoption challenges persist. Singh et al. (2024) caution that “the adoption of AI in agriculture is constrained by high costs, limited digital literacy, and inadequate rural infrastructure.”

Methodology:

The present study adopts a qualitative, review-based research methodology. Secondary data were collected from peer-reviewed journals, research articles, and institutional reports published between 2020 and 2025. This approach enables a comprehensive understanding of AI applications and productivity outcomes. Basa (2024) supports this method by stating that “a systematic review of existing literature provides a comprehensive understanding of AI applications and their real-world implications in agriculture.” The collected literature was analyzed thematically to identify key trends and challenges.

Results and Discussion:

The findings reveal that AI applications contribute significantly to enhanced agricultural productivity. Precision farming techniques enable optimized application of water, fertilizers, and pesticides, resulting in higher yields and reduced environmental impact.

Padhiary et al. (2025) report that “AI-driven decision support systems contribute to measurable increases in crop yield and input efficiency.”

Predictive analytics allow farmers to anticipate pest outbreaks, weather variations, and market fluctuations. Singh et al. (2024) observe that “predictive analytics in agriculture supports proactive planning and minimizes uncertainties related to weather variability and pest outbreaks.” Automation further enhances productivity by ensuring timely execution of farm operations. According to Anap et al. (2025), “automation through AI-enabled machinery enhances timeliness in farm operations, which is a critical determinant of crop productivity.” However, several constraints affect widespread adoption. Turgut et al. (2024) note that “explainability and trust in AI models remain essential factors influencing farmer acceptance and long-term adoption.” Financial limitations and lack of training also hinder implementation, particularly among smallholder farmers.

Conclusion and Suggestions:

The study concludes that Artificial Intelligence holds immense potential to revolutionize agriculture by enhancing productivity, sustainability, and resilience. AI-driven technologies improve resource efficiency, crop management, and decision-making processes. Basa (2024) concludes that “the future of agriculture lies in intelligent systems that integrate



technological innovation with farmer-centric approaches.” To maximize benefits, investments in digital infrastructure, farmer education, and affordable AI solutions are essential. Anap et al. (2025) suggest that “policy support, capacity building, and affordable AI solutions are imperative for ensuring inclusive and sustainable agricultural transformation.”

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Macrophytes Biodiversity and Ecological Significance in Chhatrapati Sambhajnagar District

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Abstract:

A comprehensive survey of the waterways in the Chhatrapati Sambhajnagar district of Maharashtra, India, reveals a rich and diverse population of submerged aquatic macrophytes. The study documented 24 distinct species distributed across 9 families, establishing crucial baseline data for ecological management and conservation. The Hydrocharitaceae family is overwhelmingly dominant, accounting for 12 species, or 50% of the total recorded diversity.

Aquatic macrophytes play a dual and critical role in freshwater ecosystems. They are essential for maintaining water clarity, providing structural habitats for fish and invertebrates, cycling nutrients, and stabilizing sediments. However, these vital plant communities are under significant threat globally from eutrophication, pollution, and reduced light availability. Conversely, their excessive growth can lead to nuisance conditions, classifying them as "aquatic weeds" that impair water flow and ecosystem balance. The research connects this biodiversity assessment to a broader body of work on phytoremediation, highlighting the potential of specific macrophytes species to absorb and accumulate heavy metals, offering a foundation for developing natural, cost-effective water treatment strategies.

Keywords: Aquatic vegetation, Wetland areas, submerged, and floating macrophytes, Biodiversity, aquatic resources

1. The Ecological Role of Aquatic Macrophytes:

Submerged aquatic macrophytes, or hydrophytes, are indispensable components of healthy freshwater ecosystems, particularly in shallow lakes. Their functions are multifaceted and foundational to ecological stability.

- **Ecosystem Engineering:** They are essential for maintaining clear water conditions by inhibiting sediment re suspension, which controls water turbidity. They also stabilize shorelines and lake bottoms.
- **Habitat and Refuge:** Macrophytes provide critical structural habitats that significantly influence fish communities. They offer shelter for zooplankton, macro-invertebrates, and fish, protecting them from predation. They also serve as breeding and sheltering environments.
- **Nutrient Cycling and Water Quality:** These plants play a vital role in nutrient dynamics. Their ability to generate high biomass allows them to accumulate biogenic compounds,



effectively absorbing nutrients like phosphorus and nitrogen from the water column. They also produce oxygen and are involved in biogeochemical processes such as bio mineralization and elemental cycling.

- **Food Web Support:** As primary producers, macrophytes harness solar energy that sustains the entire ecosystem. They provide food for a variety of aquatic organisms and support the proliferation of zooplankton and benthic fauna.
- **Bio-indication:** Due to their sensitivity to changes in water quality, aquatic macrophytes serve as effective bio indicators of water pollution and potential ecosystem degradation.

2. Threats and Management Challenges:

Despite their ecological importance, macrophytes populations face a global decline, and their management presents significant challenges.

- **Primary Stressors:** The primary threats to these populations include eutrophication (nutrient enrichment), untreated sewage discharge, and industrial pollutants. These factors alter the physicochemical characteristics of water, negatively impacting biodiversity.
- **Light Limitation:** A key factor contributing to the decline of submerged macrophytes is the widespread decrease in underwater light availability. This is often caused by frequent algal blooms, which are fueled by nutrient pollution and block the sunlight necessary for macrophytes growth.
- **Restoration Difficulties:** The restoration of submerged macrophytes in urban lakes is often hindered by inherent constraints such as elevated nutrient loading, artificially regulated water levels, and limited littoral zones.
- **The Problem of Overgrowth:** While essential, the excessive growth of certain macrophytes can create nuisance conditions, classifying them as aquatic weeds. Dense, monotypic stands can:
 - Adversely affect the diversity of invertebrate and fish populations.
 - Lead to eutrophication when large quantities of decaying plant matter accumulate.
 - Hinder water flow, obstruct reservoir inlets, and interfere with recreational activities.

3. Biodiversity Survey in Chhatrapati Sambhajnagar District:

The study was conducted to identify, document, and assess the abundance and distribution of submerged aquatic macrophytes in the Chhatrapati Sambhajnagar district.

3.1. Study Area Profile

- **Location:** The Chhatrapati Sambhajnagar district (formerly Aurangabad) is located in the Marathwada region of Maharashtra, India, as depicted in the provided maps (Fig. 1).
- **Geography:** Situated in the Deccan region, the district's terrain is hilly and lies primarily within the Godavari River basin, with some areas extending into the Tapi River basin. The district spans an area of 10,100 km².
- **Climate and Hydrology:** The climate is semi-arid, with an average annual rainfall of 710 mm, mostly concentrated during the monsoon season (June to September). The Godavari River and its tributaries (Purna, Dudhna, Shivna) are the main waterways.



3.2. Survey Methodology: Data was collected through systematic surveys of major waterways and water bodies during three distinct seasons (rainy, winter, and summer). Field excursions were conducted over two primary periods: June 2005 to May 2007 and June 2018 to 2022. Macrophyte specimens were collected by hand from shallow littoral zones, rinsed, preserved in 10% formalin, and identified to the species level using standard scientific literature.

3.3. Key Findings on Species Distribution

The survey confirmed that the district hosts a significant diversity of submerged macrophytes, with a total of **24 species from 9 different families** identified. The Hydrocharitaceae family is the most prevalent group in the region.

Table 1: Family-wise Distribution of Submerged Macrophyte Species

Sr. No.	Family of Submerged Macrophyte	Number of Species	Percentage of Total Species
1	Ceratophyllaceae	2	9%
2	Characeae	1	4%
3	Fabaceae	1	4%
4	Haloragaceae	2	8%
5	Hydrocharitaceae	12	50%
6	Najadaceae	1	4%
7	Nymphaeaceae	1	4%
8	Pontederiaceae	1	4%
9	Potamogetonaceae	3	13%
Total		24 species	100%

The survey documented a variety of species, including *Cabomba caroliniana* (Fanwort), *Ceratophyllum demmersum* (Coontail), *Hydrilla verticillata* (Oxygen weed), *Vallisneria spiralis* (Eelgrass), and multiple species from the *Potamogeton* (Pondweed) and *Najas* (Water nymph) genera.

4. Phytoremediation Potential and Broader Research:

This biodiversity study is part of a larger body of research by the authors that explores the practical application of macrophytes in environmental management, specifically phytoremediation.

• Focus on Metal Uptake:

A significant portion of the research by Jadhav, Babare, and colleagues investigates the capacity of various aquatic plants to absorb, accumulate, and translocate heavy metals from contaminated water.

• Scientific Evaluation:

This potential is quantified using established phytoremediation indices, including:

- **Bioaccumulation Factor (BAF)**
- **Bioconcentration Factor (BCF)**
- **Metal Enrichment Factor (MEF)**



Metal Translocation Factor (MTF):

• **Promising Species:** Rigorous studies on species such as *Ceratophyllum demersum*, *Ceratophyllum submersum*, and *Azolla caroliniana* have revealed high BCF and MEF values, identifying them as promising candidates for use in wastewater treatment and wetland restoration. Other species like *Arundo donax L.*, *Pistia stratiotes*, and *Eichhornia crassipes* have also been assessed for their bioabsorption capabilities.

• **Limitations and Future Directions:** The source acknowledges that most of the metal uptake data is based on controlled, short-term assessments. Future work is needed to validate these findings through field-scale applications and pilot studies. Further research is also required on seasonal variations in metal uptake and the safe disposal or reuse of the resulting metal-laden biomass.

5. Conclusion:

The study concludes that the Chhatrapati Sambhajnagar district possesses a remarkable diversity of submerged aquatic macrophytes, with 24 species identified across 9 families. The dominance of the Hydrocharitaceae family (12 species) is a key finding. The significance of this research lies in its establishment of a crucial ecological baseline. This data is vital for:

- Formulating conservation and management strategies for local water bodies.
- Addressing issues of eutrophication and excessive plant growth.
- Informing aquatic ecosystem restoration efforts.
- Supporting the development of phytoremediation techniques for pollution control.

The body of work bridges fundamental floristic documentation with applied environmental science, laying the groundwork for implementing cost-effective, eco-friendly water treatment solutions in India. It also calls for increased scientific focus on the specific roles of submerged macrophytes to better understand and manage aquatic habitats.

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Physico-Chemical and Microbiological Assessment of Seawater Quality at Mumbai Beaches.

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Abstract:

The discharge of inadequately treated sewage and wastewater through point and nonpoint sources is putting pressure on and degrading the water quality of Mumbai's beaches and seafronts. This study presents a comparative analysis of seawater quality parameters at five prominent beaches in Mumbai: Rajodi, Aksa, Marve, Versova and Bandra. Water samples were collected from each location and subjected to comprehensive testing for total hardness, salinity, pH, electrical conductivity (EC), dissolved oxygen (DO), biochemical oxygen demand (BOD), and coliform count using the Most Probable Number (MPN) method. The results revealed variations in seawater quality across the beaches, with significant differences observed in hardness, salinity, electrical conductivity, dissolved oxygen, biological oxygen demand and coliform levels. Rajodi Beach exhibited the highest BOD levels, indicating a higher presence of organic pollutants. In contrast, pH levels across all beaches remained nearly uniform, showing slightly basic conditions. Salinity was highest at Versova Beach, followed by Marve, while total hardness was also highest at Versova. Coliform counts were elevated at Rajodi beach, while Aksa, Marve, Versova, and Bandra recorded zero coliform presence. One of the main problems that require these findings highlight the need for regular monitoring and urgent attention is sewage disposal, as large amounts of untreated sewage are dumped into neighboring coastal areas, degrading the water quality in those places. This study also focuses on the statistical estimation of coliform count and isolation of the faecal indicator coliform *Escherichia coli* (E. coli) in collected water samples.

Keywords: Sea Water, Hardness, Salinity, pH, Electrical Conductivity, DO (Dissolved Oxygen), BOD (Biochemical Oxygen Demand), Coliform Count, MPN (Most Probable Number) method.

Introduction:

Seawater quality assessment plays a crucial role in understanding the health of aquatic ecosystems and ensuring the well-being of human populations that rely on them. The degradation of seawater quality in coastal areas poses significant environmental and public health concerns worldwide. In rapidly urbanizing cities like Mumbai, declining seawater quality at beaches has become a pressing issue, driven by increased anthropogenic activities, inadequate wastewater management, fishing operations, maritime transport, tourism, and oil



discharges. Mumbai's coastal regions are home to several picturesque beaches that serve as recreational hubs, ecological habitats, and integral parts of the city's identity. However, rapid urbanization and industrialization have placed immense pressure on these coastal ecosystems, raising serious concerns about water quality. Understanding the dynamics of seawater quality parameters in these areas is essential for promoting environmental sustainability, protecting public health, and informing responsible coastal management practices. This field project aims to conduct a comprehensive assessment of the seawater quality at the aforementioned beaches. These beaches, known for their scenic beauty and cultural importance, attract large numbers of visitors and support fisheries, local transport, and tourism — all of which contribute to the socio-economic fabric of the city. Nevertheless, rapid population growth, urban development, and inadequate waste management have raised concerns about the cleanliness and ecological health of these coastal waters. The primary objective of this study is to evaluate and compare key seawater quality parameters across the selected beaches. Parameters analyzed include total hardness, salinity, pH, electrical conductivity (EC), dissolved oxygen (DO), biochemical oxygen demand (BOD), and coliform count using the Most Probable Number (MPN) method. By analyzing these indicators, the study aims to identify variations in seawater quality, trace potential pollution sources, and assess the overall environmental condition of each beach through systematic sampling and laboratory analysis

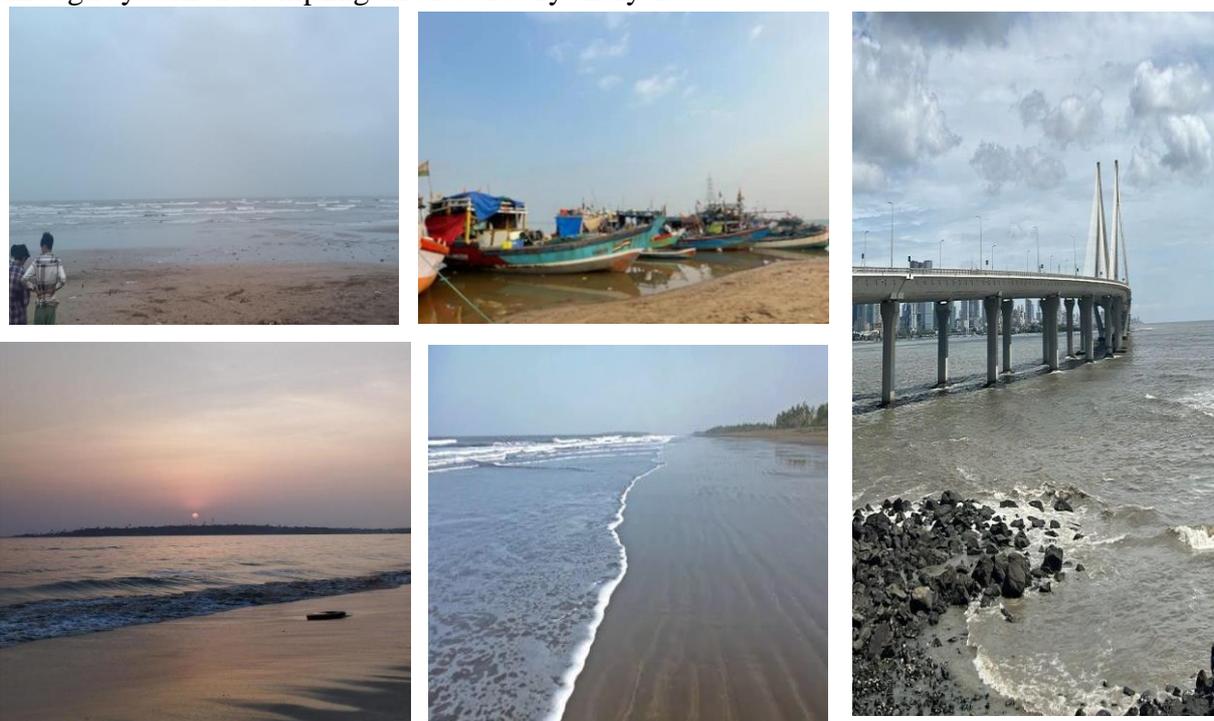


Fig. 1. Sea water sample taken from shoreline of (a) Aksa Beach (b) Marve Beach (c) Versova Beach (d) Rajodi Beach (e) Bandra Beach



Materials and Methods:

Study Area:

The coastal stretch of Mumbai plays a vital role in shaping the city's geography, economy, and culture. This study focused on five selected beaches along the Mumbai coastline, chosen based on the intensity and diversity of anthropogenic activities such as tourism, fisheries, oil discharge, and maritime transport. These human influences contribute to variations in seawater quality across different locations.

Sampling and sample collection:

Seawater samples were collected from the shoreline of each beach using the grab sampling method, which involves collecting a single sample at a specific time and location. Samples were stored in clean plastic bottles and transported to the laboratory for analysis under controlled conditions.

Sample Analysis:

Each sample was analyzed for the following parameters: total hardness, salinity, pH, electrical conductivity (EC), dissolved oxygen (DO), biochemical oxygen demand (BOD), and coliform count.

- pH and electrical conductivity were measured using digital meters (pH meter and conductometer, respectively).
- DO was determined using Winkler's method.
- Hardness and salinity were measured using titrimetric methods.
- BOD was assessed using the Five-Day BOD method.
- Coliform count was determined using the Most Probable Number (MPN) method

Observation and Result:-

The following parameters were analyzed from the collected seawater samples. Table 1 summarizes the parameters along with the methods used. Detailed descriptions of each test and its significance are provided below.

Table 1

Sr. No.	Parameter Studied	Method used
1	Salinity	Titrimetric method
2	Hardness	EDTA Titrimetric Method
3	pH	Electronic readings obtained by a pH meter
4	Electrical conductivity	Electronic readings obtained by the conductometer
5	DO (Dissolved Oxygen) BOD (Biochemical Oxygen Demand)	Winkler's method Five-Day Biochemical Oxygen
6	Determination of Coliform Count	MPN (Most Probable Number) method.



1) Estimation of hardness (EDTA Titrimetric Method)

Hardness is a measure of the concentration of divalent ions—primarily calcium (Ca^{2+}) and magnesium (Mg^{2+})—in water. Seawater is naturally hard due to its high content of dissolved minerals. These minerals are essential for the survival of marine organisms.

The hardness of the samples was estimated using complexometric titration with EDTA as the titrant.

Formula: **Hardness = $\frac{\text{volume of EDTA used (ml)} \times N \times E \times 1000}{\text{Volume of Sample}}$**

Volume of Sample

Where:

N = Normality of EDTA (0.02N)

E = Equivalent weight of CaCO_3 (50g)

Volume of sample = 20ml

Volume of EDTA used = Burette reading (ml)

The following readings of hardness were obtained:

Beaches	Hardness calculated (ppm)
Versova	3950
Bandra	2060
Aksa	1775
Marve	2945
Rajodi	1600
Standard (CaCO_3 solution)	1055

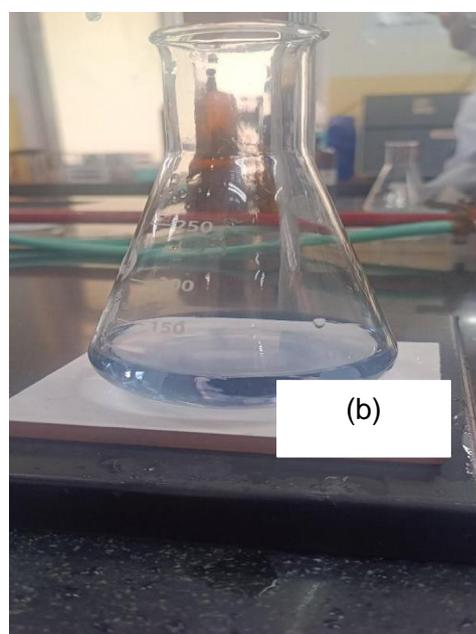
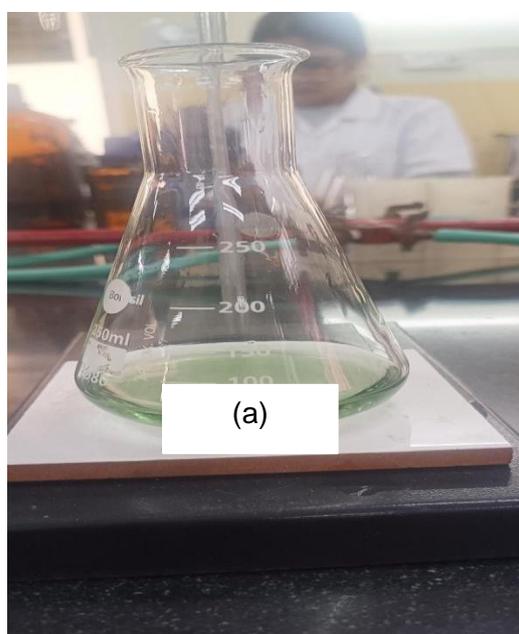


Fig.2. Hardness of Sea Water Sample (a) standardization (b) Estimation



2) Determination of Coliform Count (MPN Method)

Coliforms are gram-negative, rod-shaped, non-spore-forming bacteria that ferment lactose with the production of acid and gas at 35–37°C. While commonly found in the feces of warm-blooded animals, they also occur in soil, vegetation, and aquatic environments. Due to their presence in fecal matter, coliforms are widely used as indicators of water quality and possible contamination. The Most Probable Number (MPN) method is a standard bacteriological technique used to estimate the number of coliforms in a water sample based on lactose fermentation. The presence of acid and gas in selective media indicates positive growth. Based on the number of positive tubes, McCarty's MPN table was used to determine the coliform count.

The coliform counts for each beach are summarized below:

Beaches	MPN Count
Aksa	0
Marve	0
Rajodi	8
Versova	0
Bandra	0

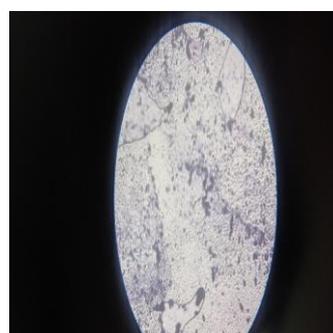


Fig. 3. Determination of Coliform Count (a) Turbidity and gas observed in Rajodi water sample. (b) Gram positive staining for Bandra water sample

3. Measurement of electrical conductivity (Conductometer Method)

Electrical conductivity (EC) is a measure of water's ability to conduct electric current, determined by the presence of dissolved inorganic ions such as chlorides, sulfates, nitrates, sodium, calcium, and magnesium. It is the reciprocal of resistivity and increases with ion concentration. In this study, conductivity was measured using a digital EC meter immediately after sample collection. The standard unit used is MilliSiemens per centimeter (mS/cm). While



NEQS guidelines do not specify limits for conductivity, it is often used to estimate Total Dissolved Solids (TDS). Seawater typically exhibits high conductivity due to its high salt content.

The table below shows the conductivity values recorded for each beach sample:

Sr no.	Seawater samples	Electrical conductivity (mS/cm)
1	Versova beach	1.01
2	Rajodi beach	1.02
3	Bandra beach	1.11
4	Aksa beach	1.49
5	Marve beach	1.07



Fig.4. Measurement of seawater conductivity using a conductivity meter

4. Measurement of pH (Digital pH meter):

pH measures the hydrogen ion concentration, indicating the acidity or alkalinity of a solution. Values below 7 are acidic, above 7 are basic, and 7 is neutral. Seawater generally has a slightly basic pH due to dissolved salts and carbonate ions. pH was determined using a calibrated digital pH meter equipped with a glass electrode. Automatic temperature compensation was employed to reduce temperature-related variation. Proper electrode maintenance, including rinsing with distilled water before use, was followed to ensure accuracy.

The pH values recorded for each beach sample are listed below:

Sr. No.	Sea water samples	Temperature(°C)	pH values
1	Versova beach	37°C	7.46
2	Rajodi beach	37°C	7.61
3	Bandra beach	37°C	7.94
4	Aksa beach	37°C	7.61
5	Marve beach	37°C	7.46



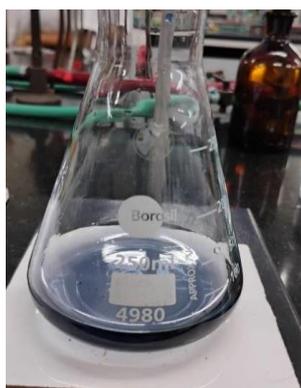
Fig.5. pH meter used to measure pH of seawater samples.

5. Determination of Dissolved Oxygen (Winkler’s Method)

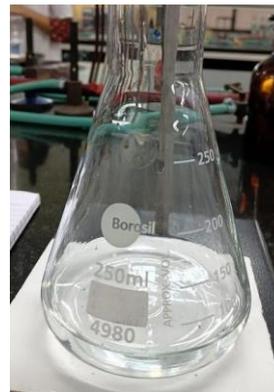
Dissolved Oxygen (DO) is the amount of oxygen dissolved in water, vital for aquatic life. Typical DO levels in healthy water are around 8 mg/L, with a minimum of 4–5 mg/L needed for survival. DO indicates water quality and pollution; low DO can harm aquatic organisms and cause chemical changes. It is also essential for monitoring wastewater treatment. DO was measured using iodometric titration, where the volume of sodium thiosulphate corresponds to the oxygen content:

$$\text{Dissolved oxygen} = \frac{\text{Volume of Sodium thiosulphate (ml)}}{\text{Volume of sample (ml)}} \times \text{Strength of Sodium thiosulphate (mg/L)}$$

Sr. No.	Seawater samples	DO (mg/L)
1	Aksa Beach	4.8
2	Marve Beach	5.6
3	Rajodi Beach	7.2
4	Versova Beach	2.8
5	Bandra Beach	6.4



(a) Before titration



(b) After titration



6) Estimation of Biological Oxygen Demand (5-Day BOD Test)

Biological Oxygen Demand (BOD) is the amount of oxygen consumed by microorganisms to decompose organic matter in water under aerobic conditions. It reflects the level of organic pollution — higher BOD indicates greater oxygen demand and more biodegradable waste. In this study, BOD was measured using the standard 5-day incubation method at 20°C. The difference between initial and final dissolved oxygen values was used to calculate BOD.

Formula: $BOD_5 = DO_{Day 1} - DO_{Day 5}$

The BOD values recorded for the set are shown below:

Sr. No.	Beaches	BOD (mg/L)
1	Aksa	4.725ppm
2	Marve	5.528ppm
3	Rajodi	7.056ppm
4	Versova	2.664ppm
5	Bandra	6.264ppm



Fig.7. Determination of biological oxygen demand

7) Determination of Salinity (Argentometric Titration Method)

Salinity refers to the concentration of dissolved salts in water, typically expressed in parts per thousand (ppt). It is a key factor influencing seawater density, marine ecosystems, and ocean circulation. Coastal salinity levels can vary due to freshwater inflow, rainfall, and human activity. In this study, salinity was determined using the argentometric titration method (Mohr’s method), where chloride ions in the sample react with standard silver nitrate solution in the presence of potassium chromate indicator.

Formula:

1) Chlorinity/litre = $\frac{\text{Estimated titre value} \times \text{Chlorinity equation} \times 1000}{\text{Volume of sample}}$

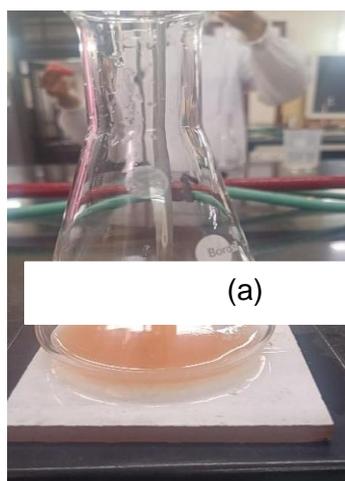
2) Salinity = $0.03 + (1.805 \times \text{Chlorinity})$

The constants (0.03 and 1.805) are derived from historical oceanographic data.



Results: The salinity values obtained from the seawater samples are as follows:

Samples	Salinity (in %)
Marve	18.92
Aksa	10.86
Bandra	17.47
Rajodi	10.61
Versova	25.42



(a)



(b)

Fig.8. (a) Standardisation for salinity

(b) Estimation for salinity

This research conducted a comparative assessment of the physical and chemical properties of seawater samples collected from five coastal locations. The table below summarizes the results across all measured parameters, providing insights into the water quality variations along the coastline.

Table 2: Sea Water Quality Parameters observed at different Beaches.

Parameters	Aksa Beach	Marve Beach	Rajodi Beach	Bandra Beach	Versova Beach
Salinity	10.86%	18.92%	10.61%	17.47%	25.42%
Hardness	1775ppm	2945ppm	1600ppm	2060ppm	3950ppm
pH	7.61	7.46	7.61	7.94	7.46
Electrical conductivity	1.49mS	1.07mS	1.02mS	1.11mS	1.01mS



DO	4.8ppm	5.6ppm	7.2ppm	6.4ppm	2.8ppm
BOD	4.725ppm	5.528ppm	7.056ppm	6.264ppm	2.664ppm
Coliform Count MPN	0	0	8	0	0

Interpretation and Conclusion :-

1) **Hardness:** Standard seawater has a hardness of 5,800–7,500 mg/L, while the sampled beaches showed lower values (1,600–3,950 ppm). This reduction may result from:

- Freshwater runoff, which dilutes seawater hardness.
- Urban and industrial effluents, altering mineral content.
- Local geography and tides, affecting ion concentrations.

These results suggest that local environmental conditions significantly influence hardness levels and merit further study

2) **Coliform count:** Coliform levels in seawater are typically high, but most sampled beaches showed negligible counts — except for Rajodi. This variation may result from:

- Environmental factors: Tidal dilution, high salinity, and sunlight can reduce coliform survival.
- Sampling factors: High-tide sampling or sampling away from sewage discharge can lower counts.
- Technical/lab factors: Delays in processing, poor storage, or heat exposure may reduce detectable bacteria.

These findings suggest that both environmental conditions and sampling protocols influence observed coliform levels.

3) **Electrical conductivity:**

Electrical conductivity in seawater is primarily influenced by salinity and temperature. Aksa beach showed the highest conductivity (1.49 mS), suggesting a higher concentration of dissolved salts, likely due to lower freshwater inflow or increased evaporation. In contrast, lower values at Versova, Rajodi, and Marve may indicate dilution from runoff or freshwater sources. Temperature also contributes, as warmer water increases ion mobility, slightly raising conductivity. Other contributing factors may include local geology and pollution, which can introduce additional ions into the water.

4) **pH:**

The pH of seawater samples ranged from 7.46 to 7.94, slightly less alkaline than typical seawater (~8.1). Beaches such as Bandra exhibited higher pH values, closer to normal seawater, possibly due to less pollution and better tidal flushing. pH variations are mainly influenced by dissolved carbon dioxide from organic matter decomposition, respiration, and



atmospheric absorption. Land runoff and pollution contribute additional acidic inputs, impacting pH levels through nutrient loading and subsequent algal decomposition.

5) DO:

DO values range from 2.8 to 7.2 ppm. Natural seawater typically requires DO levels above 5 ppm to support healthy marine life. Samples with DO above 5 ppm indicate well-oxygenated water, favorable for aquatic organisms. Conversely, samples with DO below 5 ppm, especially 2.8 ppm, suggest oxygen stress, which may threaten sensitive species and promote anaerobic conditions.

6) BOD:

BOD values between 2.664 and 7.056 ppm reflect the oxygen consumed by microorganisms during organic matter decomposition. Clean seawater usually has BOD below 3 ppm, indicating low organic pollution. Samples within this range suggest good water quality, while higher values point to moderate to significant organic pollution, likely from sewage or industrial effluents.

7) Salinity:

Salinity varied across the five Mumbai beaches, with several sites below the global average (~35 ppt) due mainly to freshwater from rainfall and river discharge. Although idol immersions during Ganpati Visarjan introduce pollutants and suspended solids, their direct impact on salinity is minimal. Previous studies also note salinity drops during monsoon and post-immersion periods caused primarily by freshwater influx.

Correlation Analysis of water quality parameters

Correlation is a statistical measure describing the strength and direction of a relationship between two quantitative variables, usually focusing on how closely they vary together in a linear way. A correlation coefficient (typically denoted *r*) ranges from -1 to +1, where values near +1 indicate a strong positive linear relationship and values near -1 indicate a strong negative linear relationship. A value near 0 suggests little or no linear association, though non-linear relationships may still exist; importantly, correlation measures co-variation, **not** causation.

Uses of correlation

- In **exploratory analysis**, correlation matrices reveal clusters of related variables and guide dimension-reduction techniques like principal component analysis and factor analysis.
- In **applied research** (e.g., environmental science, finance, health), correlations are used to quantify relationships, support or refute hypotheses, and screen predictors prior to building predictive or explanatory models.

	Salinity	Hardness (ppm)	pH	Electrical conductivity (mS)	DO (ppm)	BOD (ppm)	Coliform Count MPN
Salinity	1						



<i>Hardness (ppm)</i>	0.9517	1					
<i>pH</i>	-0.2859	-0.5588	1				
<i>Electrical conductivity (mS)</i>	-0.5317	-0.4508	0.12833	1			
<i>DO (ppm)</i>	-0.6934	-0.8049	0.52232	-0.0979	1		
<i>BOD (ppm)</i>	-0.6992	-0.8078	0.51594	-0.0849	0.99978	1	
<i>Coliform Count MPN</i>	-0.5469	-0.4951	-0.0171	-0.3358	0.6095	0.60073	1

Interpretation and Discussion:

Overall, this matrix shows extremely strong collinearity between some water-quality variables (especially DO and BOD), with salinity and hardness strongly associated and coliforms only moderately related to the physico-chemical measures.

1. Reconstructing key correlations

From the table:

- **Salinity** has very high positive correlation with hardness (0.9517) and moderately high negative correlations with pH (-0.2859), EC (-0.5317), DO (-0.6934) and BOD (-0.6992), and a moderate negative correlation with coliform count (-0.5469).
- **Hardness** correlates negatively with pH (-0.5588), EC (-0.4508), DO (-0.8049), BOD (-0.8078) and coliforms (-0.4951).
- **pH** shows a weak positive correlation with EC (0.12833), moderate positive with DO (0.52232) and BOD (0.51594), and essentially no relation with coliforms (-0.0171).
- **Electrical conductivity (EC)** is almost unrelated to DO and BOD (-0.0979, -0.0849) and has a small-to-moderate negative correlation with coliforms (-0.3358).
- **DO and BOD** have an almost perfect positive correlation (0.99978), indicating near-linear dependence.
- **Coliform count** shows moderate positive correlations with DO (0.6095) and BOD (0.60073), but only weak to moderate links with the rest.

2. Substantive interpretation

- **Salinity & hardness cluster:** Their near-unity correlation suggests they are essentially measuring the same underlying dimension (mineral content). Including both in a regression model will cause multicollinearity; one may be dropped or combined.



- **DO & BOD redundancy:** The 0.99978 correlation is so high that DO and BOD are practically interchangeable in this dataset; any multivariate model should not include both simultaneously, or variance inflation will be extreme.
- **pH as a bridging variable:** pH links weakly to EC but moderately to DO and BOD, suggesting that acidity/alkalinity relates more to oxygen demand than to ionic content in this sample.
- **Coliforms partly decoupled:** Microbial contamination (coliform count) is not strongly tied to salinity, hardness, or EC here, implying that pollution sources are more biological/organic than mineral. The moderate positive correlation with DO/BOD might reflect sites with high organic load and active decomposition rather than “clean” water.
- **Statistical cautions**
 - Magnitudes above about $|0.8|$ signal serious multicollinearity if used together in regression or PCA; salinity–hardness and DO–BOD clearly exceed this threshold.
 - Interpretation depends on sample size and context: with small n , even moderate correlations can be unstable; with large n , even small coefficients can be statistically significant yet practically trivial.
 - Correlation is symmetric and does not imply causation; these associations only describe linear co-movement, not directional effects.

Conclusion:

This study presents a comparative assessment of key seawater quality parameters at five Mumbai beaches—Aksa, Marve, Rajodi, Bandra and Versova. Results showed variations in hardness, salinity, pH, electrical conductivity, dissolved oxygen (DO), biochemical oxygen demand (BOD), and coliform counts across sites. Rajodi exhibited the highest BOD and coliform levels, indicating significant organic pollution and microbial contamination. Versova recorded higher hardness and salinity, reflecting elevated ionic concentrations. pH values remained slightly alkaline and stable across all beaches. Lower DO levels at Versova suggest oxygen depletion likely due to increased organic load and human activities. Wastewater discharge and commercial activities like shipbuilding and sand dredging further contribute to pollution and land use alterations. Conservation efforts, including regular pollution monitoring and integrated management of creeks, mangroves, and wetlands, are crucial for preserving the ecological balance in the coastal ecosystem and benefits to surrounding areas. These findings highlight the impact of urbanization, sewage discharge, tourism, and fishing on Mumbai’s coastal water quality. Regular monitoring, improved waste management, and public awareness are vital to prevent further degradation. The data provide a baseline for future assessments and support targeted conservation efforts to protect Mumbai’s coastal ecosystems.

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Efficacy of *Lemna minor* in Municipal Wastewater Phytoremediation

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Abstract:

The findings from a study on the use of the aquatic macrophyte *Lemna minor* (common duckweed) for the phytoremediation of municipal wastewater. The research, conducted in Chhatrapati Sambhajinagar, Maharashtra, demonstrates that *Lemna minor* is a highly effective, low-cost, and sustainable solution for improving sewage water quality.

Over a seven-day treatment period, the plant significantly reduced concentrations of key pollutants across various wastewater concentrations (20% to 100%). Notable results include reductions in Chemical Oxygen Demand (COD) by up to 65.6%, Biochemical Oxygen Demand (BOD) by up to 71.5%, and Total Nitrogen by up to 69.3%. Nitrate removal was nearly 100% in lower concentrations. The treatment also successfully lowered levels of suspended and dissolved solids, sulphates, and chlorides, while shifting the water's pH towards neutral. These findings confirm the potential of *Lemna minor*-based systems for decentralized wastewater management, particularly in resource-limited regions, as a viable green alternative to conventional, capital-intensive methods.

Background and Study Relevance:

Rapid urbanization has led to increased municipal wastewater generation, posing significant threats to public health and aquatic ecosystems. While effective, conventional treatment methods are often expensive and energy-dependent, limiting their application in economically constrained areas. Phytoremediation, the use of plants to remove or degrade environmental contaminants, has emerged as a cost-effective and ecologically sustainable alternative.

The aquatic plant *Lemna minor*, or duckweed, is recognized for its rapid growth, high nutrient uptake capacity, and resilience in polluted environments. It is known to absorb substantial amounts of nitrogen (N), phosphorus (P), and heavy metals. This study aimed to provide localized research by evaluating the efficiency of *Lemna minor* in treating municipal sewage under the specific climatic conditions and wastewater composition of Chhatrapati Sambhajinagar, Maharashtra. The primary objective was to quantify its effectiveness in reducing key water quality indicators such as BOD, COD, total nitrogen, and total phosphorus.

Experimental Design and Methodology:

The study was designed to measure the phytoremediation potential of *Lemna minor* on domestic wastewater under controlled conditions.



- **Location and Duration:** The experiment was conducted from April to July 2023 in Chhatrapati Sambhajnagar, Maharashtra, utilizing wastewater collected from a local pond.
 - **Experimental Setup:** 200 grams (fresh weight) of *Lemna minor* were introduced into a rectangular cement tank (195 cm x 145 cm x 75 cm) filled with untreated wastewater. The plants were allowed to grow for seven days under natural sunlight.
 - **Wastewater Concentrations:** The experiment was conducted using five different concentrations of municipal sewage, diluted with water, to assess performance under varying pollutant loads: Set I (20%), Set II (40%), Set III (60%), Set IV (80%), and Set V (100%).
 - **Parameters Analyzed:** Physicochemical parameters of the wastewater were analyzed before and after the seven-day treatment period using standard methods outlined by the American Public Health Association (APHA, 1989). Key parameters included:
 - pH and Electrical Conductivity (EC)
 - Total Suspended Solids (TSS), Total Dissolved Solids (TDS), and Total Solids (TS)
 - Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)
 - Nutrients: Nitrates (NO_3^-), Phosphates (PO_4^{3-}), Ammoniacal Nitrogen (NH_4OH), and Total Kjeldahl Nitrogen (TKN)
 - Ions: Sulphates (SO_4^{2-}) and Chlorides (Cl^-)
- Analysis of Untreated Wastewater (Baseline)
- The initial analysis confirmed that pollutant levels increased directly with sewage concentration. The 100% concentration (Set V) represented the baseline for raw municipal sewage, highlighting its high contamination load and the need for treatment.
- **pH and EC:** The wastewater was slightly acidic, with pH values ranging from 6.2 to 6.6. Electrical Conductivity (EC) increased from 262 $\mu\text{S}/\text{cm}$ in 20% concentration to 812 $\mu\text{S}/\text{cm}$ in 100% concentration, indicating a high load of dissolved inorganic salts.
 - **Solids:** Total Suspended Solids (TSS) ranged from 26 mg/L to 125 mg/L, and Total Dissolved Solids (TDS) ranged from 42 mg/L to 209 mg/L, contributing to turbidity.



- **Organic Load:** Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) levels were high, reaching 106 mg/L and 215 mg/L, respectively, in undiluted sewage. These levels significantly exceed permissible discharge limits and indicate substantial organic pollution.
- **Nutrients:** Concentrations of nitrogen and phosphorus were elevated, with total nitrogen reaching 52.5 mg/L and phosphates reaching 12 mg/L. These high nutrient levels are a primary cause of eutrophication in water bodies.

The following table summarizes the initial physicochemical characteristics of the untreated wastewater across the five concentration sets.

Table 1: Initial Physicochemical Characteristics of Municipal Sewage

Parameter	Unit	Set I (20%)	Set II (40%)	Set III (60%)	Set IV (80%)	Set V (100%)
pH		6.2	6.3	6.4	6.5	6.6
EC	µS/cm	262	321	490	647	812
TSS	mg/L	26	50	74	103	125
TDS	mg/L	42	80	122	165	209
TS	mg/L	68	130	196	268	334
BOD	mg/L	21	43	64	85	106
COD	mg/L	45	91	129	181	215
NO ₃ ⁻	mg/L	0.1	0.5	1.3	1.6	3.1
PO ₄ ³⁻	mg/L	2.1	4.8	7.3	10.1	12
SO ₄ ²⁻	mg/L	14.9	29.8	44	61	75
Cl ⁻	mg/L	7.5	15.2	21.8	34	41
NH ₄ OH	mg/L	4	7.8	12.2	14.3	18
TKN	mg/L	11	21.5	32	42.1	52.5

Post-Treatment Results and Efficacy:

Treatment with *Lemna minor* resulted in substantial improvements in water quality across all tested concentrations. The plant demonstrated a multi-faceted ability to absorb dissolved pollutants, trap suspended particles, and facilitate the degradation of organic matter.

- **pH Neutralization and EC Reduction:** The pH shifted towards a neutral range (6.5 to 7.2). EC saw a significant decline, with a maximum reduction of 497 µS/cm in the 100% concentration set, indicating effective removal of dissolved ions.
- **Solids Removal:** TSS and TDS were effectively reduced. For instance, in the 100% concentration, TSS dropped from 125 mg/L to 66 mg/L, and TDS dropped from 209 mg/L to 158 mg/L. This is attributed to particle trapping and nutrient absorption.



- **Organic Load Reduction:** A significant decrease in organic pollutants was observed. In the 100% sewage, BOD fell by 49.2% (from 106 to 53.8 mg/L) and COD fell by 65.6% (from 215 to 74 mg/L). This points to efficient assimilation of organic nutrients and enhanced microbial degradation.
- **Nutrient Removal:** The most significant finding was the effective removal of nitrogen and phosphorus. Nitrates were reduced to nearly zero in lower concentrations. In the 100% sewage, total nitrogen was reduced by 69.3% (from 52.5 to 16.1 mg/L), and ammoniacal nitrogen was reduced by 61% (from 18 to 7 mg/L). This high nutrient uptake capacity is crucial for mitigating eutrophication.

The following table details the final water quality parameters after the seven-day treatment.

Table 2: Final Physicochemical Characteristics after Treatment

Parameter	Unit	Set I (20%)	Set II (40%)	Set III (60%)	Set IV (80%)	Set V (100%)
pH		6.5	6.9	7.0	7.1	7.2
EC	µS/cm	170	140	230	289	315
TSS	mg/L	17	22	51	62	66
TDS	mg/L	27	43	83	107	158
TS	mg/L	44	65	134	169	224
BOD	mg/L	7.7	15.0	19.1	24.2	53.8
COD	mg/L	17	34	53	64	74
NO ₃ ⁻	mg/L	0	0	0	0.2	0.5
PO ₄ ³⁻	mg/L	0.4	1.3	2.1	4.7	4.9
SO ₄ ²⁻	mg/L	5.1	10.2	15.0	19.9	27
Cl ⁻	mg/L	5.1	11.0	14.5	21.2	29
NH ₄ OH	mg/L	1.1	2.4	3.5	4.2	7.0
Total Nitrogen	mg/L	3.1	7.0	9.1	13.2	16.1

Quantitative Analysis of Pollutant Reduction:

The percentage reduction in contaminants provides a clear measure of *Lemna minor*'s efficiency. The plant showed high removal rates across most parameters, although efficiency was slightly lower in the 100% concentration set for some metrics, suggesting that very high pollutant loads might require longer retention times.

Table 3: Percentage Reduction in Key Physicochemical Parameters

Parameter	Set I (20%)	Set II (40%)	Set III (60%)	Set IV (80%)	Set V (100%)
EC	35.11%	56.39%	53.06%	55.33%	61.21%
TSS	34.62%	56.00%	31.08%	39.81%	47.20%
TDS	35.71%	46.25%	31.97%	35.15%	24.40%
BOD	63.33%	65.12%	70.16%	71.53%	49.25%
COD	62.22%	62.64%	58.91%	64.65%	65.58%
NO ₃ ⁻	100.00%	100.00%	100.00%	87.50%	83.87%



PO_4^{3-}	80.95%	72.92%	71.23%	53.47%	59.17%
SO_4^{2-}	65.77%	65.77%	65.91%	67.38%	64.00%
NH_4OH	72.50%	69.23%	71.31%	70.63%	61.11%
TKN	71.82%	67.44%	71.56%	68.65%	69.33%

Conclusion:

The study demonstrates that *Lemna minor* is highly effective for the phytoremediation of municipal wastewater. The significant reductions achieved in organic load (BOD, COD), nutrients (nitrogen, phosphorus), and solids confirm its potential as a sustainable and low-cost treatment technology.

Key Implications of the study:

- **Viable Green Alternative:** The findings position duckweed-based systems as an eco-friendly alternative to conventional wastewater treatment, which is often inaccessible in developing regions.
- **Eutrophication Control:** The plant's high efficiency in removing nitrogen and phosphorus is critical for protecting natural water bodies from nutrient-induced ecological damage.
- **Decentralized Treatment:** *Lemna minor*'s ease of application makes it suitable for decentralized, small-scale treatment systems in rural or resource-limited communities.
- While the overall performance was robust, the study notes that treatment efficiency for certain pollutants was less pronounced at the highest sewage concentrations. Future research is recommended to optimize operational parameters like plant density and water retention time to maximize removal efficiency, particularly for higher pollutant loads.

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Macrophyte Diversity in Jalna District: A Synthesis of a Floristic Survey

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Abstract

A comprehensive floristic survey of the aquatic ecosystems in Jalna District, Maharashtra, reveals a significant diversity of floating and free-floating macrophytes, with 20 to 21 species recorded across 13 plant families. This biodiversity indicates the ecological richness of the region's numerous reservoirs, ponds, and wetlands. The findings highlight a critical dichotomy: the presence of ecologically valuable native species, such as *Azolla pinnata* and *Nymphaea pubescens*, coexists with the widespread dominance of aggressive invasive species, most notably *Eichhornia crassipes* (water hyacinth), *Pistia stratiotes*, and *Salvinia molesta*. The proliferation of these invasive species, which form dense mats that degrade water quality and displace native flora, is strongly linked to anthropogenic pressures. Eutrophication, driven by agricultural runoff and domestic wastewater, creates nutrient-rich conditions that favor their rapid colonization. The study concludes that while Jalna's water bodies possess the potential for balanced aquatic ecosystems, they are under increasing threat. Key recommendations include the urgent implementation of regular monitoring programs, the development of control measures for invasive species, and the creation of conservation strategies to protect native aquatic plant communities and ensure the long-term ecological health of the region's water resources.

Keywords: Macrophyte diversity, Aquatic plants, Floating Macrophytes, Free-floating macrophytes, Phytoremediation.

1. Introduction

Aquatic macrophytes are essential components of freshwater ecosystems, playing a vital role in primary production, nutrient cycling, sediment stabilization, and providing critical habitat for aquatic organisms. This study focuses on two distinct groups:

- Floating Macrophytes:** Rooted in the substrate with leaves floating on the surface (e.g., *Nymphaea spp.*).
- Free-Floating Macrophytes:** Unattached to the substrate, drifting freely (e.g., *Eichhornia crassipes*, *Lemna spp.*).

These plants serve as important bioindicators of water quality, as their growth is highly responsive to nutrient enrichment. However, the unchecked proliferation of certain free-floating species, particularly invasive ones like *Eichhornia crassipes*, poses significant ecological and economic threats. These species can form dense canopies that reduce dissolved oxygen, displace native life, and impair human use of water for irrigation and recreation.



Despite the ecological importance of the numerous freshwater bodies in Maharashtra's Marathwada region, systematic documentation of macrophyte diversity, especially in Jalna District, is scarce. This study was initiated to fill that knowledge gap by conducting a comprehensive survey to document species diversity, frequency of occurrence, and ecological associations, thereby providing crucial baseline data for sustainable aquatic ecosystem management.

2. Profile of the Study Area: Jalna District, Maharashtra

Jalna District, located in the semi-arid, subtropical Marathwada region, provides a dynamic environment for aquatic plant communities.

- a) **Geography:** Situated in the Godavari river basin, the district covers 7,612 km² of a gently undulating basaltic plateau.
- b) **Hydrology:** The Godavari River forms its southern boundary, with major tributaries including the Purna, Dudhana, and Kundlika rivers. The district's water resources are managed through a network of reservoirs (e.g., Ghanewadi, Kalyangirija, Dhamna), farm ponds, and nearly 50,000 dug wells.
- c) **Climate:** The region experiences distinct monsoon (June-September), winter (October-February), and summer (March-May) seasons. Annual rainfall averages 650-750 mm, and temperatures range from a low of 9-10°C to a high of 42-43°C.
- d) **Water Management:** Recent community-based efforts, including desilting tanks and constructing recharge structures, have improved water availability, creating a mix of perennial and ephemeral aquatic habitats ideal for macrophyte growth.

3. Survey Methodology

A systematic, multi-step approach was employed to ensure a comprehensive assessment of macrophyte diversity and habitat characteristics.

- a) **Site Selection:** Representative sampling sites were chosen from diverse aquatic systems, including rivers, reservoirs, farm ponds, seasonal tanks, and wetlands, to cover a range of ecological conditions.
- b) **Survey Timing:** Field surveys were conducted seasonally during two key periods to capture peak biomass and diversity: post-monsoon (October-December) and pre-summer (March-May).
- c) **Data Collection:** A combination of visual search and a transect-quadrat method was used. Along transects laid perpendicular to the shoreline, 1x1 meter quadrats were used to identify species and visually estimate their percentage cover.
- d) **Biomass and Water Quality:** Plant specimens were collected for taxonomic confirmation and biomass analysis (fresh and oven-dried weight). Basic water quality parameters (pH, DO, TDS, etc.) were measured on-site, with samples collected for laboratory analysis of nutrients (nitrates, phosphates) and BOD.



- e) **Data Analysis:** The collected data were analyzed using descriptive statistics to calculate species richness, frequency, and abundance. The study also considered using the Ecological State Macrophyte Index (ESMI) to evaluate wetland health.

4. Key Findings: Species Diversity and Distribution

The survey identified a total of 20 to 21 species of floating and free-floating macrophytes belonging to 13 distinct plant families. The findings reveal a complex interplay between native biodiversity and the pressures of invasive species.

The following table presents a representative list of the species observed during the survey.

Sr. No.	Scientific Name (Family)	Common Name
1	<i>Azolla pinnata</i> (Azollaceae)	Feathered mosquito fern
2	<i>Chara vulgaris</i> (Characeae)	Common stonewort
3	<i>Eichhornia crassipes</i> (Pontederiaceae)	Water hyacinth
4	<i>Enhydra fluctuans</i> (Compositae)	Hinche sak
5	<i>Hydrocharis dubia</i> (Hydrocharitaceae)	Backer/ frog-bit
6	<i>Ipomoea aquatica</i> (reptans) (Convolvulaceae)	Water spinach
7	<i>Lemna gibba</i> (Araceae)	Fat duckweed
8	<i>Lemna minor</i> (Araceae)	Duckweed
9	<i>Nelumbo nucifera</i> (Nelumbonaceae)	Water lily/teratai
10	<i>Nymphaea pubescens</i> (Nymphaeaceae)	Hairy water lily
11	<i>Nymphoides cristatum</i> (Menyanthaceae)	Crested floating heart
12	<i>Nymphoides indicum</i> (Menyanthaceae)	Water snowflake
13	<i>Pistia stratiotes</i> (Araceae)	Water lettuce
14	<i>Salvinia auriculata</i> (Salviniaceae)	Water fern
15	<i>Salvinia molesta</i> (Salviniaceae)	Giant Salvinia
16	<i>Salvinia natans</i> (Salviniaceae)	Water fern
17	<i>Spirodela polyrhiza</i> (Spirodela, Araceae)	Duckmeat
18	<i>Spirogyra</i> (Zygnemataceae)	Water silk
19	<i>Trapa natans</i> (Trapaceae)	Water chestnut
20	<i>Wolffia globosa</i> (Lemnaceae)	Asian watermeal

4.1. Dominant and Invasive Species

A key finding was the widespread presence and dominance of several invasive or opportunistic species, particularly in nutrient-rich waters affected by agricultural runoff and domestic wastewater.

- a) ***Eichhornia crassipes* (Water Hyacinth):** This species was found to be the most widespread and aggressive colonizer, forming large, dense mats in reservoirs and irrigation ponds. Its dominance is a clear indicator of eutrophic conditions.



b) **Pistia stratiotes (Water Lettuce) and Salvinia molesta (Giant Salvinia):** These species were also observed forming thick mats, especially in shallow, slow-moving waters. Their dense canopies reduce light penetration and suppress the growth of native submerged plants, altering the ecosystem's structure.

4.2. Ecologically Significant Native Species

Alongside invasive species, the survey documented several native plants that indicate healthier aquatic conditions and contribute positively to the ecosystem.

- i. **Nymphaea pubescens and Nelumbo nucifera:** These floating-leaved plants were typically found in deeper, clearer parts of ponds and reservoirs. They are often indicators of moderately healthy ecosystems, helping to stabilize sediment and provide habitat for fish and invertebrates.
- ii. **Azolla pinnata:** This small, free-floating fern was notable for its presence in stagnant, shallow ponds. Through its symbiotic relationship with nitrogen-fixing cyanobacteria (*Anabaena azollae*), it can thrive in low-nutrient waters and has potential for use in phytoremediation and sustainable agriculture.
- iii. **Duckweeds (Lemna spp., Spirodela polyrhiza, Wolffia globosa):** These small, fast-growing species were observed co-existing in calm water habitats. They are highly efficient at nutrient uptake and are often used in wastewater treatment systems.

4.3. Family-Level Distribution and Ecological Implications

Analysis of the family-wise distribution of the 20 recorded species reveals patterns related to ecological strategy and habitat condition.

Sr. No.	Family of free floating / floating macrophyte	Number of Species
1	Areaceae	4
2	Azollaceae	1
3	Characeae	1
4	Compositae	1
5	Convolvulaceae	1
6	Hydrochaitaceae	1
7	Lemnaceae	1
8	Menyanthaceae	2
9	Nelumbonaceae	2
10	Potntederiaceae	1
11	Salviniaceae	3
12	Trapaceae	1
13	Zygnemataceae	1
Total	13 Families	Total 20 species

The families **Araceae** (4 species) and **Salviniaceae** (3 species) were the most dominant. Species within these families are known for their rapid vegetative propagation and ability to thrive in eutrophic conditions. In contrast, the presence of **Nelumbonaceae** and **Menyanthaceae** (2 species each) suggests the existence of more stable, less-disturbed habitats.



The family **Pontederiaceae** is represented by only one species, *Eichhornia crassipes*, yet its aggressive, invasive nature gives it a disproportionately large and disruptive ecological impact, often suppressing overall biodiversity.

5. Conclusions and Recommendations

The floristic survey of Jalna District confirms a notable diversity of aquatic macrophytes, reflecting the richness of its freshwater habitats. However, this biodiversity is under significant threat from the dominance of invasive species, which is a clear symptom of growing anthropogenic pressures, especially nutrient pollution from agriculture.

Based on these findings, the following actions are recommended:

- 1) **Systematic Monitoring:** Implement regular, long-term monitoring programs to track changes in macrophyte distribution, species composition, and biomass across seasons.
- 2) **Invasive Species Management:** Develop and apply targeted control measures to manage the growth and spread of invasive species like *Eichhornia crassipes* and *Salvinia molesta*.
- 3) **Conservation of Native Flora:** Create conservation strategies to protect and restore native aquatic plant communities, which are essential for maintaining ecological balance.
- 4) **Community Engagement:** Promote community awareness regarding the impact of nutrient runoff and the importance of preserving aquatic biodiversity.

Future research should focus on seasonal variations in macrophyte communities, precise biomass estimation, and a deeper analysis of the ecological roles these plants play to better inform water resource management and conservation efforts in the semi-arid landscapes of Maharashtra.

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Investigation of Submerged Aquatic Macrophytes in Jalna District, Maharashtra

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Abstract:

A comprehensive survey of the waterways in Jalna District, Maharashtra, reveals a rich and significant biodiversity of submerged aquatic macrophytes, documenting 22 distinct species across 9 families. The study identifies the Hydrocharitaceae family as the most dominant, comprising 9 species (41% of the total), followed by Potamogetonaceae with 5 species (23%). These macrophytes are cornerstone species, essential for maintaining the health of aquatic ecosystems by providing critical habitat, regulating nutrient cycles, and stabilizing sediments. However, these vital populations face considerable threats from eutrophication, pollution from sewage and industrial discharge, and a widespread decline in underwater light availability. While essential, the excessive growth of certain species can lead to negative consequences, including reduced biodiversity and obstruction of waterways. The findings of this investigation provide crucial baseline data for the conservation of water bodies, the management of plant growth, and the application of phytoremediation techniques to combat pollution in the Jalna District.

Key words: Aquatic macrophytes, Diversity of Macrophytes, Submerged macrophytes, Phytoremediation

1.0 Introduction

This investigation was conducted to systematically identify, document, and assess the diversity, abundance, and distribution of submerged aquatic macrophyte species within the major waterways, lakes, ponds, and wetlands of the Jalna District in the Marathwada region of Maharashtra. The primary objective was to establish a foundational dataset on species diversity, which is essential for developing effective conservation and management plans for the district's vital water resources. The research underscores the importance of these plants as bio-indicators of water quality and their integral role in the overall functioning of aquatic ecosystems.

Study Area Profile: Jalna District

- **Location:** Central Marathwada region of Maharashtra State, India, situated on the Deccan plateau.
- **Coordinates:** Between 19° 15' and 20° 32' North latitude, and 75° 36' and 76° 45' East longitude.
- **Geography:** Total area of 7,726 sq. km, comprising eight talukas. The terrain is predominantly flat, with the Ajanta and Satamala ranges being notable exceptions.
- **Climate:** The region has a dry, tropical climate with hot summers, mild winters, and a humid southwest monsoon season (June-September). The average annual rainfall is 725.80 mm.



- **Hydrology:** The district features two primary drainage systems: the Godavari River, which forms the southern boundary, and the Purna and Dudhna Rivers.

2.0 Key Findings on Macrophyte Diversity

The survey identified a total of 22 species of submerged macrophytes belonging to 9 distinct families, indicating a noteworthy level of biodiversity in the region's aquatic ecosystems.

2.1 Family-Wise Distribution of Species

The distribution of species across families is uneven, with two families accounting for the majority of the diversity. The Hydrocharitaceae family is the most prevalent, representing 41% of all identified species.

Sr. No.	Family of Submerged Macrophyte	Number of Species	Percentage of Total
1	Hydrocharitaceae	9	41%
2	Potamogetonaceae	5	23%
3	Ceratophyllaceae	2	9%
4	Pontederiaceae	1	5%
5	Lentibulariaceae	1	5%
6	Nymphaeaceae	1	5%
7	Haloragaceae	1	4%
8	Fabaceae	1	4%
9	Characeae	1	4%
Total	9 Families	22 Species	100%

2.2 Comprehensive List of Identified Species

The following table details the 22 submerged macrophyte species documented in the water bodies of Jalna District.

Sr. No.	Scientific Name (Family)	Common Name
1.	<i>Cabomba caroliniana</i> (Nymphaeaceae)	Fanwort
2.	<i>Ceratophyllum demmersum</i> (Ceratophyllaceae)	Coontail
3.	<i>Ceratophyllum submersum</i> (Ceratophyllaceae)	Soft Hornwort
4.	<i>Chara globularis</i> (Characeae)	Green algae
5.	<i>Elodea canadensis</i> (Hydrocharitaceae)	Canadian pondweed
6.	<i>Elodea densa</i> (Hydrocharitaceae)	Brazilian pondweed
7.	<i>Elodea trifoliata</i> (Hydrocharitaceae)	Pondweed
8.	<i>Heteranthera dubia</i> (Pontederiaceae)	Water stargrass
9.	<i>Haterrauthera limosa</i> (Hydrocharitaceae)	Blue mud plantain
10.	<i>Hydrilla verticillata</i> (Hydrocharitaceae)	Oxygen weed
11.	<i>Myriophyllum spicatum</i> (Haloragaceae)	Eurasian water milfoil
12.	<i>Najas graminea</i> (Hydrocharitaceae)	Water nymph
13.	<i>Najas indica</i> (Najadaceae)	Naiads
14.	<i>Potamogeton crispus</i> (Potamogetonaceae)	Curlyleaf pondweed
15.	<i>Potamogeton gramineous</i> (Potamogetonaceae)	Pondweed
16.	<i>Potamogeton nodosus</i> (Potamogetonaceae)	Longleaf pondweed
17.	<i>Potamogeton pectinatus</i> (Potamogetonaceae)	Sago pondweed
18.	<i>Potamogeton Perfoliatus</i> (Potamogetonaceae)	Pond weed / Redhead grass
19.	<i>Trifolium fragiferum</i> (Fabaceae)	Strawberry clover
20.	<i>Utricularia vulgaris</i> (Lentibulariaceae)	Bladderwort
21.	<i>Vallisneria natans</i> (Hydrocharitaceae)	Tapegrass
22.	<i>Vallisneria Americana</i> (Hydrocharitaceae)	Eelgrass / tapegrass



3.0 The Critical Ecological Role of Submerged Macrophytes

Submerged macrophytes are not merely passive flora but are active ecological engineers that perform numerous functions vital to the health and stability of freshwater ecosystems.

- **Primary Production and Habitat:** As primary producers, they form the base of the aquatic food web. Their physical structure creates complex habitats that provide food, shelter, and breeding grounds for a wide variety of organisms, including fish, macro-invertebrates, and zooplankton.
- **Water Quality Improvement:** They play a crucial role in maintaining clear water conditions by stabilizing bottom sediments to prevent resuspension, which reduces turbidity. Through photosynthesis, they release oxygen into the water, which is essential for other aquatic life.
- **Nutrient Cycling and Regulation:** Aquatic plants effectively accumulate and store biogenic compounds, particularly phosphorus and nitrogen, from the water column. This capacity helps regulate nutrient dynamics and can mitigate the effects of eutrophication.
- **Bio-indication:** Due to their sensitivity to environmental changes, the composition and health of macrophyte communities serve as reliable indicators of water pollution and overall ecosystem integrity.

4.0 Threats and Management Challenges

Despite their importance, submerged macrophyte populations are facing a global decline, with significant challenges to their survival and restoration.

4.1 Key Threats to Macrophyte Populations

- **Eutrophication and Pollution:** The influx of untreated sewage, industrial pollutants, and agricultural runoff leads to nutrient enrichment (eutrophication), which alters water chemistry and negatively impacts plant life.
- **Decreased Light Availability:** This is identified as a major factor contributing to the decline of submerged macrophytes. Algal blooms, spurred by high nutrient loads, increase water turbidity and block the sunlight necessary for photosynthesis.
- **Human Activities:** Artificially regulated water levels and the physical alteration of littoral (shoreline) zones in urban and managed water bodies constrain the habitats available for macrophyte growth.
- **Seasonal Changes:** Natural seasonal fluctuations can also cause a marked reduction in the diversity and abundance of aquatic plant populations.

4.2 The Risks of Excessive Growth

While beneficial, uncontrolled and excessive growth of macrophytes, often termed "aquatic weeds," can have detrimental ecological and practical consequences.

- **Reduced Biodiversity:** The development of dense, monotypic stands of a single invasive species can outcompete native plants, leading to a significant reduction in overall plant biodiversity. This, in turn, can negatively affect the diversity of fish and invertebrates that rely on varied habitats.
- **Exacerbation of Eutrophication:** The decomposition of large quantities of dead plant matter releases a substantial amount of organic matter and nutrients back into the water, which can deplete dissolved oxygen and worsen eutrophic conditions.
- **Physical Obstruction:** Overgrown macrophyte beds can impede water flow, block reservoir inlets, and severely disrupt recreational activities such as boating, swimming, and fishing.



5.0 Implications for Ecosystem Restoration and Management

The data gathered in this study provides a critical foundation for strategic interventions aimed at protecting and restoring aquatic ecosystems in the Jalna District.

- **Restoration Strategies:** The restoration of submerged macrophytes is a crucial aspect of rehabilitating hypertrophic urban lakes. A key strategy is to enhance underwater light availability, potentially through artificial means, to support plant growth and reproduction.
- **Pollution Control:** Understanding macrophyte diversity is vital for pollution control experts. These plants can be utilized in phytoremediation techniques to absorb and remove heavy metals and other contaminants from wastewater.
- **Informed Management:** The baseline data allows for the development of targeted management plans to control the excessive growth of nuisance species while promoting a diverse and healthy native plant community. This is essential for balancing ecological health with human uses of water resources.
- **Call for Further Research:** The study notes that submerged macrophytes have not been as thoroughly examined as other types, and more scientific investigation is required to fully elucidate their specific roles in shaping aquatic habitats and ecosystem functions.
- NotebookLM can be inaccurate; please double check its responses.

6.0 Conclusion:

The present investigation clearly demonstrates that the aquatic ecosystems of Jalna District, Maharashtra, support a rich and diverse assemblage of submerged aquatic macrophytes, represented by 22 species belonging to 9 families. The dominance of the Hydrocharitaceae and Potamogetonaceae families highlights their ecological adaptability and key role in the region's freshwater habitats. These macrophytes function as essential ecological components by enhancing primary productivity, stabilizing sediments, regulating nutrient cycles, improving water quality, and serving as reliable bio-indicators of aquatic health. Despite their ecological significance, submerged macrophyte communities in the district are increasingly threatened by eutrophication, pollution, reduced light penetration, and anthropogenic disturbances. At the same time, unchecked proliferation of certain species may lead to ecological imbalance and management challenges. Therefore, a balanced and informed approach to conservation and control is required. The findings of this study provide valuable baseline data for future monitoring, conservation planning, and sustainable management of freshwater bodies in Jalna District. Importantly, the documented macrophyte diversity indicates strong potential for the application of phytoremediation techniques in wastewater treatment and ecosystem restoration. Continued research, coupled with effective pollution control and habitat management strategies, is essential to preserve these vital plant communities and maintain the ecological integrity of the district's aquatic ecosystems.

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Assessment of quarterly variations in Oxygen demanding parameters (DO and COD) in Nandan Pahar Pond, Deoghar, Jharkhand, India.

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Abstract:-

Freshwater ecosystems play a crucial role in maintaining ecological balance and supporting human livelihoods. Among various water quality indicators, dissolved oxygen (DO) and chemical oxygen demand (COD) serve as key parameters reflecting the biological health and organic pollution status of aquatic systems. The present investigation assessed quarterly variations in oxygen-demanding parameters, specifically **Dissolved Oxygen (DO)** and **Chemical Oxygen Demand (COD)**, in **NandanPahar Pond**, a semi urban pond located at Deoghar district, Jharkhand, over four successive seasons from **July 2024 to April 2025**. The observed DO values ranged from **5.15–6.80 mg/L**, while COD varied between **9.8–39.6 mg/L**, indicating moderate organic loading with seasonal fluctuations. Higher DO concentrations were recorded during winter, whereas elevated COD values were observed during the monsoon season due to surface runoff and organic influx. The inverse relationship between DO and COD highlights biological oxidation processes and seasonal biogeochemical dynamics. Systematic water sampling and analysis following standard methods (APHA, 2017) revealed dynamic seasonal fluctuations in both DO and COD, reflecting the influence of **hydro-meteorological cycles and organic matter load**. The monthly data indicate that DO concentration was highest during **January 2025 (6.8 mg/L)** and lowest in **October 2024 (5.70 mg/L)**, illustrating a clear inverse relationship with temperature and supporting patterns observed in similar pond studies where DO peaks in cooler seasons due to enhanced solubility and reduced biological oxygen demand (e.g., studies in Kerala pond systems. Conversely, COD values exhibited a **marked decline** from **39.6 mg/L in July 2024 to 9.8 mg/L in April 2025**, indicating lower organic pollutant load in later seasons, possibly due to natural attenuation and reduced runoff inputs during dry periods. These results align with findings in freshwater reservoirs where seasonal changes significantly affect COD distribution.

Statistical examination using appropriate seasonal analysis confirmed significant temporal variability in both oxygen-demand parameters. Elevated COD in the monsoon quarter underscores the input of allochthonous organic matter from surface runoff and increased biological activity, while relatively higher DO in winter reflects favorable aeration and reduced



biochemical consumption processes. The contrasting patterns of DO and COD highlight the **interplay between physical conditions and biochemical oxygen demand**, crucial for understanding the ecological health of shallow pond ecosystems. These seasonal trends emphasize the need for continuous water quality monitoring to inform sustainable management strategies, particularly in semi-urban ponds influenced by both natural and anthropogenic factors. The findings suggest that NandanPahar Pond remains moderately impacted but ecologically stable, requiring continuous monitoring to prevent future degradation. This study contributes baseline information essential for sustainable freshwater management and environmental conservation planning in the region.

Keywords: Dissolved Oxygen, Chemical Oxygen Demand, Seasonal Variation, Freshwater Ecology, NandanPahar Pond, Water Quality Assessment.

Introduction:

Freshwater resources constitute one of the most vital natural assets for ecological stability, biodiversity conservation, and human survival. Water makes up around 70% of the Earth's surface, with 97.5% of it being salty and 2.5% being fresh. Of this 2.5%, less than 1% is accessible (Mishra 2023). Small freshwater bodies such as ponds and lakes play a significant role in groundwater recharge, nutrient cycling, and supporting aquatic biodiversity. However, increasing anthropogenic pressures—urbanization, agricultural runoff, domestic waste discharge, and climatic variability—pose serious threats to the ecological integrity of such water bodies. Leachates from waste dumps, partially treated or untreated wastewater, pollution from human settlements without proper sanitary infrastructure, and pollution from land use activities like agriculture are the key sources of ground water pollution in less industrialized areas, Sale et al.,(2019). Among the various physico-chemical parameters used for evaluating water quality, **dissolved oxygen (DO)** and **chemical oxygen demand (COD)** are considered critical indicators of aquatic health. DO reflects the amount of oxygen available for aquatic organisms, whereas COD indicates the concentration of oxidizable organic and inorganic matter present in water. It can determine the level of water contamination based on the lack of oxygen in the water and also can indicate the increased use of oxygen by organic substances in the water, Cantor (2009). Variations in these parameters directly influence metabolic processes, biodiversity, and trophic interactions within aquatic ecosystems. Algal vegetation adds green color to water, but water with too many slits appears brown. The presence of organic debris and iron causes the water to turn yellow, Nayar(2020). In the Indian state of Rajasthan, Mahesh Kumar and G. V. Mishra et al. (2024) investigated the causes and effects of water pollution on a variety of water bodies. Researchers like Verma et al. (2025), Sharma P. et. al., (2025) etc., have also done research on Physicochemical parameters and Limnology of water bodies. NandanPahar Pond, located in Deoghar district of Jharkhand, is a culturally and ecologically important freshwater body exposed to seasonal climatic fluctuations and moderate anthropogenic pressure. Despite its significance, systematic scientific studies evaluating its oxygen-demanding parameters remain limited. Therefore, the present investigation aims to assess seasonal changes in DO and COD and interpret their ecological implications.



Study Area:

NandanPahar Pond is situated in Deoghar district, Jharkhand, characterized by a subtropical monsoon climate. The region experiences hot summers, a monsoon season with moderate to heavy rainfall, and relatively cooler winters. The pond receives water from precipitation, surface runoff, and limited anthropogenic discharge from nearby settlements and recreational activities. The hydrological regime and shallow depth make the pond sensitive to seasonal changes, influencing temperature, oxygen solubility, and organic matter decomposition.

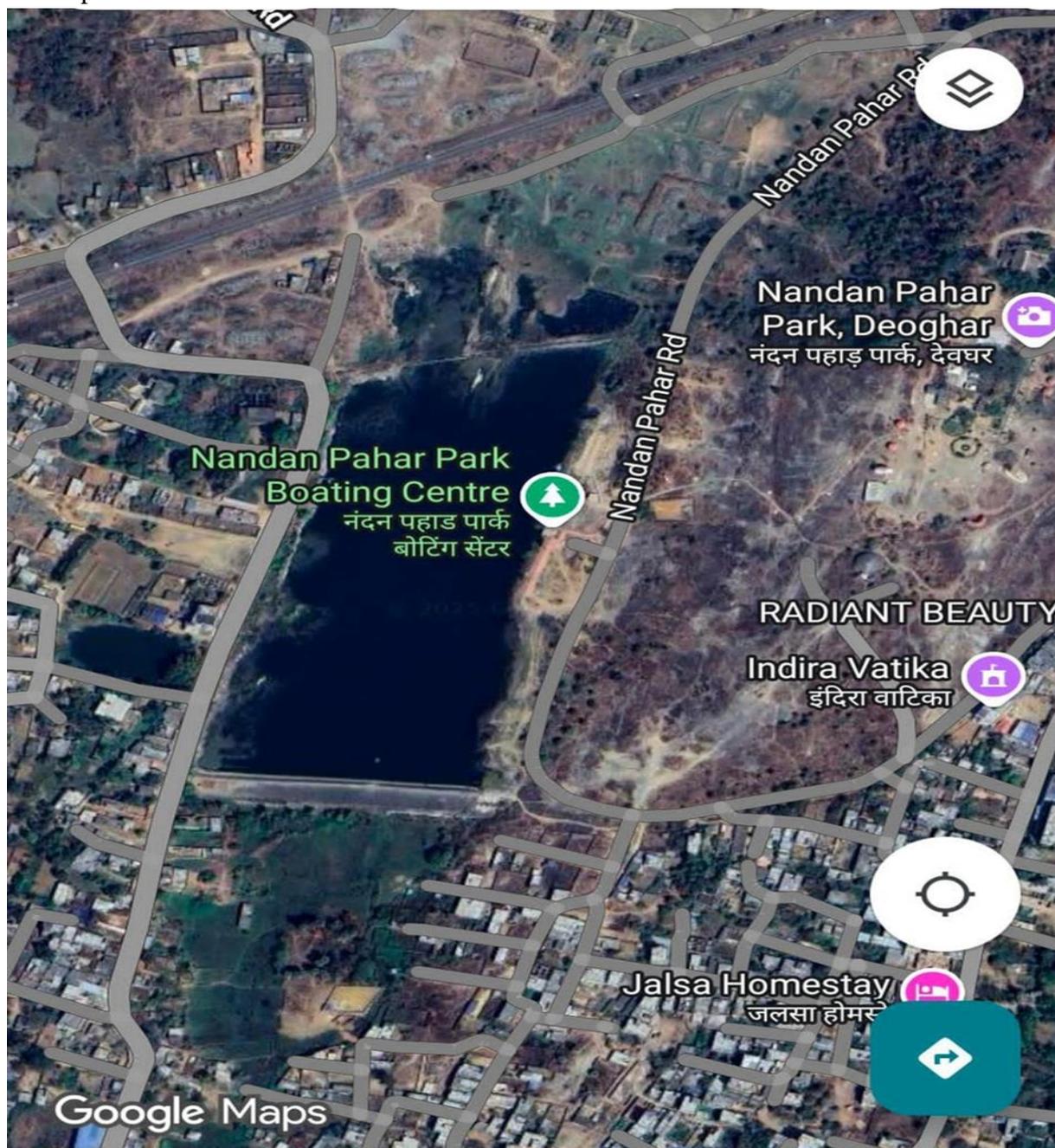


Fig1: Google Map view of Nandanpahar Pond, Deoghar, Jharkhand, India.



Materials and Methods:

Sampling Design

Water samples were collected quarterly representing four seasons -**July 2024 (Monsoon), October 2024 (Post-monsoon), January 2025 (Winter) and April 2025 (Pre-monsoon)**. Sampling was carried out during morning hours using clean, sterilized polyethylene bottles following standard sampling protocols.

Analytical Methods

Table-1: Process of measurement of oxygen demanding parameters -

Sl No	Parameters	Method follow (APHA, 2017, 23 RD Edition
1.	DO (mg/L)	4500-O-C :Oxygen (Dissolved) Determination By Azide Modification Of Winkler Method
2.	COD (mg/L)	5220-b :Chemical Oxygen Demand (COD) Determination By Open Reflux Method

All analyses were performed in triplicate to ensure accuracy and reproducibility. Research was conducted at CSIR Institute, Durgapur recognised by West Bengal pollution control board.

Results

Table 2: Quarterly variation of oxygen demanding properties of Nandanpahar Pond from July – 2024 to April – 2025.

Parameters	Units	Jul-24	Oct-24	Jan-25	Apr-25
DO	mg/L	5.8	5.70	6.8	5.15
COD	mg/L	39.6	15	9.72	9.8

DO concentrations remained within permissible limits for freshwater ecosystems, with maximum values recorded during winter due to lower temperatures and enhanced oxygen solubility. COD showed a clear declining trend from monsoon to winter and pre-monsoon periods, indicating dilution effects and reduced organic load during dry seasons. However, most of the values obtained for the physico-chemical parameters fell within the prescribed limit for tropical water bodies (McCaffrey, 2018)



Quarterly COD Distribution in Nandanpahar Pond (mg/L)

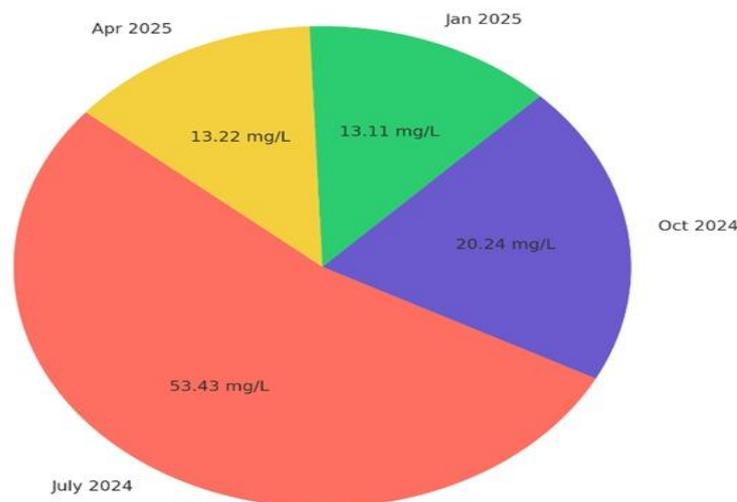


Fig. 2. Pie Chart Showing Quarterly COD distribution in Nandanpahar pond, Deoghar, Jharkhand

Quarterly DO Distribution in Nandanpahar Pond (mg/L)

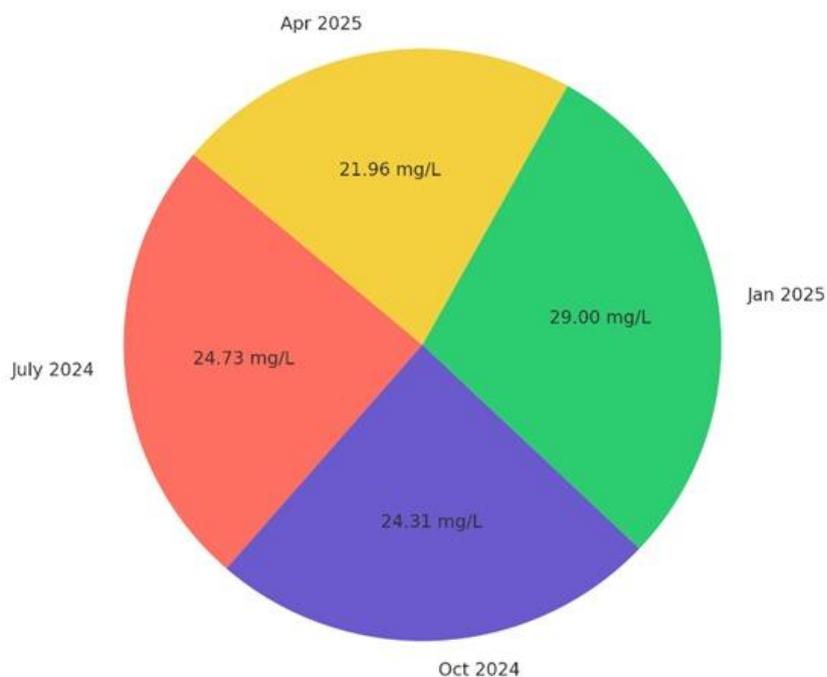


Fig. 3. Pie Chart Showing Quarterly DO distribution in Nandanpahar pond, Deoghar, Jharkhand.

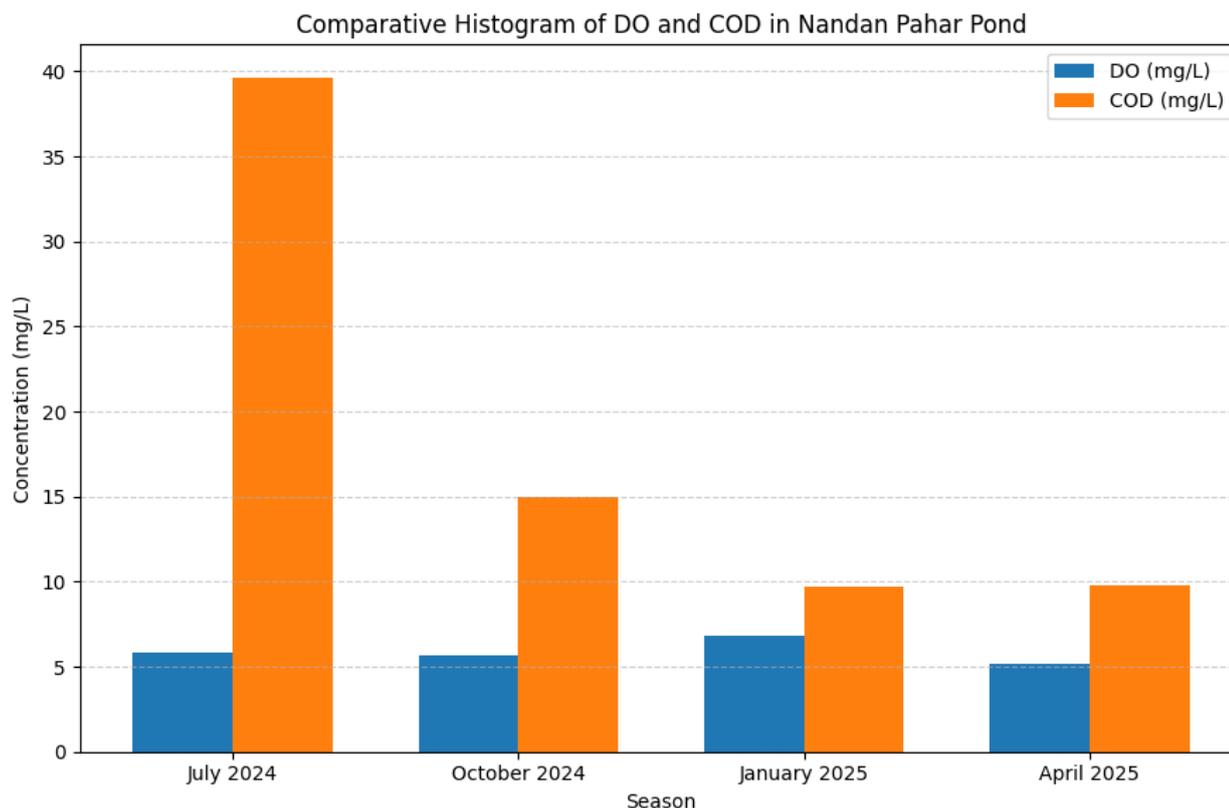


Fig.4. Quarterly comparative Histogram bar graph of DO and COD in Nandanpahar pond, Deoghar, Jharkhand, India.

Discussion:-

The DO concentration exhibited noticeable seasonal variation, with the highest value during winter (6.8 mg/L) and lowest during pre-monsoon (5.15 mg/L). This pattern aligns with temperature-dependent oxygen solubility, where cooler conditions enhance oxygen retention in water. DO was recorded as adequate generally above 4.0 in the present assessment, which is suitable for fish culture as a similar study reported in Panchobh village, Darbhanga district (Rani, 2019). The chief oxygen producers in ponds are phytoplanktons and aquatic plants. Temperatures are usually high during the pre monsoon season (May) allowing plants to synthesize oxygen through photosynthesis and release it into the Pond's water. The dynamic oxygen cycle of ponds has a higher DO during the day since phytoplanktons performs photosynthesis and respiration, Baxa et al., (2021). As a result of increased energy expenditure when feeding fish and swim the oxygen demand increases it is also known as specific dynamic action, McGaw and Whiteley, (2012). Additionally, reduced microbial activity during winter contributes to higher DO levels. The relatively stable DO values throughout the year indicate moderate ecological stability, supporting aerobic aquatic life. Temperature plays an important role in determining the DO in the water. The amount of oxygen that the water can hold depends on the temperature of the salinity and the water flow pressure, Kale (2016). The higher the DO value the better the quality of the water. On the other hand, the lower the value of DO obtained



then the lower the water quality will be, Arief(2017). Since we know that oxygen has a direct effect on feed intake metabolism and disease resistance, maintaining proper DO levels in the water is important for adequate production of fish (Begum, Mondal, Ferdous, Zafar and Ali, 2014). A sub-optimal level was very traumatic for fish and shrimp (Qian et al., 2012), so it is important to keep DO levels at optimum of above 4.0 ppm. Comparable seasonal trends have been reported in freshwater ponds across eastern India. Satya et al. (2018) investigated the physicochemical, and bacteriological characteristics of Ganga water in Patna, India. His findings revealed that untreated sewage is having a growing impact on the Ganga. Chemical oxygen demand is a test performed to determine the rate of oxygen consumption in water for the process of oxidising a solution that can dissolve in water and also oxidizing the particles or combinations of more than one particle called particulate Jaffar A. et al., (2020). Compared to BOD tests that take up to 5 days or more, COD tests take between two and three hours Tintometer (2015) and Ghalimath (2025). Like the BOD parameter, COD can provide an index to see the effects of discharges on the environment, Li.J et al., (2018). COD values were highest during the monsoon (39.6 mg/L), reflecting increased runoff carrying organic debris, soil particles, and biodegradable matter into the pond. A marked decrease during winter and pre-monsoon seasons suggests natural self-purification processes, sedimentation, and reduced external input. The inverse relationship between DO and COD observed in the present study indicates enhanced microbial oxidation of organic matter during warmer and wetter periods, which consumes dissolved oxygen. Chemical Oxygen Demand is the oxygen content of a sample that is equal to amount of organic matter that strong chemical oxidants like potassium dichromate and potassium permanganate may oxidise, Torrejon et al. (2023).

An inverse correlation between DO and COD was evident throughout the study period. Higher COD values during monsoon months corresponded with relatively lower DO, indicating increased microbial respiration. Conversely, lower COD during winter resulted in higher DO levels. Such interactions are widely reported in lentic ecosystems and serve as reliable indicators of water quality status. For survival, fish require 3-5 mg/L of DO. Direct and indirect information, such as bacterial activity, photosynthesis, nutrient availability, stratification, etc., are provided by its association with water bodies, Halim et al., (2018).

The observed DO and COD ranges in NandanPahar Pond are comparable with studies conducted in freshwater ponds of Jharkhand, West Bengal, and central India. Previous studies by reported DO ranges of 4.5–7.2 mg/L and COD values between 10–45 mg/L in semi-urban ponds, supporting the present findings.

Moderate DO levels support fish survival and microbial balance, while elevated COD during monsoon suggests periodic organic stress. Although current levels do not indicate severe pollution, continued anthropogenic activities could elevate organic loading over time. Preventive management is therefore essential to maintain ecological integrity.

Conclusion and Recommendations:-

The present study demonstrates clear seasonal variation in oxygen-demanding parameters of NandanPahar Pond. Dissolved oxygen remained within acceptable ecological



limits, while COD exhibited seasonal enrichment during monsoon months. The results indicate that the pond is moderately impacted but not critically polluted. Continuous monitoring, controlled anthropogenic activity, and sustainable watershed management are essential to preserve water quality and ecological stability. Sharma and Kumar (2025) suggested that anthropogenic activity in freshwater ponds can trigger eutrophication a process where increased nutrients promote the growth of algae and other microorganisms. As these microorganisms decompose they consume oxygen leading to low DO levels. The microbial breakdown of organic matter consumes Oxygen and this process could lead to A reduction in COD overtime. A reduction in COD suggest that the organic pollution in the water decreases. A study on the physical and chemical characteristics of wastewater effluents from industrial regions in Jaipur, Rajasthan, India, was conducted by Dhingra, P. Singh, et al. in 2015. and his findings showed that, if waste water from industrial areas is dumped directly into the ground, its temperature may have an impact on the texture of the soil .Regular seasonal monitoring of DO and COD should be implemented. Control of surface runoff and organic waste inflow is necessary during monsoon. Public awareness programs should be initiated to prevent dumping of waste. Long-term ecological assessment including biological indicators is recommended.

Funding:-

No funding interest

Competing interests:-

Authors have declared that no competing interests exist.

Acknowledgements:-

Author thankfully acknowledge the support of head and associate professor PG department of Zoology SidoKanhurMurmuUniversity Dumka, Jharkhand, India for his constant support and guidance and to CMERI CSIR lab Durgapur, West Bengal.

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Citation:-

- Pritam Sharma, Nilesh Kumar, and N.K. Mandal. 2025. "Assessment of Heavy Metal Contamination Due to Anthropogenic Activities in Shivganga Pond and Nandan Pahar Pond of Deoghar District, Jharkhand, India". *Asian Journal of Research in Zoology* 8 (4):207–218. <https://doi.org/10.9734/ajriz/2025/v8i4231>



Use of AI for Sustainable Development & Environment Protection

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Introduction:

The intersection of Artificial Intelligence (AI) and environmental science represents one of the most promising frontiers in the modern quest for global sustainability. As humanity faces unprecedented challenges ranging from accelerating climate change and biodiversity loss to resource depletion and rampant pollution, traditional methods of environmental management are proving insufficient. The introduction of AI technologies offers a transformative approach, providing the computational power necessary to analyze complex planetary data, optimize resource usage, and model future climate scenarios with unprecedented accuracy. This paper explores the dual role of AI as both an enabler of efficiency and a guardian of the natural world. By leveraging machine learning algorithms, satellite imagery analysis, and predictive modeling, stakeholders can make data-driven decisions that align economic growth with ecological preservation. However, the deployment of AI must be strategic; it requires a deep understanding of both technological capabilities and ecological necessities. This research aims to dissect the specific mechanisms through which AI contributes to the United Nations Sustainable Development Goals (SDGs), highlighting practical applications in energy, agriculture, and conservation. Ultimately, this paper argues that while AI is not a panacea, it is an indispensable tool in the urgent transition toward a greener, more resilient future for the planet.

Concept of AI

Artificial Intelligence (AI) refers to the simulation of human intelligence processes by computer systems, specifically the ability to learn, reason, and self-correct. At its core, AI encompasses a suite of technologies including Machine Learning (ML), Deep Learning, Neural Networks, and Natural Language Processing (NLP). Unlike traditional software that follows strictly pre-programmed instructions, AI systems operate by ingesting vast datasets to identify patterns, make predictions, and optimize outcomes over time. In the context of environmental protection, the "concept" of AI shifts from general automation to "Computational Sustainability." This involves using cognitive computing to solve problems that are computationally hard and dynamic, such as balancing a national power grid in real-time or tracking the migration of endangered species across fragmented habitats. The power of AI lies in its speed and scale; it can process satellite imagery of the entire Amazon rainforest in hours—a task that would take human analysts years. By converting raw environmental data into actionable intelligence, AI acts as a digital nervous system for the planet, enabling rapid responses to ecological changes that were previously imperceptible to human observation.



Concept of Sustainable Development

Sustainable development is a holistic approach to growth that seeks to meet the needs of the present generation without compromising the ability of future generations to meet their own needs. This definition, popularized by the 1987 Brundtland Report, anchors the concept in intergenerational equity. It is structurally supported by three primary pillars: Economic Viability, Social Equity, and Environmental Protection. True sustainability is not merely about conservation; it is about finding a balance where economic systems can thrive within the planet's ecological boundaries. It necessitates a shift from a linear "take-make-dispose" economy to a circular economy where resources are kept in use for as long as possible. The concept has been formalized globally through the United Nations' 17 Sustainable Development Goals (SDGs), which cover areas such as clean water, affordable energy, climate action, and life on land. Sustainable development requires systemic thinking—understanding how a decision in one sector, like agriculture, impacts others, like water security and biodiversity. It is a dynamic process of change in which the exploitation of resources, the direction of investments, and the orientation of technological development are all in harmony to enhance both current and future potential to meet human needs and aspirations.

Need of Sustainable Development & Environment Protection

The urgency for sustainable development and environmental protection has never been more critical, driven by the existential threat of planetary boundaries being breached. We are currently witnessing the "Great Acceleration," a period marked by exponential surges in human activity that are destabilizing the Earth's natural systems. Atmospheric carbon dioxide levels have surpassed 420 parts per million, driving global temperatures higher and causing extreme weather events—floods, droughts, and wildfires—that threaten food security and human safety. Simultaneously, we are in the midst of the sixth mass extinction, with biodiversity vanishing at rates hundreds of times higher than the natural baseline. The need for protection extends beyond nature; it is a matter of human survival. Fresh water sources are depleting, oceans are acidifying, and soil degradation is reducing arable land. Without immediate intervention to decouple economic activity from environmental degradation, we risk irreversible tipping points, such as the collapse of the polar ice sheets or the die-back of the Amazon rainforest. Sustainable development provides the only viable roadmap to mitigate these risks. It offers a framework to transition away from fossil fuels, reduce waste through circularity, and ensure that the benefits of development are shared equitably. The "need" is therefore not just ethical or aesthetic, but fundamental to the continuity of modern civilization and the health of the biosphere.

Use of AI for Sustainable Development & Environment Protection

1. **Smart Grid Optimization & Energy Management** AI algorithms are essential for modernizing electrical grids to accommodate renewable energy. Solar and wind power are intermittent; AI predicts weather patterns to forecast energy generation accurately. It balances supply and demand in real-time, reducing reliance on fossil-fuel peaker



- plants. This optimization significantly lowers carbon emissions and stabilizes energy infrastructure.
2. **Precision Agriculture and Food Security** AI-driven drones and sensors analyze soil health, moisture levels, and crop conditions with millimeter precision. This allows farmers to apply water, fertilizers, and pesticides only exactly where needed, drastically reducing chemical runoff and water waste. By optimizing yields per acre, AI ensures food security while minimizing the land footprint of farming.
 3. **Climate Modeling and Prediction** Traditional climate models are computationally expensive and slow; AI accelerates these simulations using deep learning. It can identify complex non-linear patterns in climate data, improving the accuracy of long-term global warming projections. Better predictions enable governments to plan more effective infrastructure adaptation and mitigation strategies against rising sea levels.
 4. **Biodiversity Monitoring and Anti-Poaching** Computer vision systems analyze camera trap images and audio sensors in forests to track wildlife populations automatically. In protected areas, AI analyzes movement patterns to detect potential poachers before they strike, alerting rangers in real-time. This technology acts as a force multiplier for conservationists protecting endangered species in remote areas.
 5. **Ocean Cleanup and Marine Life Protection** Autonomous aquatic drones powered by AI can navigate oceans to identify and collect floating plastic waste. Furthermore, AI systems analyze underwater acoustics to track marine mammals like whales, helping ships avoid collisions. These tools are vital for preserving marine ecosystems and mapping the health of coral reefs through automated image analysis.
 6. **Smart Water Management Systems** AI monitors municipal water infrastructure to detect leaks, which typically account for huge losses in urban areas. By analyzing pressure and flow data, it predicts pipe failures before they occur. Additionally, AI optimizes water treatment processes, reducing energy usage in plants and ensuring safe, clean water distribution to water-stressed regions.
 7. **Deforestation Detection and Prevention** Satellite imagery combined with AI algorithms can detect changes in forest cover in near real-time. This allows authorities to identify illegal logging or mining activities as they happen, rather than months later. Early detection is crucial for stopping deforestation in the Amazon and other critical carbon sinks, preserving global air quality.
 8. **Optimizing the Circular Economy** AI enhances the recycling process by powering robots that can sort waste more accurately and faster than humans. It also aids in designing products for longevity and recyclability by analyzing lifecycle data. This accelerates the transition to a circular economy where waste is designed out, and materials are kept in circulation.
 9. **Disaster Response and Early Warning** Machine learning models analyze seismic data, weather patterns, and historical records to predict natural disasters like earthquakes, floods, and hurricanes. AI-driven simulations help plan evacuation routes



and logistics for relief efforts. This rapid processing of data saves lives and minimizes the environmental aftermath of disasters.

10. **Urban Planning and Smart Cities** AI helps design greener cities by modeling traffic flows to reduce congestion and smog. It optimizes the placement of green spaces to combat the urban heat island effect. Furthermore, AI manages smart building systems (HVAC and lighting) to minimize the carbon footprint of dense urban environments.
11. **Carbon Capture and Storage (CCS) Optimization** AI accelerates the discovery of new materials (like metal-organic frameworks) that can absorb CO₂ efficiently. It also optimizes the operation of carbon capture plants to reduce their energy penalty. By making CCS more viable and cost-effective, AI contributes directly to reducing the net amount of greenhouse gases in the atmosphere.
12. **Supply Chain Sustainability** AI provides transparency in global supply chains by tracking products from raw material to retail. It helps companies identify inefficiencies and high-emission transportation routes. This data enables businesses to source ethically and reduce their Scope 3 emissions, driving industry-wide sustainability standards.
13. **Air Quality Monitoring and Forecasting** Hyper-local AI models use data from low-cost sensors to map air pollution at a street-by-street level. This empowers citizens and policymakers to take targeted actions to reduce exposure. Predictive models can also forecast pollution spikes, allowing for temporary traffic restrictions or health advisories.
14. **Material Science Discovery** AI accelerates the research and development of sustainable materials, such as biodegradable plastics or more efficient battery chemistries. By simulating molecular interactions, AI reduces the time needed for trial-and-error in the lab. This rapid innovation is key to replacing polluting materials with eco-friendly alternatives.
15. **Educating and Engaging the Public** AI-powered apps and chatbots provide personalized advice to individuals on how to reduce their carbon footprint. They can analyze personal spending or travel habits to suggest sustainable alternatives. This democratization of data empowers the general public to participate actively in environmental protection efforts.

Conclusion

In conclusion, the integration of Artificial Intelligence into sustainable development strategies represents a critical evolution in our approach to planetary stewardship. As explored in this paper, AI provides the analytical depth and operational speed required to tackle the complexity of modern environmental challenges, from optimizing vast energy grids to monitoring the minute movements of endangered species. The synergy between technology and ecology offers a pathway to decouple economic progress from environmental degradation, making the goals of the 2030 Agenda more attainable. However, this technological revolution is not without its paradoxes; the training of large AI models itself consumes significant energy



and water, a challenge that the tech industry must address through "Green AI" initiatives. Looking forward, the focus must shift from pilot projects to scalable implementations, supported by robust policy frameworks that ensure data privacy and equitable access to these tools. If steered responsibly, AI will not merely be a tool for efficiency, but a catalyst for a profound transformation in how humanity interacts with the natural world. The future of environmental protection lies in the intelligent synthesis of human wisdom and machine capability, working in concert to secure a habitable and thriving planet for generations to come.

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Role of Artificial Intelligence in Sustainable Development: A Case Study of Jalna District, Maharashtra

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Abstract

Sustainable development in agrarian regions like Jalna District, Maharashtra, faces significant challenges from climate change, water scarcity, and inefficient resource use. Artificial Intelligence (AI) emerges as a transformative tool to address these issues through precision agriculture, predictive analytics, and renewable energy optimization. This paper examines AI's role in enhancing sustainability in Jalna district, drawing on government initiatives like the Maha Agri-AI Policy 2025–2029 and local projects such as the Cropin-ATMA collaboration. By using AI for crop monitoring, pest management, and energy efficiency, Jalna district can achieve higher productivity and resilience. Findings indicate potential yield increases of 20–40% and reduced resource waste,

Keywords: Artificial Intelligence in Agriculture, Sustainable Development in Jalna District,

1.1 Introduction

Sustainable development, as elaborated by the Brundtland Report (1987), entails meeting present needs without compromising future generations' abilities. In India, agriculture supports 68% of rural livelihoods, yet it grapples with climate change, resource depletion, and low productivity. Jalna District in Maharashtra exemplifies these tensions: a drought-prone area in the Marathwada region, it relies heavily on rain-fed crops like wheat, Bajara, Jowar, soybean, cotton, and pulses, which cover over 80% of its cultivable land. Recurrent droughts, erratic rainfall, and soil degradation have led to crop losses exceeding 50% in severe years, exacerbating farmer distress and migration. Artificial Intelligence offers innovative solutions by leveraging data analytics, machine learning (ML), and Internet of Things (IoT) for real-time decision-making. In Maharashtra, the MahaAgri-AI Policy determine 2025–2029 allocates 500 crore to integrate AI across the agricultural value chain, aiming for climate-resilient farming and SDG alignment. This paper focuses on Jalna, exploring AI's applications in agriculture and irrigation and energy utilization, while addressing implementation barriers. Through secondary data analysis and case studies, it argues that AI can drive equitable, eco-friendly growth in Jalna district.

1.2 Study Area:

Jalna district is approximately situated at the central part of the Maharashtra state of Republic of India and northern direction of Marathwada region specially district lies between 19°01' North to 21°03' North latitudes and 75°04' East to 76°04' East Longitude. Jalna district erstwhile a part of Aurangabad district was formed on 1st May, 1981 by carving out Jalna, Bhokardan, Jafrabad and Ambad tahsils of Aurangabad district and Partur tahsil of Parbhani district. The boundaries of Jalna are adjacent to Parbhani and Buldhana on east, Aurangabad



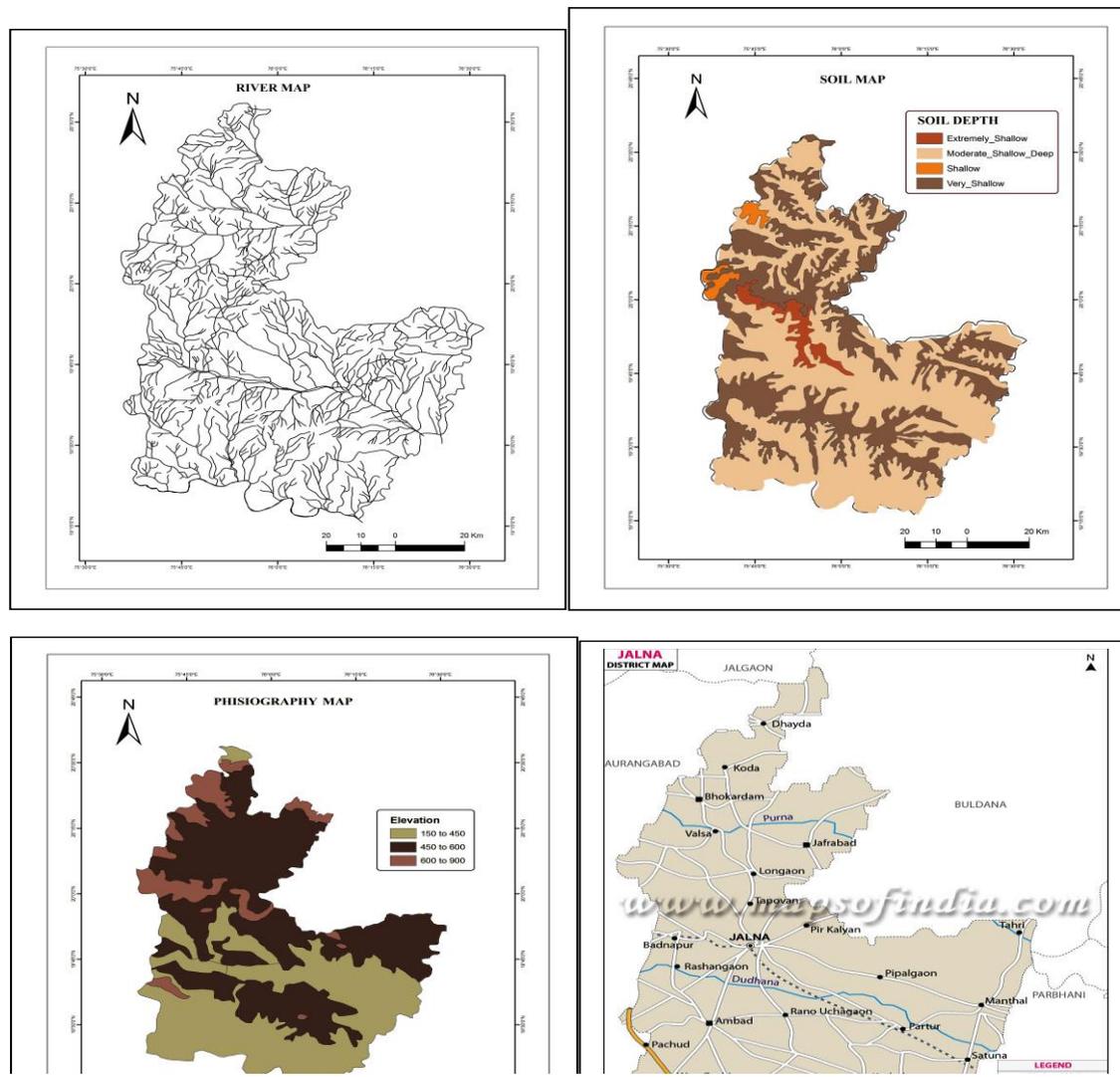
on west, Jalgaon on north and Beed on South. Jalna district covers an area of 7,612 sq.km which is 2.47 percent of the total state area of Maharashtra, and it has population of 16.12 lakh as per 2001 census. Recently Jalna district is divided into eight tahsil for administrations these are Jalna, Ambad, Bhokardan, Jafrabad, Badnapur, Partur, Mantha and Ghansawangi.

1.3 Objective –

To examine the development level of awareness of Artificial Intelligence technologies in various sectors of Jalna district **such as agriculture, irrigation, energy and rural development.**

To assess how AI-based tools and applications can contribute to sustainable agricultural practices in Jalna district.

Location map of Study area



Sustainability indices (SLSI), revealing Jalna's low ecological scores (0.45/1.0) but potential for AI-driven improvements in soil and water metrics.



Table No.1.1 AI Application in Jalna District

Sr.No.	AI Application	Key Feature in Jalna district	Expected impact
1.	Pest Surveillance (CROPSAP)	Real Time Advisers via Mahavistar App	20-30% crop failure reduction
2.	Yield Prediction (MAHAAGRI.AI)	Satellite + ML for Soyabeen/Cotton Forecast	30 % income increase
3.	Water Management	Io T fir Drip Irrigation Optimization	20 % water savings

Source-Renewable Energy and Climate Resilience

Maharashtra's Digital Twin initiative, launched in 2025, uses AI to model solar grids, enhancing rural electrification in Jalna district(Kusum Yojana by State Govt.) .By simulating renewable integration, it reduces pollution and supports off-grid solar pumps, aligning with SDG 7 (Affordable Energy).

1.6 Broader Ecosystem Integration

The MahaAgri-AI Policy funds startups for AI in supply chains, including Jalna's pulse exports, minimizing post-harvest losses (currently 15–20%). Voice-based chatbots like Kisan e-Mitra provide Marathi advisories, bridging digital divides.

1.7. Discussion

following conclusion has come out through AI's integration yields tangible benefits: In similar Maharashtra pilots, yields rose 40% for sugarcane, adaptable to Jalna's crops. Environmentally, reduced inputs lower emissions by 15–20%, aiding SDG 13 (Climate Action). Economically, it empowers 50,000+ Jalna farmers via apps, cutting costs by 30%.Challenges include low digital literacy (only 40% smartphone penetration in rural Jalna), data biases favoring large farms, and infrastructure deficits. Ethical AI deployment, as per MahaAgri guidelines, is crucial to avoid exacerbating inequalities.

1.8. Conclusion

AI plays vital role for Jalna district sustainable development, transforming vulnerabilities into opportunities through targeted interventions. The MahaAgri-AI Policy and local pilots like Cropin-ATMA provide a blueprint for replication, potentially elevating Jalna's Sustainability Index by 25% by 2030. Government should prioritize training, subsidies for IoT devices, and inclusive data ecosystems. Future research could quantify long-term ROI via longitudinal studies. Ultimately, AI not only sustains Jalna's agrarian heritage but fosters a resilient, equitable tomorrow.

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Animals Role in sustainability

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Abstract

Sustainability refers to ability to meet human development goals and enabling natural systems to provide necessary natural resources and ecosystems. The livestock farming serves the people in different ways to make them sustainable. The farming of livestock such as beef, cattle, swine, goat, sheep and fish play an important role providing a subsidiary income source for many families'. The agricultural and husbandry sector has been a boon of our country for a long time. The livestock farming helps people to provide empowerment and maintain sustainability.

Keywords: Sustainability, livestock, farming, production

Introduction

Livestock is the integral part of agricultural system and also a major entrepreneurial entity in the form of commercial specialized farming systems. The modernization and precision livestock farming system have succeeded to increase production and profitability .Sustainable development practices play an important role for the country's growth in various ways.it will in turn help to protect important natural resources for future generations.In India's society sustainable development is to promote the wellbeing of citizens by providing them with access to education,health care food production,housing and other basic needs Animal role is important in the context of sustainable development . conserving wildlife and their habitats is crucial to achieving the sustainable development growth and improving human well – being (IFAW) .The development of society is based on the existence of food resources .the FAO predicted a higher increase of the consumption of foods of animal origin by 2050 (Giuseppe, 2014). Growth in agricultural production and productivity is needed to raise rural incomes to support the increasing numbers dependent on the industry and to meet the food and raw material needs of the faster growing urban populations (martin,2004).

In animal farming systems of developing countries have an integral role and the full range of animal products are utilized.Animals also provide a strategic source of cash and help to alleviate poverty and increase household food security. FAO has attached the highest priority to sustainable development of both plants and animals in its programmes (FAQ1998).Farming of animals that are raised for meat ,fibers,milk or other products plays an important role in the economic sustainabilityof civilians.Livestock has played an indispensable role in the indian economy. Animal husbandary is culturally and economically integratedinto the society (Shanmathy et al., 2020) Animal husbandary has its role in empowering society and financial independence and sustainability.

Sheep and Goat production

Sheep and goat production includes the raising of animals for meat, fleece,milk,pets. Farming needs systems have intense management while others have little to no management. Sheep and goats play an important role in the indian economy and sources of livelihood and employment



to millions of rural households. Sheep and goats in India are mostly maintained on natural vegetation on common grazing lands, wastelands and uncultivated lands, stubbles of cultivated crops and top feeds (Shivakumara et al., 2020). In India for farmers sheep and goats is an insurance against crop failure and provides an alternate source of livelihood round the year. It provides a dependable source of income to 40 percent of the rural population below the poverty line. Mainly sheep and goats are reared for wool, meat and milk. Skin and manure constitute important sources of earning. Porwal (2007) findings show that the socioeconomic characteristics of the sample farmers indicate the majority of the sheep and goat rearing are important for their sustainability. Sheep and goats are particularly very useful and hardy animals and can be productive in the environmental conditions (Promod & Basanta 2021). Studies have shown that the distribution of goat and sheep varies between economically developed and developing countries. Sheep is almost equally distributed throughout the world. Particularly goat production fulfills important social and economic functions in arid and semi-arid areas of the lower central and upper southern regions of the world.

Beef Cattle Production

From the ancient period beef cattle production was done within a system that includes grazing on large amounts of land for farming. They were fed high-calorie food for a few months in large numbers and immediately prior to slaughter. These animals have long gestation and growth periods so that animals are sold. Texas (US) had the most cattle in 2023 followed by Nebraska and Kansas. The United States is the largest producer of beef in the world followed by Brazil, European Union, China and India. The livestock of beef and cattle plays an important role in the Indian economy. Studies have shown that 20.5 million people depend upon livestock for their livelihood. It contributes about 16 percent to the income for small farm households and an average of 14 percent for rural households. Three elements that always interact in household activity are production, income and consumption. Process of production, consumption, income and labor utilization of beef cattle farmers is influenced by government regulation. Cattle farmers have to work hard in order to increase their income and production. India has its significant role in livestock sector. Rural population as it employs a major section of country labour force and also provides a large share of draft power being used to farming crop land. India's livestock sector holding 11.6 percent of world livestock population, contributes GDP is 4.1 to 0.8 percent respectively (Islam et al., 2016).

Poultry Production

Poultry farming primarily for meat and eggs also for feathers. The mass production of chicken meat and eggs began in the early 20th century through small and specialized type of industrial producers. Today the market for chicken has grown worldwide reaching nearly about 13.8 million tons (Britannica). It generates employment for world and increase the income level of the people and eradicate poverty. It provides meat and eggs to the world population which is the rich source of the vitamins and proteins which play great role in health development. It is a short cut business for the farming communities (Naushad et al., 2021). Poultry farming in India, in spite of several constraints, has progressed considerably during the last decade.



(vetrivel,2013). In India poultry refers to village /unorganized poultry production because this enterprise operates in a low scale,using less capital and traditional technology. The unit volume of production is low due to the above constraints. All over the world poultry farming is a significant source of revenue generation for small in developing countries.It plays a vital role in fulfilling the dally protein requirements of humans through meat and eggs consumption.

Swine Production

Swineor Pig farming consists of raising and breeding of domestic pigs mostly for food and for their skin purpose. Pigs are able to recycle most materials and help farmers to reduce most feeding costs and waste. In comparison to other livestock rearing, the advantages of pig farming are extremely high. Pigs are the most prolific breeders with a high fecundity rate. The smallholders play an important role in securing the livelihoods of rural communities and their sustainability through pig farming.Countries like ESA and other developing countries such as India ,Vietnam and China are doing well in pig production (Cheng et al ,2011).Pig production plays an important role in the Socio-economic circumstances and sustainability of pig farmers.

Aqua Organisms Production

Aqua farming is the controlled cultivation of aquatic organisms such as fish,crustaceans ,mollusks,algae and aquatic weeds in all types of waters under controlledand semi natural conditions.Sustainable development of fisheries and aquaculture that would meet the the growing demand of food andnutritional needs of worlds teeming masses .Fish and fisheries play a vital role in the socio-economic development of the country by fulfilling the animal protein demand, creating employment opportunity, alleviating poverty of the large population and earning foreign currency. Fisheries and aquaculture contribute significantly to food security and livelihoods. Fish provides essential nutrition for nearly 3 billion people and at least 50% of animal protein and minerals to 400 million people from the poorest countries. Over 500 million people in developing countries depend, directly or indirectly on fisheries and aquaculture for their livelihoods (Nirmal Singh et al, 2019).The farmers along with fishermen community whose livelihood depends on only fish and fisheries. In India the importance of the fisheries sector in the socioeconomic development and as a source of livelihood for around 2.8 crore number of fishers,fish farmers,fish workers and fish vendors at the primary level several croresalong the value chain.The sector also contributed rupees 46,663 crores through exports during 2019-20 (Ministry of Fisheries ,Govt. of India).

The livestock serve the poor/Farmers in various ways.It is a source of subsidiary income for many families in our country, especially the resource poor who maintain few heads of animals.

Conclusion

Overall impact of animal welfare is very positive to the mankind. It is to be done by the people, for the livestock and ultimately for the benefit of people. It is mutually beneficial for the human and animal. The animal welfare is reciprocal and not unidirectional. After all existence of healthy livestock as a part of living beings is equally needed for a sustainable ecosystem. Momentum increase in production should be avoided; rather sustainable system of



production is the need for a perpetual environment. We ought to engage with nonhuman animals in best way possible keeping in mind for the wellbeing of animal, environment and the people. It is will be wise to view animal welfare from the ethical point of view. Necessarily the best way one engage with nonhuman animals is called ethics. The animal welfare and ethics are essentially important in the natural, organic, integrated and backyard farming systems to sustain a regular long term benefits.

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Relevance of Artificial Intelligence for Environmental Conservation

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Introduction

Environmental degradation has emerged as one of the most critical challenges of the twenty-first century. Rapid industrialization, population growth, urban expansion, and unsustainable consumption of natural resources have severely affected ecosystems. Climate change, deforestation, pollution, biodiversity loss, and water scarcity threaten both present and future generations. Traditional conservation methods, though valuable, are often limited by human capacity, time, and resources. In this context, Artificial Intelligence (AI) has gained global attention as a powerful technological tool. AI enables faster data processing, accurate prediction, and real-time monitoring of environmental changes. Governments, researchers, and environmental organizations are increasingly integrating AI into conservation strategies. AI-based systems support informed decision-making and efficient resource management. By enhancing precision and reducing human error, AI contributes significantly to sustainable environmental practices. Thus, understanding the relevance of AI for environmental conservation is essential in today's digital age.

Concept of Artificial Intelligence (AI)

Artificial Intelligence refers to the ability of machines to simulate human intelligence. It involves designing systems that can learn, reason, analyze data, and make decisions. AI operates through algorithms, machine learning, deep learning, and neural networks. These technologies allow computers to identify patterns from large datasets. AI systems improve their performance over time through experience. Unlike traditional computing, AI can handle complex and unstructured information. AI applications include image recognition, speech processing, prediction models, and automation. In environmental studies, AI processes satellite images and sensor data. It supports predictive analysis and risk assessment. AI reduces dependence on manual observation and field surveys. Hence, AI represents an advanced fusion of computer science and intelligent decision-making.

Need of Environmental Conservation

1. Protection of Biodiversity

Environmental conservation is essential to protect diverse plant and animal species. Loss of biodiversity disrupts ecological balance. Conservation ensures the survival of endangered species.

2. Climate Change Mitigation

Rising global temperatures demand urgent conservation measures. Forests and oceans act as carbon sinks. Conserving them helps reduce greenhouse gas emissions.



3. Sustainable Use of Natural Resources

Natural resources are finite and rapidly depleting. Conservation promotes their responsible and sustainable use. It ensures availability for future generations.

4. Protection of Forest Ecosystems

Forests regulate climate and support livelihoods. Deforestation causes soil erosion and habitat loss. Conservation maintains ecological stability.

5. Water Resource Management

Freshwater resources are under severe stress. Conservation helps prevent water pollution and wastage. It ensures clean water availability.

6. Control of Air Pollution

Industrial emissions and urbanization degrade air quality. Conservation encourages cleaner energy use. It improves human and environmental health.

7. Soil Conservation

Soil degradation reduces agricultural productivity. Conservation prevents erosion and nutrient loss. Healthy soil supports food security.

8. Marine Ecosystem Protection

Oceans support biodiversity and climate regulation. Overfishing and pollution threaten marine life. Conservation preserves oceanic balance.

9. Disaster Risk Reduction

Environmental degradation increases natural disasters. Conservation strengthens ecosystem resilience. It minimizes flood and drought impacts.

10. Public Health Protection

Environmental pollution causes serious health issues. Conservation reduces exposure to harmful substances. It promotes healthier living conditions.

11. Economic Sustainability

Natural resources support agriculture, tourism, and industry. Conservation ensures long-term economic stability. It prevents resource exhaustion.

12. Intergenerational Equity

Future generations have a right to natural resources. Conservation preserves environmental heritage. It ensures fairness across generations.

13. Urban Environmental Balance

Rapid urban growth strains natural systems. Conservation improves green spaces and air quality. It enhances urban sustainability.

14. Preservation of Ecosystem Services

Ecosystems provide food, water, and climate regulation. Conservation maintains these services. It supports human survival.

15. Ethical Responsibility

Humans have moral responsibility toward nature. Conservation reflects environmental ethics. It promotes harmony with nature.



Relevance of AI for Environmental Conservation

1. Climate Change Prediction

AI analyzes climate data to predict temperature and rainfall changes. It improves climate modeling accuracy. This helps in early planning and mitigation.

2. Wildlife Monitoring

AI-powered cameras track animal movement and population. It helps identify endangered species. This supports effective wildlife protection.

3. Deforestation Detection

AI processes satellite images to detect illegal deforestation. It provides real-time alerts. Authorities can take immediate action.

4. Disaster Management

AI predicts floods, cyclones, and droughts using historical data. It improves early warning systems. This reduces loss of life and property.

5. Air Quality Monitoring

AI analyzes pollution levels continuously. It predicts pollution trends. This supports effective environmental regulation.

6. Water Resource Management

AI detects water leaks and pollution patterns. It optimizes water usage. This ensures sustainable water management.

7. Waste Management

AI improves waste segregation and recycling. It identifies waste patterns. This reduces environmental pollution.

8. Renewable Energy Optimization

AI enhances efficiency of solar and wind energy systems. It predicts energy demand and supply. This promotes clean energy use.

9. Agricultural Sustainability

AI supports precision farming and soil analysis. It reduces chemical usage. This protects ecosystems and biodiversity.

10. Ocean Monitoring

AI tracks ocean temperature and pollution. It supports marine conservation. This protects marine biodiversity.

11. Urban Planning

AI assists in sustainable city planning. It analyzes traffic and pollution data. This improves urban environmental quality.

12. Environmental Policy Support

AI provides data-driven insights for policymakers. It improves decision-making accuracy. This strengthens conservation policies.

Conclusion

Artificial Intelligence has emerged as a transformative tool for environmental conservation. It enhances the capacity to analyze complex environmental data accurately and efficiently. AI



bridges the gap between environmental challenges and technological solutions. Through predictive modeling, AI supports proactive conservation measures. It enables real-time monitoring of ecosystems and natural resources. AI reduces human error and improves decision-making. It supports sustainable development goals at local, national, and global levels. However, ethical use and responsible deployment of AI are essential. Technological solutions must complement traditional conservation practices. Capacity building and data transparency are crucial for success. Governments and institutions must invest in AI-based environmental research. Public awareness and policy integration are equally important. AI cannot replace nature but can protect it. Thus, AI plays a vital role in ensuring environmental sustainability. Its relevance will continue to grow in the future. Environmental conservation through AI represents hope for ecological balance. Sustainable coexistence of technology and nature is achievable. Responsible innovation will define the success of AI-driven conservation.

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A Hybrid Mathematical--Artificial Intelligence Framework for Predictive Modelling in Environmental Economics

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Abstract

The increasing conflict between economic growth and environmental sustainability has created a clear need for dependable prediction tools in environmental economics. Conventional mathematical and econometric approaches provide strong analytical structure, yet they often face limitations when systems exhibit nonlinear interactions, uncertainty, and large, multi-source datasets. In contrast, artificial intelligence (AI) techniques have shown strong predictive strength through data-driven learning, particularly in complex environments. The present study proposes a hybrid analytical framework that integrates mathematical modelling, core economic reasoning, and AI-based prediction methods for environmental economic analysis. Dynamic pollution equations, welfare-based optimisation models, and representative machine learning architectures are discussed to show how these methods can complement each other. Conceptual tables and a framework description are used to highlight how mathematical transparency and AI adaptability together can improve predictive performance and strengthen policy relevance.

Keywords: Environmental Economics, Mathematical Modelling, Artificial Intelligence, Machine Learning, Sustainability, Forecasting.

1. Introduction

Environmental degradation linked with industrialisation, rising energy consumption, and population growth poses a serious challenge to long-term economic welfare and stability. Environmental economics addresses these issues by developing analytical methods that incorporate environmental costs into economic decision-making through the idea of internalising externalities. However, environmental-economic systems are typically complex due to feedback effects, nonlinear responses, and time-lagged impacts, which are not always captured adequately through traditional analytical approaches alone.

Mathematical modelling has remained central to economic analysis because it provides logical consistency, conceptual clarity, and disciplined interpretation. At the same time, AI has emerged as a useful tool for extracting patterns from large and heterogeneous datasets and for handling nonlinear relationships in forecasting tasks. Therefore, integrating mathematical structure with AI-based learning offers a practical direction for improving prediction and policy analysis in environmental economics. The present paper develops such an integrated



framework and explains its relevance for predictive studies and decision support in environmental policy.

2. Conceptual Foundations of Environmental Economics

Environmental economics examines how economic activities generate environmental externalities and how policy instruments may be designed to regulate them efficiently. A central concern is the interaction between economic output and environmental quality, where higher production may increase pollution and reduce environmental well-being if not regulated.

Let

$Y(t)$ denote economic output,

$P(t)$ denote accumulated pollution, and

$E(t)$ denote environmental quality.

A basic relationship can be expressed as:

$$E(t) = E_0 - \alpha P(t), \alpha > 0$$

This indicates that environmental quality declines as pollution accumulates over time, highlighting the need for regulation and effective forecasting within an environmental economic framework.

3. Mathematical Representation of Environmental Dynamics

3.1 Pollution Accumulation Models

Pollution accumulation is inherently dynamic and is naturally represented through differential equations. A widely used formulation is:

$$\frac{dP(t)}{dt} = \beta Y(t) - \gamma P(t)$$

Here,

β measures the pollution intensity linked with economic activity, and γ represents the natural regenerative or absorption capacity of the environment.

This formulation captures the long-run interaction between economic growth and environmental degradation and provides a tractable structure for analysing policy interventions over time.

3.2 Welfare-Based Optimization

Environmental regulation is also studied using welfare-maximisation frameworks that formalise the trade-off between economic benefits and environmental damages. A standard representation is:

$$\max \int_0^T [U(Y(t)) - D(P(t))] dt$$

subject to:

$$\frac{dP(t)}{dt} = \beta Y(t) - \gamma P(t)$$

In this setting, $U(Y)$ denotes the economic benefit derived from production, whereas $D(P)$ represents environmental damage associated with pollution. This structure supports the analysis of regulatory design by explicitly linking output decisions to environmental outcomes and welfare considerations.



Table 1: Mathematical Techniques Used in Environmental Economic Analysis.

Mathematical technique	Purpose	Policy use
Differential equations	Model pollution dynamics	Assess long-run environmental impact
Optimization methods	Maximise welfare objective	Support regulatory design
Statistical models	Estimate parameters from data	Enable empirical assessment
Dynamic systems	Study stability and behaviour	Evaluate sustainability conditions

4. Artificial Intelligence in Environmental Economic Forecasting

4.1 Rationale for AI Adoption

Environmental and economic datasets are now often large, multidimensional, and nonlinear in nature. AI methods are suitable for such data settings because they can learn complex relationships directly from observations and can improve predictive performance relative to purely linear approaches in many applications.

4.2 Mathematical Structure of AI Models

A general neural network representation may be written as:

$$\hat{y} = f(Wx + b)$$

Where

x represents economic and environmental inputs, W denotes trainable parameters, b is a bias term, and $f(\cdot)$ is a nonlinear activation function.

From a mathematical viewpoint, such models act as flexible function approximators and can represent nonlinear mappings that are difficult to specify in closed form using conventional econometric equations.

Table 2: Traditional Econometric Models versus AI-Based Predictive Models

Criterion	Econometric models	AI-based models
Functional form	Predominantly linear	Nonlinear
Data handling	Limited scale	Large-scale
Interpretability	High	Moderate
Prediction accuracy	Moderate	High
Adaptability	Low	High



5. Integrated Mathematical--AI Framework

5.1 Framework Description

The proposed framework integrates mathematical structure with AI-driven adaptability so that both theoretical meaning and predictive strength are retained. Mathematical models provide economic interpretation, constraints, and transparency, while AI algorithms learn complex relationships from observed data and improve forecasting where classical assumptions may be restrictive.

Figure 1: Conceptual Framework for Mathematical--AI Integration in Environmental Economic Prediction

Economic, environmental, and demographic indicators form the primary inputs. These inputs are structured using mathematical models and preprocessing techniques. Artificial intelligence algorithms then process the structured data to generate predictions of pollution and environmental quality. The predicted outcomes are interpreted through an environmental economic policy lens, creating a feedback mechanism for continuous refinement.

5.2 Predictive Formulation

Let the input vector be:

$$\mathbf{x} = (Y, E_c, N, T)$$

where

E_c denotes energy consumption,

N denotes population, and

T denotes technological progress.

The predictive relationship is expressed as:

$$P = f_{AI}(\mathbf{x})$$

This formulation extends conventional econometric prediction by allowing flexible nonlinear interactions among variables, while still permitting interpretation through the economic and environmental structure provided by the mathematical component.

6. Implications for Environmental Policy

The integrated framework can support environmental policy and planning by linking theory-driven structure with data-driven prediction. Key implications include the following:

- Improved long-term forecasting of pollution trends.
- Better comparison of alternative regulatory strategies under different assumptions and scenarios.
- Support for emission control measures and sustainability planning through scenario-based prediction.
- Stronger evidence base for policy decisions, particularly when multiple indicators must be analysed jointly.
- Overall, combining mathematical clarity with AI-based forecasting can strengthen both the design and evaluation of policy interventions.



7. Challenges and Limitations

Despite its potential, the hybrid approach faces limitations that must be acknowledged in academic and policy applications. Major concerns include sensitivity to data quality, reduced transparency for complex AI models, computational requirements, and ethical issues related to algorithm-supported decision-making.

Table 3: Challenges in AI-Based Environmental Economic Modelling and Possible Responses

Issue	Likely impact	Possible response
Data limitations	Forecast bias	Robust preprocessing
Model transparency	Policy scepticism	Explainable AI
Computational cost	Resource intensity	Model optimisation
Ethical concerns	Social implications	Regulatory safeguards

8. Conclusion

The present study outlines a hybrid mathematical--artificial intelligence framework for predictive analysis in environmental economics. Mathematical modelling contributes theoretical discipline and interpretability, whereas AI enhances predictive performance through adaptive learning from complex data. Together, the integrated approach provides a stronger analytical base for addressing contemporary environmental challenges and for supporting policy decisions through data-informed forecasting and evaluation.

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Mathematical Cosmological Models with Artificial Intelligence for Sustainable Universe Dynamics

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1. Abstract:

This work shows that the modern cosmological models using math. It considered on Friedmann–Robertson–Walker (FRW) cosmology, dark energy models, and non-singular bouncing universes. This study interprets cosmological sustainability as long-term stability, physical parameters quantities that can change, and the avoidance of initial and future singularities. It uses many methods such as differential equations, dynamical systems theory, stability analysis, and optimization methods, mathematical model as its core mathematical framework. In this study, we use artificial intelligence as a helpful computer tool for things like estimating parameters, fitting data, and classifying phase space. We designed it to make analysis more transparent, not to replace it.

The results show that complex math is still key to cosmological modeling, and AI can actually improve traditional analytical methods. This research is about artificial intelligence, sustainable development, and environmental challenges.

Keywords: Mathematical cosmology, FRW universe, Differential equations, Dynamical systems, Artificial intelligence, Sustainable evolution

2. Introduction

Cosmology is fundamentally a mathematical as well as physical science which gives the description and prediction of the large-scale structure and evolution of the Universe. Since its inception, the field of cosmology has relied on the principles of geometry, calculus, and differential equations to develop models of cosmic expansion. Observational discoveries, including cosmic MBR (microwave background radiation) and accelerated expansion of the universe, have further underscored the necessity for mathematically consistent cosmological models. In recent decades there are some works shows that the accelerated expansion of the universe has emerged as a particularly vexing problem in theoretical cosmology.

This phenomenon is commonly attributed to dark energy, an exotic form of energy characterized by negative pressure. Within the broader theme of sustainability, cosmological models may be interpreted through long-term stability and avoidance of catastrophic singularities. Bouncing cosmological models, which replace the initial Big Bang singularity with a smooth bounce, offer a mathematically sustainable framework. This paper explores such models using rigorous mathematical tools and demonstrates how AI can assist in analyzing their stability and observational viability.

3. Mathematical Preliminaries: The mathematical and physical framework of cosmology is based on differential geometry and tensor calculus which play vital role. The space-time



structure of the Universe is described by a four-dimensional Lorentzian manifold equipped with a metric tensor. The evolution equations governing this manifold arise from Einstein's field equations, which are nonlinear partial differential equations. In order to study global dynamics, these equations are often reduced to ordinary differential equations under assumptions of homogeneity and isotropy. Dynamical systems theory provides a natural mathematical language to analyze equilibrium points, stability, and long-term behavior of the give model sample.

4. FRW Space- Time Geometry

The Friedmann–Robertson–Walker metric represents the most general homogeneous and isotropic space-time and is given by

$$ds^2 = - dt^2 + a^2(t) \left[\frac{dr^2}{(1 - k r^2)} + r^2 (d\theta^2 + \sin^2 \theta d\phi^2) \right]$$

where $a(t)$ is the cosmic scale factor and k denotes spatial curvature. This metric reduces Einstein's field equations to a system of ordinary differential equations governing $a(t)$.

The Einstein field equations lead to the Friedmann equations:

$$H^2 = \left(\frac{8\pi G}{3} \right) \rho - \frac{k}{a^2} + \frac{\Lambda}{3}$$

$$\frac{dH}{dt} = -4\pi G(\rho + p) + \frac{k}{a^2}$$

These equations describe the expansion dynamics of the Universe. Conservation of energy-momentum yields the continuity equation

$$\frac{d\rho}{dt} + 3H(\rho + p) = 0$$

Dark Energy and Equation of State:

Dark energy is commonly characterized by an equation of state $P = \rho \omega$ where ω is a dimensionless parameter, P is the pressure, ρ is the density. Mathematical analysis shows that accelerated expansion occurs for the value $\omega < -1/3$. Various dark energy models shows different functional forms of ω , leading to distinct dynamical behaviors.

Dynamical System Analysis

By introducing dimensionless variables, the cosmological equations can be transformed into an autonomous system. Phase-space analysis allows classification of equilibrium points and determination of their stability properties. Stable fixed points correspond to sustainable cosmic evolution.

Bouncing Cosmological Models

A cosmological bounce is defined by the conditions $H = 0$ and $\frac{dH}{dt} > 0$. Such models avoid the Big Bang singularity and ensure bounded physical quantities. From a mathematical



standpoint, bouncing models represent globally regular solutions of the cosmological equations.

Stability and Energy Conditions

Classical energy conditions impose inequalities on energy density and pressure. Bouncing models often require violation of these conditions. Stability analysis ensures that such violations do not lead to physical or mathematical inconsistencies.

Artificial Intelligence in Mathematical Cosmology

Artificial Intelligence techniques are introduced as optimization and approximation tools. Neural networks and regression models assist in parameter estimation and classification of stability regions while preserving mathematical interpretability.

Sustainability in Cosmology

Sustainability in cosmology refers to long-term stable evolution, absence of singularities, and bounded solutions. Mathematical criteria derived from dynamical systems theory provide quantitative measures of sustainability.

Results and Discussion

The combined analytical and AI-assisted approach reveals that bouncing cosmological models provide stable and sustainable solutions under appropriate parameter ranges. AI enhances computational efficiency without replacing analytical reasoning.

Conclusion:

This full-length study demonstrates that mathematics remains the foundation of cosmological research. Artificial Intelligence acts as a complementary tool that strengthens analytical modelling. The work is well aligned with interdisciplinary themes while remaining deeply rooted in mathematical theory.

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Environmental No Impact Factor for Decision making on Pollutants

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Abstract:

The decision making process based on environmental impacts of pollutants can be mathematically expressed. It will be helpful for taking right decisions on discharge of water pollutants and emissions of air pollutants in the environmental recipient components. No effect release can be made possible by reducing the pollutants with suitable decision making for which the indicators for potential impacts from the produced pollutant release has to be developed as Environmental No Impact Factor (ENIF). With the development of suitable mathematical models, NEIF can be applied to different pollutant releases in order to select the best option for reducing the potential impacts from the released/discharged pollutants. The present paper describes the scientific aspects in brief for such model applicable for discharge of water pollutants, emission of air pollutants and release of soil pollutants by which decision making becomes easier.

Keywords: *Environmental Pollutants, Decision making, Pollutant release, Pollutant discharges, Environmental Effectss, Environmental Impact Assessment, modeling.*

Introduction:

When materials and goods are produced or finished, the pollutants are separated and discharged or released into the environment in the forms of air pollutants, soil pollutants or water pollutants. These contaminants may of organic or inorganic nature in the forms of different compounds. These pollutants may represent a potential for causing harmful impacts on the environmental components, mainly the biota in the recipient environment. The amount of pollutants discharged/released will normally at a later stage too and may exceed the limits of their assimilation in that environmental component. Therefore it becomes of a major concern for the environment and its management. This calls for the development of a suitable method for evaluating the potential environmental risks associated with these pollutants arising from their discharges/emissions or release.

The proposed method gives a quantitative measure of the potential risks and thus is able to form a strong basis for the reduction of such impacts in a scientific and systematic manner. This is based on the calculation of No Environmental Impact Factor similar to Dose related Risk and Effect Assessment model. The No Environmental Effect Factor is based on a Predicted Environmental Effect Concentration (PEEC) and Predicted Environmental No Effect Concentration (PENEC) assumptions. In this concept, the Predicted Environmental Effect



Concentration (PEEC) of the pollutant under consideration for the discharge/emission/release is to be compared with some threshold limits of Predicted Environmental No Effect Concentration (PENEC) for those pollutants. If the PEEC (Predicted Environmental Effect Concentration) is higher than the threshold PNEEC (Predicted Environmental No Effect Concentration), then there can be a risk for damaging impact. If the PEEC (Predicted Environmental Effect Concentration) is lower than the threshold PENEC (Predicted Environmental No Effect Concentration) then the probable risk for damaging impact can be considered as 'Acceptable'.

Predicted Environmental Concentration:

The PEEC (Predicted Environmental Effect Concentration) is time dependant variable concentration resulted in the receiving environmental component due to discharge/emission/release of pollutants. It can be calculated for all sort of pollutants and containment compounds which have potential for harmful effects on the biological components. These calculations can be made as per Does related Risk and Effect Assessment. It is helpful for calculating the behavior of pollutant in the receiving environmental component under the influence of various forces, processes like mixing, turbulence, temperature, degradation etceteras which may get generated for dynamic changes.

Predicted Environmental No Effect Concentration:

The Predicted Environmental No Effect Concentration (PENEC) denotes the lower limit at which the effect of pollutant under consideration on the recipient environmental component is encountered. Such level is almost derived for all major pollutants and is available in publically available common literatures. Such levels are obtained by experimental investigations after laboratory and field testing for each of these pollutants under considerations just like Lethal Dose 50, Lethal Concentration 50 or similar tests and No Observed Effect concentrations are derived and then the Predicted No environmental Effect Concentrations are obtained. For practical decision making assessment process, the considerable data from the work done is to be collected and reliability is to be tested and then assessment is to be carried out.

The Environmental Impact Factor:

The No Environmental Impact factor is related to recipient environmental component like air, soil or water for which the Ratio of PEEC (Predicted Environmental Effect Concentration) to PENEC (Predicted Environmental No Effect Concentration) is greater than 1 for any pollutant or group of pollutants or contaminant compounds. This ratio is related to the probability of damaging effect on the environmental recipients. If this ratio equals to 1, the probability of damage is equal to 5 percent. This ratio method has a major benefit over the other methods like screening of chemicals that it considers and can calculates the risk associated from the sum of chemicals or individual pollutants those are discharged/emitted or released. For calculating the total risk from a sum of pollutants, the Cumulative Risk is calculated by using the following probability relationship.



$$P(A + B) = P(A) + P(B) - P(A) * P(B)$$

Where, P(A) is the probability of environmental risk for compound A and P(B) is the probability of risk for compound B. For small risks (that is, P(A) and P(B) are both small), the risks can be considered to be linearly additive, approximately.

The total risk for a given discharge is calculated by means of the Dose Related Risk and Effect Model. The total risk contribution (in %) is calculated by this model for every point and time within the complete domain of the model. The total sum of risks for every individual pollutant and time is then summarized and converted back to a corresponding Ratio of PEEC (Predicted Environmental Effect Concentration) to PENECC (Predicted Environmental No Effect Concentration)

The Environmental Impact Factor is defined as the total mass of recipient environmental component where the PEC/PNECC > 1, divided by a unit volume of recipient component. In addition, the Environmental Impact Factor for recipient mass is adjusted upwards by a factor of two for those polluting compounds which have a small biodegradation factor combined with a large bioaccumulation factor (Johnsen et al., 2000) Such studies for produced oil and its impacts have been conducted and different aspects have been widely developed by various field workers (Johnsen et.al., 2000; Rye et.al., 2004; Reed et.al., 2001; Singaas et.al., 2008; EU, 1996; EU, 2003; EU, 2006; Karman, 1994, Karman, 1996; Karman and Reerink, 1997; Holguin-Veras, 1993)

An attractive feature of the Environmental Impact Factor consideration is that the method is also able to discriminate between the various pollutant contributors for environmental risks. In addition to show that the actual number for the Environmental Impact Factor, it can also show which of the polluting compounds, constituent chemicals or compound groups contribute to the environmental risks. This makes the present method more attractive in particular when the measures have to be chosen in order to arrive at the zero discharge/emission or release alternative option.

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Phytoremediation of Municipal Wastewater Using *Phragmites karka*

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Abstract:

The study on the phytoremediation capabilities of the emergent macrophyte *Phragmites karka* for treating municipal wastewater. The study, conducted using a constructed wetland (CW) model, demonstrates that *P. karka* is highly effective at reducing a wide range of pollutants. The CW system incorporating the plant showed markedly superior performance in removing contaminants—including suspended and dissolved solids, organic matter, and nutrients—when compared to a control system that relied solely on natural degradation processes.

The key conclusion is that the effluent from the *P. karka* treatment system meets the standards set by the Bureau of Indian Standards (BIS) for disposal and is suitable for various reuse applications such as irrigation, aquaculture, and gardening. This positions phytoremediation with *P. karka* as a viable, low-cost, and sustainable alternative to conventional, high-cost wastewater treatment technologies, particularly for expanding urban areas in developing nations like India. The research addresses the critical environmental challenge of water pollution driven by rapid urbanization while highlighting a nature-based solution that is both effective and economical.

1. Introduction:

Rapid urbanization, coupled with industrial and agricultural growth, has led to significant environmental degradation, with water pollution emerging as a primary concern. The reliance on outdated technologies often results in the discharge of untreated or inadequately treated wastewater into natural water bodies. In India, a minimal proportion of municipal sewage undergoes treatment. While large metropolitan areas may have treatment facilities, smaller cities frequently discharge untreated sewage directly into rivers and lakes. The primary cause of pollution in many water bodies, such as those in China, is nutrient enrichment from untreated phosphorus and nitrogen. Water pollution poses a direct threat to human health, limits usable water resources, and jeopardizes the sustainability of alternative water sources.



Limitations of Conventional Treatment Methods

Advanced wastewater treatment technologies, such as activated sludge systems and membrane technology, are standard in developed countries. However, their application in developing nations faces significant barriers.

- **High Costs:** These technologies involve substantial construction and operational expenses, making them impractical for many municipalities, especially smaller cities in India.
- **Chemical and Equipment Dependency:** Conventional methods rely on expensive equipment and chemicals, contributing to their high overall cost.
- **Inefficiency for Certain Pollutants:** In some cases, these systems struggle to reduce specific pollutants like heavy metals or nitrogen to acceptable levels.

The Constructed Wetland (CW) as a Sustainable Alternative

Constructed wetlands have emerged as an effective, economical, and sustainable solution for wastewater treatment, particularly for small communities.

- **Low Cost and Energy:** CWs are characterized by low capital and operational costs, minimal energy consumption, and relative ease of operation.
- **Natural Processes:** They utilize a combination of physical, chemical, and biological processes to treat wastewater, accommodating varying levels of organic content. The systems harness renewable energy sources like solar and wind.
- **Role of Macrophytes:** Vegetation is a critical component, enhancing purification through multiple mechanisms:
 - providing oxygen to microorganisms in the root zone.
 - Absorbing and breaking down nutrients like phosphates and nitrates.
 - enhancing the hydraulic conductivity of the substrate.
- **Historical Context:** The scientific use of macrophytes for water purification dates back to the early 1950s, pioneered by Dr. Kathe Seidel at the Max Planck Institute in Germany.

II. Experimental Design and Methodology

The study's objective was to assess the treatment efficacy of the emergent macrophyte *Phragmites karka* in a constructed wetland model for treating municipal wastewater.

Test Organism: *Phragmites karka*

- **Selection Rationale:** *Phragmites karka*, a type of reed grass, was chosen due to its local availability and proven success in previous studies treating both domestic and industrial wastewater.



- **Characteristics:** It is a tall, perennial aquatic plant belonging to the Gramineae family, capable of growing up to 4 meters in height. It thrives in moist, waterlogged environments and is native to tropical and subtropical regions of Asia.
- **Focus on Emergent Macrophytes:** The study highlights the ecological importance of emergent macrophytes, which are often overlooked in research compared to submerged species. Emergent vegetation can influence ecosystem processes, provide refuge for aquatic organisms, and is crucial for fish habitats in certain water bodies.

Experimental Setup and Procedure

- **Wastewater Source:** Municipal sewage was collected from a *nala* (drain) adjacent to the bridge near Nath Seeds on Paithan Road in Chhatrapati Sambhajnagar.
- **Reactors:** The experiment used polyvinyl chloride (PVC) crates as reactors, each with a working capacity of 32 liters of wastewater.
- **Treatment Groups:** Two sets of experimental conditions were established:
 1. **Macrophyte Set:** Reactors containing municipal wastewater and *Phragmites karka* plants (planted at a density of 25 plants per square meter).
 2. **Control Set:** Reactors containing only municipal wastewater to measure the effects of natural degradation without plants.
- **Acclimatization:** The *P. karka* plants underwent a one-month acclimatization period in domestic wastewater to enhance their resilience to pollution before being introduced to the experimental setup.
- **Data Collection:**

Wastewater samples from both sets were analyzed at regular intervals over a 15-day period (Day 1, 3, 6, 9, 12, and 15). The following parameters were measured using standardized methods: pH, Electrical Conductivity (EC), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Total Solids (TS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Nitrate (NO₃), Phosphate (PO₄), Sulfate (SO₄), and Chloride (Cl⁻).

Key Findings: Comparative Treatment Performance:

The study conclusively found that the application of *Phragmites karka* in a constructed wetland significantly enhances the treatment of municipal wastewater compared to natural processes alone. The plants exhibited robust growth throughout the experiment, showing no signs of phytotoxicity.

Baseline Performance: The Control Set (Natural Degradation)

In the control set without macrophytes, a slight but consistent reduction in pollutants was observed over the 15-day period. This gradual purification is attributed to the activity of naturally present microorganisms like bacteria and fungi.

Superior Performance: The *Phragmites karka* Set (Phytoremediation)



The treatment set containing *P. karka* demonstrated a substantially greater and more rapid reduction across all measured pollution indicators. The macrophytes played a direct and crucial role in absorbing nutrients and facilitating the breakdown of organic pollutants.

Net Pollutant Reduction by *Phragmites karka*

To isolate the specific contribution of the plant, the net change in pollution parameters was calculated by subtracting the reduction observed in the control set from the reduction in the macrophyte set. The following table summarizes the net reduction achieved by *P. karka* by Day 15 of the experiment.

Parameter	Initial Value (Day 1)	Net Reduction by Day 15
pH	6.77	+0.30 (net increase)
EC ($\mu\text{S}/\text{cm}$)	259	33
TSS (mg/L)	593	241
TDS (mg/L)	1062	404
TS (mg/L)	1655	645
BOD (mg/L)	46.72	20.0
COD (mg/L)	136	64
Nitrate (NO ₃) (mg/L)	28.4	9.5
Phosphate (PO ₄) (mg/L)	24	5.9
Sulfate (SO ₄) (mg/L)	168	77
Chloride (Cl ⁻) (mg/L)	228	79

Note: The net reduction values are sourced from the study's final summary table (Table 6).

Key Observations from Parameter Analysis:

- **Organic Matter (BOD & COD):** The macrophyte system achieved a significant net reduction in both BOD and COD, indicating effective removal of organic pollutants.
- **Solids (TSS, TDS, TS):** The presence of *P. karka* led to a dramatic decrease in all forms of solids compared to the minimal settling observed in the control.
- **Nutrients (Nitrates, Phosphates, Sulfates):** The plants were highly effective at nutrient uptake, a critical factor in preventing eutrophication. The nutrient removal rate was rapid in the initial treatment phases and continued throughout the study.

Conclusion:

The study concludes that municipal wastewater treated with *Phragmites karka* in constructed wetlands is of sufficient quality for various reuse applications. The significant reductions achieved in solids, organic demand, and nutrients render the effluent suitable for:

- Irrigation (including gardening)
- Aquaculture
- Cleaning and other secondary uses

Furthermore, the final pH and EC levels of the treated water meet the discharge standards set by the **Bureau of Indian Standards (BIS)** for land disposal, release into flowing water, and connection to public sewer systems.



Advantages and Future Scope:

This phytoremediation method presents significant advantages over conventional treatment systems, particularly in the context of developing nations.

- **Sustainability:** The system does not require electrical equipment or chemical additives.
- **Cost-Effectiveness:** It utilizes naturally available materials (plants, gravel, sand), resulting in low capital and operational costs.
- **Ecological Benefits:** The process enhances local biodiversity and ecosystem health.

Identified Limitations of Phytoremediation

While highly promising, the study acknowledges several limitations inherent to phytoremediation that require consideration and further research.

- **Time-Intensive:** The process is not rapid and can take several years to achieve target pollutant reductions in large-scale, deeply contaminated sites.
- **Depth Constraints:** Plant roots have a limited reach, making the method less effective for contaminants located deep in soil or sediment.
- **Climatic Dependence:** The effectiveness is influenced by climate, as the selected plant species must be able to thrive in the local environment.
- **Wildlife Impact:** A potential risk exists that animals may ingest contaminated plants, introducing pollutants into the food chain. This requires careful management in areas with abundant wildlife.

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Air Pollution in Aurangabad City (Chh.Sambhajinagar): A Study of PM₁₀, PM_{2.5}, SO_x, and NO_x Levels and Their Impact

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Abstract:

Air pollution has become a significant environmental and public health concern in Aurangabad, Maharashtra, due to rapid urbanization, industrialization, and vehicular emissions. This study aims to assess the levels of particulate matter (PM₁₀ and PM_{2.5}), sulphur oxides (SO_x), and nitrogen oxides (NO_x) in Aurangabad and evaluate their impact on air quality and public health. The data collected from air quality monitoring stations are alarming concentrations of these pollutants that exceed national air quality standards, leading to increased risks of respiratory diseases, cardiovascular conditions, and environmental degradation. The paper further explores mitigation strategies to improve air quality in the city and reduce the associated health risks.

Keywords: PM₁₀, PM_{2.5}, NO_x, SO_x

1. Introduction

Aurangabad, a historic city in Maharashtra, is facing growing challenges due to dust pollution. Known for its rich cultural heritage, the city is witnessing rapid industrialization and urban development. Dust pollution, primarily arising from vehicular emissions, construction activities, and road dust, has escalated over the past decade. This urban pollution not only compromises the quality of air but also poses a significant risk to human health and the environment. As the city expands, it becomes increasingly important to address dust pollution to ensure sustainable growth and improve quality of life. As a result, the air quality in the city has deteriorated, with pollutants such as particulate matter (PM₁₀ and PM_{2.5}), sulphur oxides (SO_x), and nitrogen oxides (NO_x) becoming a major concern. These pollutants contribute to several health problems, including respiratory illnesses, cardiovascular diseases, and premature deaths.

This paper investigates the levels of PM₁₀, PM_{2.5}, SO_x, and NO_x in Aurangabad, with a focus on their impact on air quality, human health, and the environment. The study uses data collected from air quality monitoring stations and relevant studies to provide a comprehensive analysis of air pollution in the city.

2. Air Pollution in Aurangabad: Sources and Causes

Air pollution in Aurangabad is primarily attributed to the following sources:

- **Vehicular Emissions:** The rising number of vehicles in the city, especially diesel-powered vehicles, is a significant source of nitrogen oxides (NO_x), particulate matter (PM_{2.5} and PM₁₀), and carbon monoxide (CO).



- **Industrial Emissions:** Factories, power plants, and other industrial activities in and around Aurangabad emit sulphur dioxide (SO₂), NO_x, and particulate matter. The cement industry and textile mills are major contributors.
- **Construction Activities:** Ongoing urban development projects, including infrastructure expansion and housing construction, contribute to dust pollution, leading to elevated levels of PM₁₀ and PM_{2.5}.
- **Agricultural Activities:** Crop burning in the surrounding rural areas of Aurangabad increases seasonal pollution levels, particularly for PM_{2.5} and NO_x.

3. Air Quality Data: PM₁₀, PM_{2.5}, SO_x, and NO_x Levels in Aurangabad

Air quality monitoring data from the indicate that the levels of PM₁₀, PM_{2.5}, SO_x, and NO_x in Aurangabad exceed permissible limits. The following table summarizes the concentrations of these pollutants:

Results

Table: 1

Location	Pollutant	Average Concentration (µg/m ³)	National Air Quality Standard (NAAQS)
Naregaon (chikalthana)	PM ₁₀	180 µg/m ³	100 µg/m ³
	PM _{2.5}	121 µg/m ³	60 µg/m ³
	SO _x	57 µg/m ³	50 µg/m ³
	NO _x	60 µg/m ³	40 µg/m ³

Table:2

Location	Pollutant	Average Concentration (µg/m ³)	National Air Quality Standard (NAAQS)
Baba Petrol Pump Chowk	PM ₁₀	135 µg/m ³	100 µg/m ³
	PM _{2.5}	89 µg/m ³	60 µg/m ³
	SO _x	38 µg/m ³	50 µg/m ³
	NO _x	31 µg/m ³	40 µg/m ³

- **PM₁₀:** The average concentration of PM₁₀ in Naregaon and Baba petrol pump chowk is found to be 180 and 135 µg/m³, which is significantly above the NAAQS limit of 100 µg/m³. The primary sources of PM₁₀ in the city include dust from construction activities, vehicle emissions, and industrial discharges.
- **PM_{2.5}:** With an average concentration of 121 and 89 µg/m³, PM_{2.5} levels in Naregaon and Baba petrol pump chowk also exceed the NAAQS standard of 60 µg/m³. Fine particulate matter, such as PM_{2.5}, is linked to severe respiratory diseases and cardiovascular conditions.



- **SO_x**: Sulphur oxides, primarily emitted from industrial processes, are within acceptable limits in the city, with an average concentration of 35 and excluding the Naregaon 57 $\mu\text{g}/\text{m}^3$ against the NAAQS standard of 50 $\mu\text{g}/\text{m}^3$.
- **NO_x**: Nitrogen oxides, primarily from vehicular emissions and industrial activities, have an average concentration of 45 and 31 $\mu\text{g}/\text{m}^3$, exceeding the permissible limit of 40 $\mu\text{g}/\text{m}^3$.

4. Health and Environmental Impact

• Human Health:

The elevated levels of PM₁₀ and PM_{2.5} in Aurangabad pose significant health risks. Exposure to particulate matter, particularly PM_{2.5}, has been associated with chronic respiratory diseases, such as asthma, chronic obstructive pulmonary disease (COPD), and lung cancer. Additionally, NO_x and SO_x can aggravate cardiovascular diseases and increase the risk of premature death. Vulnerable groups such as children, the elderly, and individuals with pre-existing health conditions are most at risk.

• Environmental Impact:

Air pollution in Aurangabad also affects the local environment. SO_x and NO_x contribute to the formation of acid rain, which can damage soil quality, crops, and water bodies. High concentrations of particulate matter reduce visibility and affect the natural beauty of the region, including its historical monuments. Additionally, ground-level ozone, formed due to the reaction of NO_x and VOCs, can damage vegetation and reduce agricultural yields.

5. Mitigation Strategies for Improving Air Quality

To address the issue of air pollution in Aurangabad, several mitigation strategies should be implemented:

- **Stricter Vehicular Emission Standards:** The introduction of stringent emission standards for vehicles, along with the promotion of electric vehicles (EVs) and cleaner fuels, can significantly reduce the levels of PM₁₀, PM_{2.5}, and NO_x.
- **Industrial Emission Controls:** Industrial facilities should adopt cleaner technologies, such as scrubbers and filters, to reduce emissions of PM, SO_x, and NO_x. Additionally, enforcing stricter pollution control measures and conducting regular inspections will help in ensuring compliance.
- **Green Spaces and Urban Planning:** Increasing the number of green spaces and promoting sustainable urban planning can help mitigate air pollution. Planting trees and increasing vegetation can absorb pollutants and improve air quality.
- **Public Awareness Campaigns:** Educating the public about the health risks associated with air pollution and promoting environmentally friendly practices, such as reducing vehicle usage and avoiding waste burning, can help reduce pollution levels.

6. Conclusion

Air pollution in Aurangabad is a growing concern that requires immediate attention from local authorities, industries, and residents. The levels of PM₁₀, PM_{2.5}, SO_x, and NO_x in the city exceed permissible limits, contributing to significant health problems and



environmental degradation. While some measures, such as air quality monitoring and industrial regulations, are already in place, more aggressive actions are needed to mitigate the effects of air pollution. Through stricter regulations, technological advancements, and public participation, it is possible to improve air quality in Aurangabad and protect the health and well-being of its residents.

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AI and Environmental Protection

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Introduction

Artificial Intelligence (AI) is a fast-growing technology that helps machines think and act like humans. It uses data, algorithms, and computing power to solve complex problems. Today, the world is facing serious environmental issues such as pollution, climate change, deforestation, and loss of biodiversity. These problems are increasing due to industrialization, population growth, and overuse of natural resources. Traditional methods of environmental management are often slow and less effective. AI provides new tools to observe, analyze, and protect the environment more efficiently. It can process large amounts of environmental data quickly and accurately. AI helps governments, scientists, and organizations take timely decisions. It improves prediction, monitoring, and control of environmental damage. By using AI, environmental protection can become more scientific and data-driven. Therefore, AI plays a vital role in achieving sustainable development and environmental conservation.

Degradation of Environment

- **Air Pollution**

Industrial emissions and vehicle smoke increase harmful gases in the air. This causes respiratory diseases and global warming. Poor air quality reduces human health and life expectancy.

- **Water Pollution**

Industrial waste and sewage are released into rivers and lakes. This affects aquatic life and drinking water quality. Polluted water spreads diseases.

- **Deforestation**

Large areas of forests are cut for agriculture and urban development. This leads to loss of biodiversity and climate imbalance. Forest loss increases carbon dioxide levels.

- **Soil Degradation**

Excessive use of chemical fertilizers damages soil fertility. Soil erosion reduces agricultural productivity. Degraded soil affects food security.

- **Climate Change**

Greenhouse gas emissions raise global temperatures. This causes extreme weather events like floods and droughts. Climate change threatens human and natural systems.

- **Loss of Biodiversity**

Natural habitats are destroyed by human activities. Many species face extinction. Biodiversity loss weakens ecosystems.



- **Plastic Pollution**

Plastic waste accumulates in land and oceans. It harms wildlife and marine life. Plastics take hundreds of years to decompose.

- **Urbanization**

Rapid urban growth reduces green spaces. It increases waste, pollution, and energy use. Cities become environmentally stressed.

- **Overuse of Natural Resources**

Excessive mining, fishing, and water use reduce resources. This creates scarcity for future generations. Resource depletion harms ecosystems.

- **Noise Pollution**

Traffic and industrial noise disturb humans and animals. It causes stress and health problems. Noise pollution affects quality of life.

Use of AI in Environment Protection

- **Climate Change Prediction**

AI analyzes climate data to predict temperature and rainfall patterns. It helps scientists understand future climate risks. Early warnings support disaster preparedness. This reduces damage to life and property.

- **Air Quality Monitoring**

AI systems monitor pollution levels in real time. They identify pollution sources accurately. Authorities can take quick action. Public health risks are reduced.

- **Water Resource Management**

AI detects water pollution and leakage in pipelines. It improves water conservation and distribution. Clean water availability increases. Wastage is minimized.

- **Wildlife Protection**

AI tracks animal movements using sensors and cameras. It prevents poaching and illegal hunting. Species protection becomes more effective. Biodiversity is conserved.

- **Forest Monitoring**

AI uses satellite images to detect deforestation. Illegal logging is identified early. Forest fires are predicted and controlled. Forest resources are protected.

- **Waste Management**

AI helps in sorting and recycling waste. Smart systems reduce landfill use. Recycling efficiency improves. Environmental pollution decreases.

- **Renewable Energy Management**

AI optimizes solar and wind energy production. Energy supply becomes more reliable. Fossil fuel dependence is reduced. Clean energy use increases.

- **Disaster Management**

AI predicts floods, earthquakes, and cyclones. Early alerts save lives. Emergency responses improve. Environmental damage is reduced.

- **Smart Agriculture**



AI supports efficient use of water and fertilizers. Crop yield improves with less environmental harm. Soil health is protected. Sustainable farming is promoted.

- **Urban Environmental Planning**

AI helps design eco-friendly cities. Traffic and energy use are optimized. Pollution levels decrease. Urban sustainability improves.

Conclusion:

Environmental degradation is a serious global challenge. Traditional methods alone are not enough to protect nature. AI offers advanced tools to monitor, analyze, and manage environmental problems. It improves accuracy, speed, and decision-making. AI supports climate action, biodiversity conservation, and pollution control. However, AI must be used responsibly and ethically. Data quality and human supervision are important. Governments and institutions should promote AI-based environmental solutions. Public awareness and policy support are also essential. In conclusion, AI can become a powerful partner in environmental protection. Proper use of AI will help achieve a sustainable and healthy future.

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Overview Of Doping Effect on Players and the Psychological Outcome Of The Problems in Hockey

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ABSTRACT:

The current sport scenario is facing threat, which creates a negative effect both on the players and on the whole game, irrespective of the type of game and the set of team or team players involved.

One such happening issue is “Doping”. The present study gives a details account on the happening problems and its negative effect in general and game specific, relating to Hockey. Doping refers to any banned drugs usages to enhance an individual’s performance in the sport. Such usages is a fake way of dealing with the actualized activity called sport and also has an impact of excited behavior in players, thus affecting his or her behavior and finally bringing in ill effects both at individual level and sport level. The idea of this thematic paper presentation is to throw light on the happenings of the problems of Doping in Hockey players and the disastrous outcome of the same. The expected outcome of the paper is to bring in more awareness and spread the same through “word by mouth” communication regarding the dangers of Doping, both directly and indirectly in the minds of sports players in general.

Introduction:

Burstim (1963) According to reports of Philostratos and Galen, various remedies were used to enhance the athletic performance as early as the end of the third BC. Chinery (1983) The Indian physician Sutruta recommended the eating of testicles to enforce virility around 300BC, and the Huns consumed testicles before battles obviously with the same aim. Hallucinogenic mushrooms were taken in the third century BC to enhance performance during Olympic competitions, which were held between 776 BC and 393 AD. These study clearly reveal that the threat of using drugs had began way back and now the intensity has increased and it’s high time that we need to set things right so as to motivate the real players and avoid gambling in the games.

Theoretical revelations of the study:

Due to the increase use of doping in many sport games, by the 1920s doping has become evident that drug restrictions were essential in 1963. Brent Hadley (2007) The use of performance enhancing drugs (referred to as ‘doping’) puts athletes’ health at risk and undermines the principles of “fair play”. Any artificial advantage for the athlete is not fair to others who rely on their natural potential. (IOC, 2004; “Lausanne declaration on doping in sport,”) France was the first country to enact an anti-doping legislation in response to the proliferation of drug usage in sport. Until 2005 the NHL had no formal anti doping policy. However, in the wake of scandals that dogged other major sports in recent years, the league unveiled its first such policy in September 2015 at a congressional hearing on drug use in



professional sports. Under the new policy, NHL players are subject to a maximum of two random tests with no advance notice during the NHL season for the performance-enhancing drugs designated on the World Anti-Doping Agency's (WADA) "Prohibited List" (2007, <http://www.wadama.org/enprohibitedlist.ch2>). A first-time positive test will result in a twenty-game suspension. The suspension increases to sixty games for a second offense, and a third positive test can result in permanent suspension from the league.

Health Risks of Steroid Use

Steroid abuse has been linked with a wide range of health hazards, both physical and mental. Among the

Drug	Division I				Division II				Division III			
	1993	1997	2001	2005	1993	1997	2001	2005	1993	1997	2001	2005
(n=1,423)	(n=6,123)	(n=8,773)	(n=8,543)	(n=68,253)	(n=4,863)	(n=4,343)	(n=40,533)	(n=7,523)	(n=6,493)			

Note: All N/A's reflect that questions regarding that drug were not asked in that particular year. n=sample size.

Amphetamines	2.1%	2.5%	3.2%	4.0%	2.0%	3.3%	3.3%	3.8%	1.9%	3.7%	3.7%	4.6%
Anabolic steroids	1.9%	1.2%	1.6%	1.2%	4.3%	1.1%	2.5%	1.2%	1.9%	1.3%	1.4%	1.0%
Ephedrine	N/A	3.0%	2.4%	2.4%	N/A	4.2%	4.1%	2.6%	N/A	3.8%	2.5%	2.6%
Nutritional Supplements	N/A	N/A	46.0%	33.4%	N/A	N/A	41.5%	27.9%	N/A	N/A	39.8%	28.1%

Physical problems are liver and kidney tumors, high blood pressure, elevated cholesterol levels, fluid retention, and severe acne. Ormsbee and Vukovich note that some studies associate steroid use with serious cardiovascular problems, including cardiomyopathies (inflammation of the heart muscle), irregular heart rhythm, development of embolisms (blockage of an artery by a clot or particle carried in the bloodstream), and heart failure. Men sometimes experience symptoms such as shrunken testicles; reduced sperm count, baldness, breast development, and increased risk of prostate cancer. Among women, growth of facial hair, male-pattern baldness, menstrual cycle disruptions, and deepening of the voice have all been reported. Adolescents who use steroids run the risk of halting their growth prematurely, as their bones fuse ahead of schedule. Another problem for teenagers is that steroids cause muscles to grow but do not strengthen the tendons that connect these muscles to bones. This can increase the risk of injury.



Emotional psychological problems stemming from abuse of steroids include extreme mood swings, depression, paranoid jealousy, irritability, delusions, and impaired judgment. Sometimes these steroid-induced mood swings lead to violent behavior, a condition popularly referred to as “roid rage.”

Mental Anorexia

This term means to be fearful of gaining weight, eating certain specific foods, be secretive and not wanting to talk about problems and not least over exercising. This mental block of the person will cause him to be unable to grow healthily and maintain a healthy lifestyle. Anorexia nervosa is also the direct opposite of bulimia nervosa, which means to stuff oneself with food so as to relieve stress.

Obsessive-Compulsive Disorder (OCD)

It is a type mental illness that causes someone to have repeated unwanted thoughts. A very good example would be: fearing that everything you touch has germs and bacteria and thus you keep heading to the bathroom to wash your hands. This illness is very severe. Doping is a major problem in Indian sport and NADA has been forced to become more proactive as it deals with one doping scandal after another, involving mainly athletes, wrestlers and weightlifters.

Keun-Youl (2005) study reveals some of the psychological and certain physiological effects of doping and they are Libido changes, Sub fertility, Decreased Luteinizing hormone and follicle-stimulating hormone. Increased aggressiveness and sexual appetite, sometimes resulting in aberrant sexual and criminal behavior. In Males Only: Impotence with chronic repeated use, testicular shrinkage (atrophy), breast enlargement (gynecomastia), prostatic enlargement, reduction of sperm production, premature baldness. In Female Only: masculinization/ Hirsutism, excessive hair growth on the face & body, deepening of the voice, enlargement of clitoris, abnormal menstrual cycles (suppression of ovarian function and menstruation), reduced breast size. Polycystic ovarian syndrome. Psychological effects / Behavior effects are Mood swings, Aggression, Mania, Depression, Withdrawal, and Dependence. (Cooper CJ et al, 1996) Direct cause of significant disturbances in personality profiles. Aggression and anxiety.

Consumption of too many drugs will lead to aggression and anxiety. For females especially, they will seem to develop more male characteristics. For males, too much aggression may lead to the murdering or doing illegal things to satisfy or relieve the surge of immense anger. Anxiety too plays a part by making the athletes paranoid over small and trivial matters.

Psychological disturbances

Athletes who are doping or used to dope have high risks of getting psychological disturbances such as sharp headaches. Stimulant doping drugs may lead to severe migraines in the athlete. This will affect the athlete's performance in their event, totally opposite of what the athlete really wants- to improve focus and strength so as to accomplish their goal. Sometimes, they may also feel very confused and unable to think clearly. Other effects include mania,



withdrawal (become anti-social) and mood swings. Depression may also occur in several cases. Some dopers also become very dependent on others. The doper's personality may also change significantly and drugs are usually the direct cause of it. A doper may also tend to tremble more often.

Emotional Effects

Unusual patterns of behavior Drugs may cause athlete to suffer an emotional breakdown. Perhaps, this may even result in depression or in the worst case scenario-committing suicide. This may seem very extreme to, athletes, do use this method as they find they are too depression and by dying, will can resolve all their problems.

Conclusion:

The attitude of the players plays a key role in the success of the game both at sport and national level. Today's world is based on high spirits of competition and achievement which feeds as a great enhancement for an individual's self esteem. Sometimes the attitude of "only I must win" (Musturbation) brings in inappropriate behavior that pushes them to take the wrong path like Doping. It is suggested that winning any game through the self actualized way leads positive results and it also avoids irrerelevant guilt feel to any players. The sport community and the personnel at the authorized positions may triggers the though process of the dopers, thus avoiding fraudulent practice and finally totally abolishing for a long term.

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Artificial Intelligence in India: Accountability, Misuse and Legal Protection

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Introduction:

Artificial Intelligence (AI) is reshaping multiple sectors in India — from healthcare and finance to law enforcement and governance. This research article provides a detailed examination of the legal dimensions of AI in India, focusing on accountability, avenues of misuse, and existing and proposed legal protections. It synthesizes policy context, current legal instruments, gaps, recommendations, and practical steps for regulators and organizations.

Executive Summary

India currently relies on a patchwork of sectoral statutes and policy documents (DPDPA, IT Act, sectoral guidelines, NITI Aayog reports, and MeitY consultations) to regulate AI-related harms. Accountability remains ambiguous for many AI deployments, while misuse such as deepfakes, AI-driven fraud, and mass surveillance is growing. This paper recommends a risk-based AI law, clearer liability allocation, mandatory audits for high-risk systems, and targeted measures against deepfakes and automated fraud.

Detailed Legal Landscape in India

The following table summarises principal laws, policies, and their relevance to AI in India:

Law/Policy	Relevance to AI	Limitations
Digital Personal Data Protection Act, 2023 (DPDPA)	Governs digital personal data processing; consent, obligations	Does not directly regulate algorithms or automated decision-making
Information Technology Act, 2000 (IT Act)	Cybersecurity, intermediary liability, electronic records	Outdated for many AI-specific harms (deepfakes, generative AI)
Consumer Protection Act, 2019	Liability for defective goods/services (including AI-enabled products)	No clarity on responsibility between developer and deployer
Sectoral Guidelines (RBI, SEBI, MoHFW, IRDAI)	Sector-specific oversight: fintech, healthcare, insurance, securities	Fragmented; inconsistent across sectors
Proposed Digital India Act (DIA)	Expected to modernize IT Act, include content moderation and new governance	Drafting stage; details and timelines uncertain

Key reference points:

- Digital Personal Data Protection Act, 2023: establishes data processing obligations and significant data fiduciary provisions.
- Information Technology Act, 2000: remains India's primary cyber statute but is dated for modern AI harms.



- NITI Aayog’s AI strategy and MeitY’s ongoing AI governance consultations are shaping policy direction.

Accountability: Who is Responsible?

Assigning accountability for AI-related harms involves legal, technical, and organizational considerations. The table below maps typical use-cases, harms, accountable parties, and legal gaps:

Use Case	Potential Harm	Potential Accountable Parties	Legal Gaps
Autonomous Vehicles	Accidents causing injury/death	Manufacturer, software developer, fleet operator	No precedent; requires product liability clarity
AI in Banking & Lending	Algorithmic bias; wrongful denial of service/credit	Bank/Platform, model vendor, data provider	No mandatory fairness audits; weak disclosure norms
Facial Recognition in Policing	Wrongful identification; privacy breach	Law enforcement agency, vendor	Weak oversight and transparency; constitutional concerns
Healthcare AI	Misdiagnosis; patient harm	Hospital/clinician, AI developer	Regulation patchy; clinical validation standards needed

Discussion:

In many scenarios Indian courts would apply existing negligence, contract, or product liability doctrines. However, AI introduces opacity (black-box models), continuous learning, and multi-party supply chains (data providers, model developers, deployers), complicating fault allocation. Policy options include: mandatory risk assessments, strict liability for certain autonomous harms, and clarity in service-vendor contracts.

Misuse of AI: Forms, Examples, and Legal Status

The following table summarises common misuse categories, examples, and their current legal status in India:

Form of Misuse, Examples/Consequences, Current Legal Status
 Deepfakes and Politically-motivated Manipulation, "Election-time misinformation, defamation, harassment", No specific statute for deepfakes; IPC/IT Act used indirectly
 Automated Financial Fraud (voice-cloning, phishing)", Significant monetary loss to victims and institutions, Covered under IT Act/IPC but enforcement challenging
 Mass Surveillance & Facial Recognition, "Erosion of privacy, chilling effect on civil liberties", Raises right to privacy issues (Puttaswamy Judgment)
 Algorithmic Bias & Discrimination, "Marginalization in hiring, credit, policing", No statutory fairness or audit obligations
 Misinformation Amplification (automated bots), "Social unrest, reputational harm", Content moderation rules exist but enforcement and detection remain weak



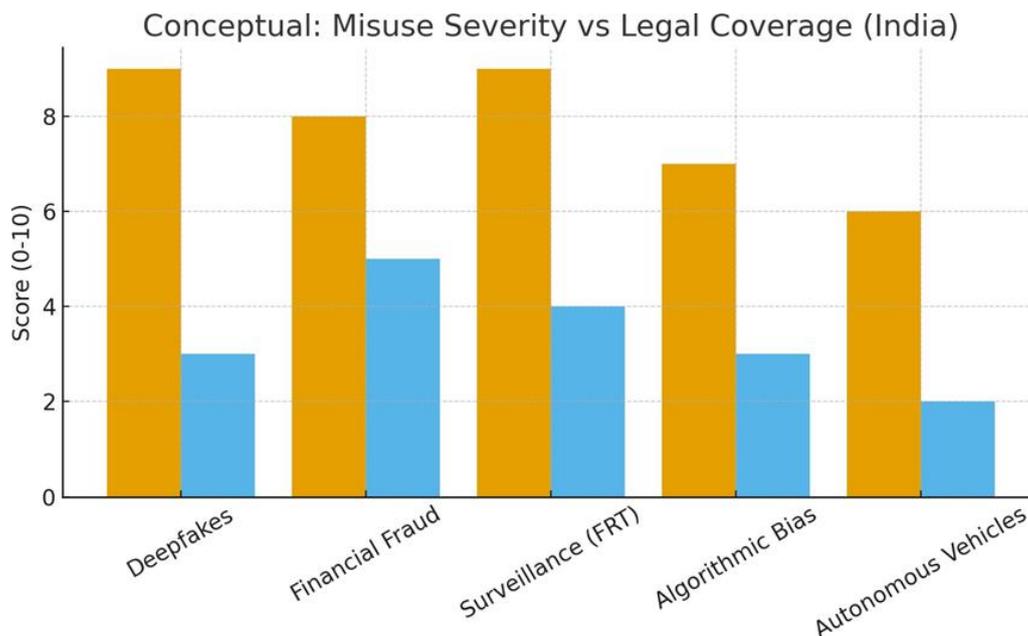
Form of Misuse	Examples/Consequences	Current Legal Status
Deepfakes and Politically-motivated Manipulation	Election-time misinformation, defamation, harassment	No specific statute for deepfakes; IPC/IT Act used indirectly
Automated Financial Fraud (voice-cloning, phishing)	Significant monetary loss to victims and institutions	Covered under IT Act/IPC but enforcement challenging
Mass Surveillance & Facial Recognition	Erosion of privacy, chilling effect on civil liberties	Raises right to privacy issues (Puttaswamy judgment)
Algorithmic Bias & Discrimination	Marginalization in hiring, credit, policing	No statutory fairness or audit obligations
Misinformation Amplification (automated bots)	Social unrest, reputational harm	Content moderation rules exist but enforcement and detection remain weak

Notable recent developments (examples):

- CERT-In advisories and government advisories on deepfake threats and countermeasures.
- Parliamentary recommendations urging tougher rules on deepfakes, OTT platforms and social media.

5. Chart: Misuse Severity vs Legal Coverage (Conceptual)

The chart below is conceptual—intended to illustrate where high-severity misuse converges with low legal coverage in India. (High score = greater severity / stronger legal coverage).



Legal Protections: Existing Remedies and Their Limits:

Existing legal instruments (DPDPA, IT Act, IPC, Consumer Protection Act, and sectoral circulars) provide remedies for data breaches, cybercrime, fraud, and consumer harms. However, these laws are often applied indirectly to AI harms, leading to uncertainty. Key



limitations include absence of AI- specific regulation, lack of mandatory fairness or safety audits, limited transparency obligations, and enforcement capacity constraints.

Recommendations for Lawmakers and Practitioners:

- Enact a risk-based AI framework (e.g., Digital India Act + AI rules) that categorizes systems by risk and prescribes corresponding obligations.
- Clarify liability: define roles and responsibilities for data providers, model developers, deployers, and operators. Consider strict liability for certain autonomous harms.
- Mandate AI impact assessments and independent audits for high-risk systems (health, finance, policing).
- Criminalize malicious deepfake creation and distribution where used for fraud, extortion, or election interference; ensure proportionality and due process.
- Strengthen data governance: transparency obligations, provenance logging, and rights to explanation for automated adverse decisions.
- Build technical and enforcement capacity (CERT-In, police cyber cells, regulators) with guidelines for detection and rapid response to AI misuse.
- Promote public-private collaboration for dataset stewardship, open standards for provenance, and shared red-teaming resources.
- Implementation Roadmap (Practical Steps)
 - Short term (6-12 months): Issue targeted advisories (deepfakes, financial fraud), require high-risk registries, and publish model documentation guidance.
 - Medium term (1-3 years): Pass risk-based AI rules, implement mandatory audits for critical sectors, and operationalize DPDPA enforcement mechanisms.
 - Long term (3-5 years): Create statutory frameworks for liability apportionment, invest in AI-labelling/provenance infrastructure, and harmonize with global standards.

Appendix: Tables (CSV-friendly) & Sources

The tables used in this document are included in CSV-friendly form at the end of this Word document for reuse.

Legal Landscape (CSV):

Law/Policy, Relevance to AI, Limitations "Digital Personal Data Protection Act, 2023 (DPDPA)", "Governs digital personal data processing; consent, obligations", Does not directly regulate algorithms or automated decision-making "Information Technology Act, 2000 (IT Act)", "Cybersecurity, intermediary liability, electronic records", "Outdated for many AI-specific harms (deepfakes, generative AI)" "Consumer Protection Act, 2019", Liability for defective goods/services (including AI-enabled products), No clarity on responsibility between developer and deployer "Sectoral Guidelines (RBI, SEBI, MoHFW, IRDAI)", "Sector-specific oversight: fintech, healthcare, insurance, securities", Fragmented; inconsistent across sectors Proposed Digital India Act (DIA), "Expected to modernize IT Act, include content moderation and new governance", Drafting stage; details and timelines uncertain.



Accountability:

Use Case, Potential Harm, Potential Accountable Parties, Legal Gaps Autonomous Vehicles, Accidents causing injury/death, "Manufacturer, software developer, fleet operator", No precedent; requires product liability clarity AI in Banking & Lending, Algorithmic bias; wrongful denial of service/credit, "Bank/Platform, model vendor, data provider", No mandatory fairness audits; weak disclosure norms Facial Recognition in Policing, Wrongful identification; privacy breach, "Law enforcement agency, vendor", Weak oversight and transparency; constitutional concerns Healthcare AI, Misdiagnosis; patient harm, "Hospital/clinician, AI developer", Regulation patchy; clinical validation standards needed

Conclusion:

India stands at a crossroads: AI offers transformative benefits but also raises urgent legal and social questions about accountability and misuse. A balanced legal approach combining risk-based regulation, clearer liability rules, technical preparedness, and targeted criminal measures is essential to protect rights while enabling innovation.

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Exploring Ethnobotanical Insights and the Role of Artificial Intelligence in Plant Identification of Red Bead Tree (*Adenanthera pavonina* L.)

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Abstract:

Adenanthera pavonina L., commonly known as the red bead tree or red sandalwood, is a deciduous tree native to the tropical regions of Asia, but it is widely distributed in India, Africa, and the Pacific Islands [1]. This review examines its traditional uses in folk medicine across various cultures, focusing on applications for ailments such as diarrhea, inflammation, rheumatism, asthma [2, 3]. Drawing from ethnopharmacological studies, the plant's leaves, seeds, bark, and roots have been employed for their purported antidiarrheal, anti-inflammatory, antimicrobial, and antioxidant properties [4, 5]. While scientific validation is ongoing, preliminary research supports some of these uses, highlighting potential bioactive compounds like flavonoids, saponins, and alkaloids [6, 7]. This paper synthesizes historical and cultural contexts, emphasizing the need for further clinical studies to substantiate safety and efficacy.

Key Words: Red bead tree, Mimosaceae, Traditional medicinal value,

Introduction:

Adenanthera pavonina L. belongs to the Fabaceae family (subfamily Mimosoideae) and is recognized for its vibrant red seeds, often used in jewelry and as weights in traditional trade due to their uniform mass (approximately 0.25 g per seed) [8]. The tree grows up to 15-20 meters tall, with bipinnate leaves, small yellowish flowers, and curved pods containing 8-12 seeds [9]. It thrives in tropical climates and has been naturalized in many regions beyond its native Southeast Asia and India [1].

Traditional medicine systems, including Ayurveda, Siddha, and folk practices in Africa and the Pacific, have long utilized parts of this tree [2]. The seeds, bark, leaves, and roots are prepared as decoctions, powders, or pastes to treat a range of conditions [3, 10]. This review compiles these uses, supported by available scientific literature, to provide a comprehensive overview.

Traditional Uses in Different Cultures

India and Ayurvedic Medicine

In India, *A. pavonina* is known as "Raktachandan" or "Manjadi." Ayurvedic texts describe its cooling, astringent, and anti-inflammatory properties [2, 9].

- **Seeds:** Used to treat boils, inflammations, and eye ailments. A paste of ground seeds is applied topically for skin eruptions and rheumatism. Internally, seed decoctions are used to address diarrhea, dysentery, and hemorrhages [5, 10].
- **Bark and Leaves:** Decoctions for chronic rheumatism, gout, and asthma. Bark infusions serve as antiseptics for wounds [3, 7].
- **Roots:** Employed in treating pulmonary issues and as a tonic for general debility [1].



Studies indicate that rural communities in Maharashtra and Kerala use seed extracts for antidiarrheal purposes, aligning with its astringent tannins [8].

Sri Lanka and Traditional Practices

In Sri Lankan folk medicine, the plant is called "Madatiya."

- **Leaves and Bark:** Used for inflammatory conditions and as an antidiarrheal agent. A study documented its use in treating cancer in traditional formulas combined with other herbs [1,7].
- **Seeds:** Applied in ointments for skin diseases and joint pain [5].

Ethnopharmacological surveys highlight its role in managing diabetes and hypertension [2].

Africa and Pacific Islands

In West Africa (e.g., Nigeria), it's known as "Oyo" or "red bead vine."

- **Seeds and Bark:** Treat stomachaches, diarrhea, and urinary infections. Seed oil is used for skin care [1, 6].
- **Leaves:** Decoctions for fever, convulsions, and as an antimalarial [4].

In the Pacific (e.g., Fiji), seeds are roasted and eaten, with medicinal uses for respiratory issues [8].

Other Regions

In Brazil and the Caribbean, where the tree is introduced, leaves and seeds treat wounds and inflammation, reflecting adapted traditional uses [1, 7].

Bioactive Compounds Supporting Traditional Uses

Phytochemical analyses reveal compounds that may explain traditional applications:

- **Flavonoids and Saponins:** Anti-inflammatory and antioxidant effects, supporting use in rheumatism and skin conditions [3, 4].
- **Alkaloids and Tannins:** Astringent properties for diarrhea and wound healing [9, 10].
- **Steroids and Terpenoids:** Potential antimicrobial activity [6].

For instance, seed extracts show trypsin inhibitory proteins with potential antidiabetic effects by modulating enzyme activity [5].

Scientific Validation and Potential Applications

While traditional uses are widespread, scientific studies provide preliminary support:

- **Antidiarrheal:** Aqueous seed extracts reduced castor oil-induced diarrhea in rats, validating folk remedies [7, 10].
- **Anti-inflammatory:** Methanolic leaf extracts inhibited paw edema in animal models [3].
- **Antimicrobial:** Bark extracts showed activity against bacteria like *Staphylococcus aureus* [10].
- **Antioxidant:** High phenolic content in leaves correlates with free radical scavenging [4].

However, human clinical trials are limited, and toxicity studies suggest safety at traditional doses, though raw seeds contain antinutrients requiring cooking [1, 6].

Conclusion

Adenanthera pavonina L. represents a valuable repository of traditional knowledge, with documented applications across cultures for gastrointestinal, inflammatory, and infectious disorders. Its rich phytochemical profile featuring flavonoids, tannins, and trypsin inhibitors



underpins these uses and holds promise for drug discovery and functional foods. On the other hand, transitioning from ethnopharmacological knowledge to clinical practice demands robust human trials, standardized extracts, and comprehensive toxicity profiling. Listing sustainable cultivation is vital to preserve this resource among growing demand and ecological pressures. Future interdisciplinary efforts, including AI-driven bioactive screening, could unlock its full therapeutic and industrial potential.

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छत्रपती संभाजी नगर जिल्ह्यातील अवलंबन गुणोत्तराचे भौगोलिक अध्ययन

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सारांश:

अवलंबन गुणोत्तर हे कुठल्याही प्रदेशातील कार्यकारी लोकसंख्येवर अवलंबून असलेल्या अकार्यकारी लोकसंख्येचे प्रमाण असते. ज्या प्रदेशात कार्यकारी लोकसंख्येचे प्रमाण अकार्यकारी लोकसंख्येपेक्षा जास्त असते त्या प्रदेशात अवलंबन गुणोत्तर कमी असते. अवलंबन गुणोत्तर हे आर्थिक विकासावर प्रभाव टाकत असते. अवलंबन गुणोत्तर कमी असल्यास आर्थिक विकासाची गती चांगली असते तर अवलंबन गुणोत्तर जास्त असल्यास आर्थिक विकासाची गती मंदावलेली असते.

प्रस्तुत संशोधनात मराठवाडा भागातील छत्रपती संभाजी नगर जिल्ह्यातील अवलंबन गुणोत्तराचे तालुकानिहाय अर्धवर्षीय करण्यात आलेले आहे.

बीज संज्ञा: छत्रपती संभाजी नगर जिल्हा, अवलंबन गुणोत्तर, ग्रामीण, नागरी, एकूण

प्रस्तावना:

ज्या क्षेत्रात अवलंबन गुणोत्तर अधिक असते अशा क्षेत्रात कार्यकारी लोकसंख्या प्रमाण कमी असते. अशा भागात अवलंबन प्रमाण अधिक असल्याने आर्थिक विकास हा कमी झालेला असतो. ग्रामीण आणि नागरी भागातील अवलंबन गुणोत्तरात तफावत आढळून येत असते. प्रस्तुत संशोधनात छत्रपती संभाजी नगर जिल्ह्यातील ग्रामीण, नागरी आणि एकूण लोकसंख्येच्या अवलंबन गुणोत्तराचे तालुकानिहाय तुलनात्मक अध्ययन करण्यात आलेले आहे.

उद्दिष्ट्ये

प्रस्तुत संशोधनाचे मुख्य उद्दिष्ट्ये पुढीलप्रमाणे आहेत.

1. अभ्यास क्षेत्रातील ग्रामीण लोकसंख्येच्या अवलंबन गुणोत्तराचे अध्ययन करणे.
2. अभ्यास क्षेत्रातील नागरी लोकसंख्येच्या अवलंबन गुणोत्तराचे अध्ययन करणे.
3. अभ्यास क्षेत्रातील एकूण लोकसंख्येच्या अवलंबन गुणोत्तराचे अध्ययन करणे.



माहिती स्रोत:

प्रस्तुत संशोधन हे द्वितीयक स्रोताद्वारे प्राप्त झालेल्या आकडेवारीवर आधारित आहे. प्रस्तुत आकडेवारी ही जनगणना अहवाल मधून प्राप्त केलेली आहे. ग्रामीण व नागरी क्षेत्रातील लोकसंख्येचे अवलंबन गुणोत्तर हे वर्ष १९९१, २००१ आणि २०११ याकाळातील जनगणनेच्या आकडेवारीवर आधारित आहे.

विधीतंत्र:

ग्रामीण, नागरी आणि एकूण लोकसंख्येचे अवलंबन गुणोत्तर काढण्यासाठी पुढील सूत्राचा उपयोग करण्यात आलेला आहे.

अवलंबन गुणोत्तर = (अकार्यकारी लोकसंख्या + कार्यकारी लोकसंख्या) X १००

सूत्राद्वारे प्राप्त झालेली आकडेवारी ही सारणी मध्ये दर्शविण्यात आलेली आहे. तसेच त्याचे वितरण हे नकाशामध्ये दर्शविण्यात आलेले आहे.

अभ्यास क्षेत्र

छत्रपती संभाजी नगर जिल्हा हा महाराष्ट्र राज्यात असून याचा अक्षवृत्तीय विस्तार १९° २३' ३९" उत्तर ते २०° ३९' ३६" उत्तर अक्षवृत्त असून रेखावृत्तीय विस्तार हा ७४° ३६' ४६" पूर्व ते ७५° ५७' ०३" पूर्व रेखांश आहे. जिल्ह्याचा अधिकांश भाग हा गोदावरी व तापी नदीच्या खोऱ्यात असून जिल्ह्यात एकूण ९ तालुक्यांचा समावेश होतो.

जिल्ह्यात २०११ च्या जनगणनेनुसार एकूण लोकसंख्या हि ३७०१२८२ असून त्यापैकी २०८१११२ ग्रामीण तर १६२०१७० लोकसंख्या हि शहरी भागात असल्याचे आढळते.

ग्रामीण लोकसंख्येचे अवलंबन गुणोत्तर:

ग्रामीण क्षेत्रातील एकूण अवलंबन गुणोत्तर १९९१ मध्ये १०२.१८ होते. म्हणजेच ग्रामीण भागात दर १०० कार्यकारी लोकसंख्येमागे १०२ ते १०३ लोकसंख्या अवलंबित होती. वैजापुर तालुक्यात अवलंबन गुणोत्तर सर्वात कमी होते. या तालुक्यात हे गुणोत्तर ९०.२५ होते तर इतर तालुक्यात हे गुणोत्तर १०० पेक्षा जास्त होते. ग्रामीण पुरुषांचे अवलंबन गुणोत्तर ९३.०१ तर स्त्रियांचे ११२.९४ होते. स्त्री कार्यकारी लोकसंख्येचे प्रमाण कमी असल्यामुळे हे गुणोत्तर जास्त होते. वैजापुर तालुक्यात पुरुष व स्त्री दोन्ही अवलंबन गुणोत्तर कमी होते. कारण या तालुक्यात कार्यकारी लोकसंख्येचे प्रमाण अधिक होते. खुल्ताबाद तालुक्यात पुरुषांचे अवलंबन गुणोत्तर १०० पेक्षा जास्त होते. पैठण व वैजापुर तालुक्यात ९० पेक्षा कमी व उर्वरीत तालुक्यात ९० ते



१०० दरम्यान होते. स्त्री अवलंबुन गुणोत्तर केवळ वैजापुर मध्येच १०० पेक्षा कमी होते तर इतर तालुक्यात १०० पेक्षा अधिक होते.

ग्रामीण प्रदेशातील एकूण अवलंबुन गुणोत्तर २००१ मध्ये १०९.७९ होते. हे गुणोत्तर १९९१ पेक्षा वाढलेले होते. वैजापुर व नंतर फुलंब्री तालुक्यात अवलंबुन गुणोत्तर हे १०० पेक्षा कमी होते तर इतर तालुक्यात १०० पेक्षा अधिक होते. छत्रपती संभाजी नगर तालुक्यात याचे प्रमाण सर्वात जास्त होते. ग्रामीण पुरुष अवलंबुन गुणोत्तर ९३.७३ तर स्त्रियांचे १३०.१८ होते. वैजापुर तालुक्यात पुरुष व स्त्रिया दोघांचेही अवलंबुन गुणोत्तर कमी होते. कन्नड व सिल्लोड या तालुक्यात ग्रामीण पुरुष अवलंबुन गुणोत्तर १०० पेक्षा अधिक तर इतर तालुक्यात ८० ते १०० दरम्यान होते. ग्रामीण स्त्री अवलंबुन गुणोत्तर केवळ वैजापुर मध्ये १०० पेक्षा कमी होते. इतर तालुक्यात ११५ पेक्षा अधिक असून छत्रपती संभाजी नगर मध्ये सर्वात जास्त होते. छत्रपती संभाजी नगर जिल्ह्यात २०११ नुसार एकूण ग्रामीण अवलंबिता दर ९९.२१ आहे. हे प्रमाण १९९१ व २००१ पेक्षा कमी झालेले आढळते. सिल्लोड, छत्रपती संभाजी नगर व खुल्ताबाद या तालुक्यात अनुक्रमे हे गुणोत्तर सर्वाधिक आढळते. या तालुक्यात हा दर १०० पेक्षा अधिक असून इतर तालुक्यात त्यापेक्षा कमी आहे. वैजापुर मध्ये अवलंबुन गुणोत्तर सर्वात कमी आहे. एकूण ग्रामीण पुरुष अवलंबुन गुणोत्तर ८२.२३ व स्त्रियांचा १२१.५५ आहे. वैजापुर मध्ये पुरुष व स्त्री दोन्ही अवलंबिता दर कमी आहेत. २०११ नुसार सर्वच तालुक्यात ग्रामीण पुरुषांचे अवलंबुन गुणोत्तर १०० पेक्षा कमी आढळते. सिल्लोड मध्ये हा दर सर्वात जास्त आढळतो. सोयगाव व वैजापुर तालुक्यात ग्रामीण स्त्री अवलंबुन गुणोत्तर १०० पेक्षा कमी असून इतर तालुक्यात त्यापेक्षा जास्त आहे. छत्रपती संभाजी नगर मध्ये हे गुणोत्तर सर्वाधिक आढळते.

सारणी क्रमांक १

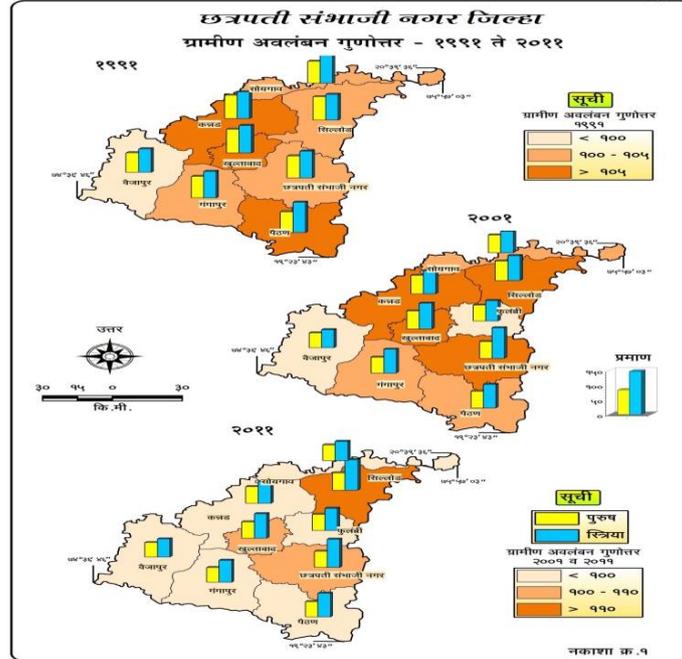
छत्रपती संभाजी नगर जिल्हा : ग्रामीण लोकसंख्येचे अवलंबन गुणोत्तर (१९९१ ते २०११)

ग्रामीण लोकसंख्येचे अवलंबन गुणोत्तर									
ग्रामीण तालुके	१९९१			२००१			२०११		
	एकूण	पुरुष	स्त्री	एकूण	पुरुष	स्त्री	एकूण	पुरुष	स्त्री
छत्रपती संभाजी नगर	१०२.२०	९३.०२	११३.०५	१२२.१८	९१.९४	१६८.६४	१०९.५९	८४.३४	१४७.१५
गंगापूर	१००.४८	९०.८५	१११.८६	१०७.११	८७.९९	१३२.७०	९२.८५	७६.३३	११४.५०
कन्नड	१०५.३६	९८.९२	११२.७५	११३.८६	१०१.९०	१२८.४३	९९.१९	८७.३१	११३.९६



खुलताबाद	१०८.१२	१००.७	९	११६.७१	११७.६६	९८.९६	१४२.१८	१०२.७३	८४.५०	१२६.७९
पैठण	१०६.५५	८८.६१	१२९.५०	१०९.०४	९२.१०	१३०.४९	९७.८३	७९.२६	१२२.४६	१२२.४६
फुलंब्री				९९.०२	८७.४६	११२.८३	९७.०६	८३.१७	११४.६४	११४.६४
सिल्लोड	१०३.८८	९९.०७	१०९.२०	१२१.०६	१०७.४१	१३७.५०	११७.९०	९०.२९	१५८.५८	१५८.५८
सोयगाव	१०४.६०	९३.०५	११८.३३	१०७.४०	९८.५०	११७.७४	९०.०८	८१.८३	९९.९४	९९.९४
वैजापूर	९०.२५	८२.२८	९९.४६	९०.१४	८२.००	९९.५३	८३.०३	७४.०७	९३.७०	९३.७०
एकूण	१०२.१८	९३.०१	११२.९४	१०९.७९	९३.७३	१३०.१८	९९.२१	८२.२३	१२१.५५	१२१.५५

स्त्रोत - संशोधक



नागरी लोकसंख्येचे अवलंबन गुणोत्तर

औरंगाबाद जिल्ह्यातील एकूण नागरी अवलंबन गुणोत्तर १९९१ मध्ये २४६.८५ होते. ग्रामीण अवलंबन गुणोत्तरापेक्षा नागरी गुणोत्तर दुपटीपेक्षाही जास्त होते. कार्यकारी लोकसंख्येचे प्रमाण नागरी क्षेत्रात कमी असल्याने हा दर जास्त आढळला. नागरी क्षेत्रात कमी १९९१ मध्ये सर्वच तालुक्यात अवलंबिता दर २०० पेक्षा अधिक होता. गंगापूर तालुक्यात तो सर्वात कमी होता. तर खुलताबाद मध्ये सर्वाधिक होता. पुरुष अवलंबिता दर १२२.०८ व स्त्रियांचा ८५१.४७ होता. स्त्रियांचा अवलंबिता दर नागरी क्षेत्रात पुरुषापेक्षा जवळपास ८ पटीने जास्त होता. गंगापूर मध्ये पुरुष व स्त्री दोन्ही अवलंबन गुणोत्तर व छत्रपती संभाजी नगर मध्ये स्त्री अवलंबन गुणोत्तर सर्वात जास्त होते. तर खुलताबाद मध्ये पुरुष अवलंबन गुणोत्तर व छत्रपती संभाजी



नगर मध्ये स्त्री अवलंबुन गुणोत्तर सर्वात जास्त होते. गंगापूर सोडून स्त्री अवलंबिता दर सर्वच तालुक्यात ५०० पेक्षा अधिक होता.

एकूण नागरी अवलंबुन गुणोत्तर २००१ मध्ये २४६.०५ होते. २००१ मध्येही सर्वच तालुक्यातील नागरी अवलंबुन गुणोत्तर २०० पेक्षा अधिक होते. वैजापूर मध्ये हे गुणोत्तर सर्वात कमी तर सिल्लोड मध्ये ते सर्वाधिक होते. एकूण नागरी पुरुष अवलंबुन गुणोत्तर ११८.३९ तर स्त्रियांचे ८७६.५४ होते. पैठण मध्ये पुरुष अवलंबिता दर सर्वात कमी तर सिल्लोड मध्ये सर्वात जास्त होता सर्वच तालुक्यातील अवलंबुन गुणोत्तर १०० पेक्षा अधिक होते. स्त्री अवलंबुन गुणोत्तर सर्वच तालुक्यात ५०० पेक्षा अधिक होता. वैजापूर मध्ये तो सर्वात कमी तर कन्नड मध्ये सर्वात जास्त होता.

सारणी क्रमांक २

छत्रपती संभाजी नगर जिल्हा : नागरी लोकसंख्येचे अवलंबन गुणोत्तर (१९९१ ते २०११)

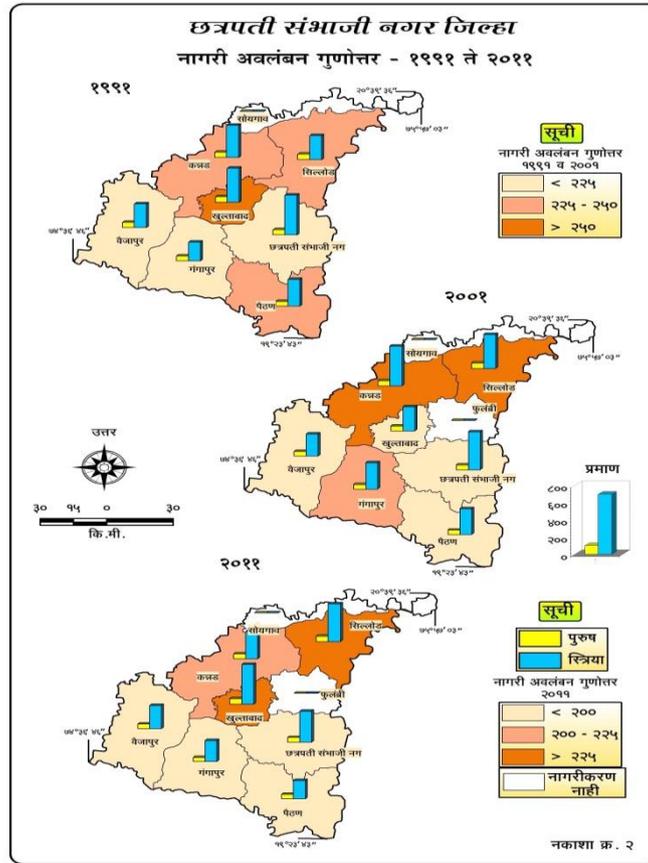
नागरी लोकसंख्येचे अवलंबन गुणोत्तर									
नागरी तालुके	१९९१			२००१			२०११		
	एकूण	पुरुष	स्त्री	एकूण	पुरुष	स्त्री	एकूण	पुरुष	स्त्री
छत्रपती संभाजी नगर	२२१.१४	१२२.४०	९३९.८०	२१८.२०	११८.२८	९२६.८६	१८९.२१	१००.४३	६५१.४६
गंगापूर	२००.५६	११३.४८	४३८.०८	२२६.२९	११५.५८	६४२.७३	१६९.७९	८५.९८	४३९.५५
कन्नड	२४७.८४	१२३.६५	७६०.७७	२५७.६९	१२१.४७	९६६.७७	२०६.८०	१०३.४८	५७७.७८
खुलताबाद	२६२.६०	१३१.०१	८०६.२८	२२४.८९	११८.१५	५८९.३५	२४२.४४	११४.६६	८३१.३४
पैठण	२२५.७५	१११.५४	६३७.३९	२२१.६१	१०९.८४	६२९.८२	१७१.४०	९२.४२	३८२.७३
फुलंब्री				०	०	०	०	०	०
सिल्लोड	२३३.४६	१३०.३०	५६९.२५	२६४.४०	१३३.८८	८२९.७६	२३४.२५	११०.९१	७९०.४५
सोयगाव	०.००	०.००	०.००	०	०	०	०	०	०
वैजापूर	२२३.८६	११९.२४	५६३.०२	२११.६७	१११.२७	५३३.९१	१८७.४२	९४.४६	४८२.२६
एकूण	२४६.८५	१२२.०८	८५१.४७	२४६.०५	११८.३९	८७६.५४	२०५.४६	९९.५७	६१८.७७

स्त्रोत - संशोधक

अभ्यास क्षेत्रातील एकूण नागरी अवलंबुन गुणोत्तर २०११ नुसार २०५.४६ आहे म्हणजेच नागरी क्षेत्रात दर १०० कार्यकारी लोकसंख्येवर सरासरी २०५ ते २०६ लोकसंख्या अवलंबित आहे.



हे गुणोत्तर १९९१ व २००१ पेक्षा कमी झालेले असले तरी ग्रामीण भागापेक्षा दुपटीने जास्त आहे. गंगापूर तालुक्यात हे गुणोत्तर सर्वात कमी आढळते. छत्रपती संभाजी नगर, गंगापूर, पैठण व वैजापूर या तालुक्यात हे गुणोत्तर २०० पेक्षा कमी असून इतर तालुक्यात त्यापेक्षा अधिक आहे. खुल्ताबाद मध्ये याचे प्रमाण सर्वात जास्त आढळते. एकूण नागरी पुरुषांचे अवलंबुन गुणोत्तर ९९.७७ तर स्त्रियांचे ६१८.७७ आहे. गंगापूर तालुक्यात पुरुष अवलंबुन गुणोत्तर सर्वात कमी असून गंगापूर, पैठण व वैजापूर मध्ये पुरुष अवलंबुन गुणोत्तर १०० पेक्षा कमी असून इतर तालुक्यात १०० पेक्षा अधिक आहे. स्त्री अवलंबिता दर पैठण मध्ये सर्वात कमी असून सिल्लोड मध्ये सर्वाधिक आहे. गंगापूर, पैठण व वैजापूर मध्ये नागरी स्त्री अवलंबन गुणोत्तर ५०० पेक्षा कमी असून इतर तालुक्यात ५०० पेक्षा अधिक आढळते.



एकूण लोकसंख्येचे अवलंबन गुणोत्तर

अभ्यास क्षेत्रात १९९१ मध्ये एकूण अवलंबन गुणोत्तर १३४.१८ होते. सर्वच तालुक्यातील एकूण अवलंबन गुणोत्तर हे १०० पेक्षा अधिक होते. वैजापूर मध्ये सर्वात कमी तर खुल्ताबाद मध्ये सर्वात जास्त होते. एकूण पुरुष अवलंबिता दर १०१.८४ व स्त्री १८३.४२ होता. वैजापूर



मध्ये पुरुष अवलंबिता दर कमी तर खुलताबाद मध्ये तो जास्त होता. स्त्री अवलंबिता दर छत्रपती संभाजी नगर मध्ये ३८६.९४ सर्वाधिक होता तर सोयगाव मध्ये तो सर्वात कमी होता.

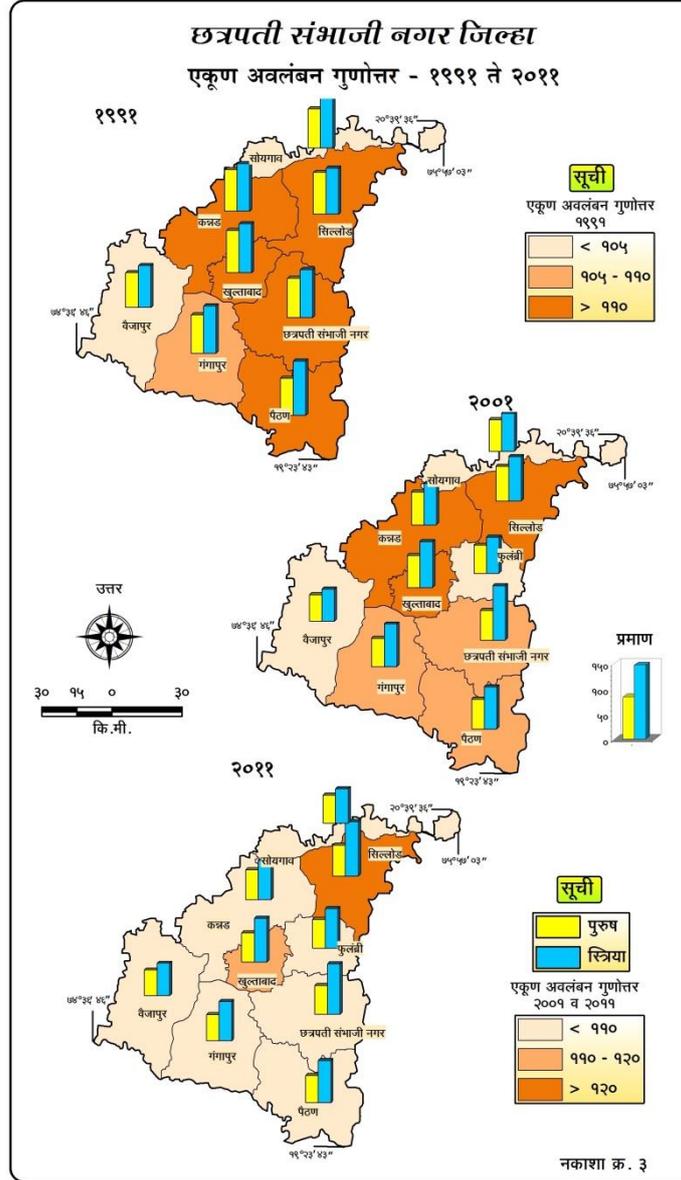
सारणी क्रमांक ३

छत्रपती संभाजी नगर जिल्हा : एकूण लोकसंख्येचे अवलंबन गुणोत्तर (१९९१ ते २०११)

एकूण लोकसंख्येचे अवलंबन गुणोत्तर									
तालुके	१९९१			२००१			२०११		
	एकूण	पुरुष	स्त्री	एकूण	पुरुष	स्त्री	एकूण	पुरुष	स्त्री
छत्रपती संभाजी नगर	११०.१४	१०१.३४	३८६.९४	११८.६४	१०३.७४	४२५.८६	१०५.२३	८७.३६	३९३.६२
गंगापूर	१०६.१०	९२.५४	१२२.८४	११३.३५	८९.९४	१४६.१५	१०९.८९	७९.००	१५८.३५
कन्नड	११२.२०	१००.६६	१२६.१४	१२४.५२	१०४.०३	१५१.७६	१०७.९०	८९.१०	१३३.११
खुलताबाद	११७.८०	१०३.५३	१३५.६८	१२७.१०	१०१.१९	१६३.७२	११४.३७	८८.००	१५२.३२
पैठण	११५.६४	९०.९८	१४९.४२	११८.२२	९४.०७	१५१.१८	१०६.३६	८१.१४	१४२.४०
फुलंब्री				९९.०२	८७.४६	११२.८३	९७.०६	८३.१७	११४.६४
सिल्लोड	१११.८८	१०१.८०	१२३.७३	१३४.९९	१११.०६	१६७.००	१३०.९१	९३.३३	१९२.३५
सोयगाव	१०४.६०	९३.०५	११८.३३	१०७.४०	९८.५०	११७.७४	९०.०८	८१.८३	९९.९४
वैजापूर	१०१.४९	८६.५६	१२०.१४	१०१.३५	८५.७०	१२१.००	९२.३०	७६.५२	११२.६०
एकूण	१३४.१८	१०१.८४	१८३.४२	१४६.१७	१०२.३९	२२१.३५	१३४.९९	८९.४४	२१७.७३

स्त्रोत - संशोधक

एकूण अवलंबन गुणोत्तर २००१ मध्ये १४६.१७ होते. १९९१ पेक्षा २००१ मध्ये हे गुणोत्तर वाढलेले आढळते. फुलंब्री तालुक्यात अवलंबन गुणोत्तर सर्वात कमी ९९.०२ होते तर इतर तालुक्यात १०० पेक्षा अधिक होते. सिल्लोड मध्ये याचे प्रमाण सर्वात जास्त होते. पुरुष अवलंबन गुणोत्तर १०२.३९ तर स्त्रियांचे २२१.३५ होते. वैजापूर मध्ये पुरुष अवलंबन गुणोत्तर सर्वात कमी होते. वैजापूर, गंगापूर, पैठण व फुलंब्री व सोयगाव ह्या तालुक्यात पुरुष गुणोत्तर १०० पेक्षा कमी असून इतर तालुक्यात त्यापेक्षा जास्त होते. स्त्री अवलंबन गुणोत्तर सर्वच तालुक्यात १०० पेक्षा अधिक होते. छत्रपती संभाजी नगर मध्ये सर्वाधिक ४२५.८६ तर फुलंब्री मध्ये सर्वात कमी ११२.८३ होते.



छत्रपती संभाजी नगर जिल्ह्यात २०११ नुसार एकूण अवलंबन गुणोत्तर १३४.९९ आहे. २००१ पेक्षा हे कमी झालेले आढळते. सोयगाव, वैजापुर व फुलंब्री मध्ये हे गुणोत्तर १०० पेक्षा कमी असून इतर तालुक्यात अधिक आहे. खुल्ताबाद मध्ये एकूण अवलंबन गुणोत्तर जिल्ह्यात सर्वात जास्त आढळते. पुरुष अवलंबन गुणोत्तर ८९.४४ व स्त्री गुणोत्तर २१७.७३ आहे. सिल्लोड मध्ये पुरुष अवलंबन गुणोत्तर सर्वात जास्त ९३.३३ आहे तर इतर तालुक्यात ९० पेक्षा कमी आहे. वैजापुर मध्ये ते सर्वात कमी आढळते. स्त्री अवलंबन गुणोत्तर सोयगावमध्ये सर्वात कमी ९९.९४ आहे. इतर तालुक्यात १०० पेक्षा अधिक आहे. छत्रपती संभाजी नगर मध्ये स्त्री अवलंबिता दर सर्वाधिक ३९३.६३ आढळतो.



निष्कर्ष

अभ्यास क्षेत्रात अवलंबन गुणोत्तर ग्रामीण क्षेत्रापेक्षा नागरी क्षेत्रात अधिक आहे. नागरी क्षेत्रात जन्मदर जास्त असल्याने अवलंबिता असणा- या लोकसंख्येचे प्रमाण अधिक आढळते. तसेच एकूण स्त्री अवलंबन गुणोत्तर पुरुष अवलंबितेपेक्षा दुपटीपेक्षाही जास्त आहे. तर नागरी क्षेत्रात जवळपास सातपटीने जास्त आहे. स्त्री लोकसंख्येचे घटते प्रमाण, कार्यकारी लोकसंख्येची कमी या कारणांमुळे स्त्रियांचे अवलंबन प्रमाण अधिक आढळते. सद्यस्थितीत जिल्ह्यामध्ये दर १०० कार्यकारी लोकसंख्येवर सरासरी १३४ ते १३५ लोकसंख्या अवलंबून आहे. यात स्त्रियांचे प्रमाण सर्वाधिक आहे.

अभ्यास क्षेत्रात अवलंबन गुणोत्तरात वाढ झालेली आहे. म्हणजेच लोकसंख्या नियंत्रण अजूनही पूर्णपणे यशस्वी झालेले नाही. ग्रामीण भागात रोजगारांची उपलब्धता अधिक प्रमाणात झाल्यास नागरी भागात होणारे शालान्त्र कमी होईल. त्यामुळे नागरी भागातील अवलंबन गुणोत्तर कमी होण्यास मदत होईल.

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मानसिक आरोग्य संवर्धनात पर्यावरण आणि AI ची भूमिका एक अभ्यास

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गोषवरा:

मानवाच्या सर्वात महत्वाचा आणि जवळचा मुदा म्हणजे आरोग्य होय. मानसिक आरोग्य हे आरोग्यातील एक महत्वाचा भाग असलेले आरोग्य आहे. यानुसार आजच्या युगात मानसिक आरोग्य संवर्धनासाठी पर्यावरण आणि AI ची भूमिका एक अभ्यास हा विषय निवडण्यात आला आहे. वाढत्या स्पर्धात्मक युगात पर्यावरण आणि AI या दोन्ही घटकाची आवश्यकता आहे. या संशोधनामध्ये दुय्यम संसाधनांचा वापर करण्यात आला आहे. तसेच प्रत्यक्ष मानसिक आरोग्य क्षेत्रातील कार्य करणाऱ्या तज्ञांचा अनुभव विचारात घेण्यात आला आहे. तेव्हा संशोधनांती असे दिसून आले आहे की, मानसिक आरोग्य संवर्धनात पर्यावरणाबरोबरच AI ची भूमिका महत्वाची आहे.

मुख्य शब्द: मानसिक आरोग्य, पर्यावरण, मानसशास्त्र, AI.

प्रस्ताविक:

मानसशास्त्र हे मानव व मानवेत्तर प्राण्यांच्या वर्तनाचे अभ्यास करणारे शास्त्र आहे. यामध्ये मानसिक आरोग्य विषयक वर्तनाचे कार्य-कारण अभ्यासले जाते. मानसिक आरोग्य संदर्भात अनेक वर्षांपासून शास्त्रीय पध्दतीने निदान-उपचार, कार्य-कारण, आरोग्य संवर्धनासाठी उपाय इत्यादींचा अभ्यास करत आहे. बदलत्या काळानुसार मानवी वर्तन देखील बदलत आहे. यामुळे आरोग्य संवर्धनासाठी नवनवीन समस्या व त्यांच्या उपायाचा विचार देखील होत असलेला दिसून येतो.

पूर्वी मानव जंगलात राहत असे, त्यामुळे तेव्हा त्याचे मानसिक आरोग्य हे सभोवताली असलेल्या हिंस्र प्राण्यांमुळे तसेच पर्यावरणीय बदलांमुळे प्रभावीत होत होते. प्रगती करत असताना कामामुळे, वेळेचा अभाव, स्पर्धा, यश-अपयश, सत्ता-संपत्ती, इत्यादींमुळे मानसिक आरोग्य प्रभावीत होत आहे. यावर मात करण्यासाठी तंत्रज्ञानाची मानवाने सोबत घेतली आहे. तरी देखील मानवी



आरोग्यात सुधारणा किंवा समाधानकारकता दिसून येत नाही. कारण नवनवीन समस्या तयार होत आहेत. आता पुन्हा नवनवीन उपाय देखील शोधले जात आहेत. AI मुळे वेळेची बचत होत आहे. अनेक घटकाचा सर्वांगी विचार काही सेकंदात AI करून रोगांचे कार्य-कारण स्पष्ट करताना दिसून येत आहे.

संशोधनाची उद्दिष्ट:

- मानसिक आरोग्य संवर्धनात पर्यावरण आणि AI ची भूमिका अभ्यासणे.

संशोधनाची गृहितक:

- मानसिक आरोग्य संवर्धनात पर्यावरण आणि AI ची भूमिका महत्वाची आहे.

संशोधन पध्दती:

सदरील संशोधन हे अप्रयोगिक पध्दतीचे आहे. यामध्ये द्वितीय संसाधनांचा वापर करण्यात आला आहे. यामध्ये संशोधन प्रबंध, वर्तमानपत्रे, संशोधन पत्रे, संबंधीत माहिती पुस्तके, इत्यांचीचा वापर करण्यात आला आहे. तसेच प्रत्यक्ष मानसिक आरोग्य क्षेत्रातील कार्य करणाऱ्या डॉक्टर, मनोविकारतज्ञ, मानसोपचारतज्ञ, समुपदेशक इत्यादींचा अनुभव विचारात घेण्यात आला आहे. यासाठी AI वरून मुलाखत पध्दतीचा वापर करण्यात आला आहे.

विषय विवेचन:

सदरील संशोधनात मानवी वर्तनातील आरोग्य विषयक विचार केला असता पारंपारिक (पर्यावरण) आणि (AI) आधुनिक तंत्र याचा विचार करण्यात आला आहे. पर्यावरण हे मानवी निर्मितीच्या आधीपासून आहे. तर AI हे मानवनिर्मित तंत्रज्ञान आहे. या दोन्हीचा मानवी आरोग्य सुधारण्यासाठी वापर करण्याचा नवीन विचार आजकाल होत असलेला दिसून येत आहे.

अ) मानसिक आरोग्य व पर्यावरण:

मानव हा निसर्गाचाच एक भाग आहे. त्यामुळे मानसिक आरोग्य व पर्यावरण यांचा जवळचा संबंध आहे. निसर्गाच्या सानिध्यात राहिल्याने मानवी मेंदुतील cortisol या तणाव वाढवणाऱ्या रसस्त्राव (हार्मोनस) पातळी कमी होते असे दिसून आले आहे. आरोग्य सुधारण्यासाठी मानसोपचार तंत्र पर्यावरण पुरक Eco therapy ही परंपारीक पध्दत वापरली जाते. यामध्ये निसर्गाच्या सानिध्यात मानवाचे मानसिक आरोग्य सुधारणा होते. निसर्गात फिरल्याने मेदूला शांतता लाभते. नैसर्गिक आवाजाचा वापर मानवी ताण-तणाव कमी करण्यासाठी होते असे दिसून आले आहे. बागकाम करणारे काम करताना रोपाची काळजी घेतात. यामधून त्यांना कार्य समाधान मिळते. जगात अनेक संस्कृतीत अनेक पध्दतीने निसर्गपूजा केली जाते. भारतात नागपंचमीला नागाची पुजा, पोळा



हा बैलाचा, नारळी, कोजागीरी पोर्णिमा इत्यादीचा परिणाम समाधान कारक भावना तयार होतात. जपान मध्ये **forest Bathing** ही जंगलातील अंधोळ म्हणून करण्याची परंपरा दिसून येते.

आधुनिक काळात पर्यावरण पुरक घराचे बंधकाम करण्याची पध्दती दिसून येते. यामुळे लोकांना समाधानकारक भावना तयार झाल्याचे अनुभव येत आहे. रंग देताना निळा आणि हिरवा यामुळे देखील घराची पर्यावरणपुरक रचना करताना दिसून येत आहे. यामधुन तणाव मुक्ती करण्याचा प्रयत्न दिसून येतो. तसेच मानसिक आरोग्य संवर्धनास मदत होत असल्याचे दिसून येत आहे.

फायदे:- पर्यावरणीय उपचार पध्दतीने शाश्वत आरोग्य सुधारणा होते. नैसर्गिक साधन संपत्तीचा सदुपयोग होतो. मानव पर्यावरणाला सुधारण्यासाठी कार्य करतो.

तोटे:- खुपच वेळ खाणारी उपचार पध्दती आहे. यामध्ये अनेक मनोविकृतीवर उपचार करणे शक्य नाही.

आ) **मानसिक आरोग्य आणि AI टुल:**

आजच्या आधुनिक युगात एक नविन समिकरण बनू पाहत आहे. ते म्हणजे मोबाईलचे तंत्रज्ञान होय. यामध्ये सर्व क्षेत्रात आता AI चा वापर सुरू झाला आहे. या मधून मानवी जीवन सुखकर करण्याचा प्रयत्न चालू आहे. "घंटो का काम मिंनटोमे" या म्हणी प्रमाणे आजकाल लोक कमी वेळ जास्त काम करतात. AI मुळे आरोग्य विषयक अनेक माहितीचे संस्करण करण्याची प्रक्रिया लवकर होत आहे. एखाद्या आजाराचे निदान असे की, आजाराचा इतिहास, उपचार पध्दती, इत्यादीचा अचुक वापर AI करताना दिसून येत आहे. यामुळे या क्षेत्रात दिवसेंदिवस AI टुलचा वापर वाढतांना दिसून येत आहे.

स्मार्ट वॉच किंवा फिटनेस बॅल्ट या तंत्राचा वापर करून आपल्या संभाव्य आजाराचा अंदाज देखील यामुळे घेता येतो. मानवाच्या हातात असलेला मोबाईल आता स्मार्ट झाला आहे. यामध्ये अनेक नवनवीन ऍप्स उपलब्ध झाले आहेत. यामुळे मानवी जीवन सुखकर, आनंदी, मनोरंजनात्मक, माहितीपूर्ण माहिती मिळवण्याचा प्रयत्न केला जात आहे. AI टुल आरोग्य विषयक महत्वाचे सध्या उपलब्ध असलेले काही App मध्ये wysa हे एका मित्रा प्रमाणे मानवाला आनंदी ठेवण्यासाठी मदत करतो. Headspace हा ध्यानधारणा साठी मदत करणारे AI टुल आहे. Youper हे भावनिक आरोग्याचा सहाय्यक म्हणून काम करते. Calm यामुळे झोप येण्यास मदत होते. Woebot हा मित्राप्रमाणे दररोज विचारपुस करतो, तसेच CBT तंत्राचा वापर देखील करतो. Nature Sounds मुळे नैसर्गिक आवाज देखील मिळतात. या व अशा अनेक AI तंत्रामुळे



देखल मानसिक आरोग्य संवर्धनात मदत होते. कार्य- कारण शोधण्यास मदत होत आहे. येणाऱ्या काळात AI प्रगत होत जाईल त्याच बरोबर अनेक नवनवीन तंत्रज्ञान तयार होईल.

फायदे:- आरोग्य विषय संपूर्ण माहिती एका क्लिकवर उपलब्ध झाली आहे. विषयतज्ञाना अनेक वर्ष अभ्यास करून होणारे निदान काही सेकंदात हा AI करत असल्याचे दिसून येते. महागडी फी आणि वेळ यांची बचत होते. त्वरित मदत उपलब्ध होते.

तोटे:- आरोग्य संदर्भात मिळणारी माहिती ही उपचारासाठी वापरताना व्यक्ती सापेक्ष फरक असतो. ती सर्वांना समान पध्दतीने वापरण्यात येते. गोपनीयता आणि नैतिकता धोक्यात येते. मानवी संवादाचा अभाव यामध्ये दिसून येतो. डेटा चोरीची भीती असते.

वरील विषय विवेचनावरून असे दिसून येते की, प्रत्येक उपचार पध्दतीचे काही फायदे आणि तोटे असले तरी देखील काही खालील निष्कर्ष दिसून येतात.

निष्कर्ष:-

- 1) मानवी आरोग्य संवर्धनामध्ये पर्यावरण आणि AI यांची भूमिका महत्वाची आहे.
- 2) मानवी मानसिक आरोग्यात सामान्य पातळीवरील निदानावरच या पर्यावरण आणि AI ची मदत घेणे चांगले आहे.

शिफारशी:-

पर्यावरणामुळे मानसिक आरोग्य संवर्धनात मानवी मनाची आणि निसर्गाशी आपले नाते संतुलित असणे आवश्यक आहे. AI हे एक साधन म्हणून उत्तम आहे. त्याच्या वापरावर फायदे आणि तोटे अवलंबून आहे. आरोग्य विषयक काळजी घेतांना तज्ञांची मदत घेणे आवश्यक आहे.

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ऐतिहासिक वारसा स्थळांच्या शाश्वत विकासामध्ये कृत्रिम बुद्धिमत्तेची भूमिका

प्रा. डॉ. नारायण अंबू शिंदे

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सारांश (Abstract)

कृत्रिम बुद्धिमत्ता हा मानवी बुद्धिमत्तेने निर्माण केलेला अद्भुत चमत्कार आहे. या तंत्रज्ञानामुळे अनेक अद्भुत गोष्टी साध्य होऊ शकतात या तंत्रज्ञानाच्या विकासाचा वेग विलक्षण आहे. आगामी काळात हे तंत्रज्ञान आपल्याकडून अपरिहार्यपणे स्वीकारले जाणार आहे. आपल्या दैनंदिन जीवनाचा महत्त्वपूर्ण भाग बनणार आहे. जगामध्ये आर्टिफिशियल इंटेलिजन्स वापरणाऱ्यांची संख्या अमेरिका, चीन पाठोपाठ भारतात देखील वाढत आहे. हे तंत्रज्ञान ऐतिहासिक स्थळांच्या शाश्वत विकासासाठी देखील अतिशय उपयुक्त ठरू शकते.

ऐतिहासिक स्थळे ही एखाद्या राष्ट्राच्या सांस्कृतिक वारशाची, सामाजिक ओळखीची आणि ऐतिहासिक परंपरेची साक्ष देणारी अमूल्य संपत्ती आहेत. किल्ले, स्मारके, मंदिरे, गुहा, लेणी, पुरातत्त्वीय स्थळे यांसारखी वारसास्थळे केवळ भूतकाळाची आठवण नसून शिक्षण, पर्यटन आणि आर्थिक विकासासाठीही अत्यंत महत्त्वाची आहेत मात्र सध्या ही स्थळे हवामान बदल, प्रदूषण, नैसर्गिक आपत्ती, शहरीकरण, अतिक्रमण, तोडफोड आणि अतिपर्यटन अशा विविध समस्यांमुळे गंभीर धोक्यांना सामोरे जात आहेत. त्यामुळे ऐतिहासिक वारसा स्थळांचा शाश्वत विकास करणे ही बदलत्या काळाची महत्त्वाची गरज बनली आहे.

अलीकडच्या काळात कृत्रिम बुद्धिमत्ता (Artificial Intelligence - AI) ही एक प्रभावी आणि आधुनिक तंत्रज्ञान प्रणाली म्हणून उदयास आली असून ती ऐतिहासिक स्थळांच्या संवर्धन आणि व्यवस्थापनासाठी अत्यंत उपयुक्त ठरू शकते. AI आधारित संगणकीय दृष्टी, मशीन लर्निंग, ड्रोन तंत्रज्ञान आणि पूर्वांनुमान विश्लेषण यांच्या साहाय्याने स्मारकांमधील झीज, भेगा, संरचनात्मक कमजोरी आणि पर्यावरणीय धोके लवकर ओळखता येतील. त्यामुळे वेळेआधी योग्य उपाययोजना करून ऐतिहासिक स्थळांचे नुकसान टाळता येवू शकते.



याशिवाय कृत्रिम बुद्धिमत्ता शाश्वत पर्यटन व्यवस्थापन, डिजिटल दस्तऐवजीकरण, 3D मॉडेलिंग, आभासी संग्रहालये आणि व्हर्चुअल टूर यांद्वारे ऐतिहासिक स्थळांचे संरक्षण आणि प्रसार करण्यात महत्त्वाची भूमिका बजावू शकते. शिक्षण आणि जनजागृती वाढवण्यासाठी AI आधारित आभासी मार्गदर्शक आणि संवादात्मक तंत्रज्ञान प्रभावी ठरणार आहे. तथापि, तंत्रज्ञानाचा उच्च खर्च, प्रशिक्षित मनुष्यबळाचा अभाव, डेटा गोपनीयतेचे प्रश्न आणि सांस्कृतिक संवेदनशीलता यांसारखी काही आव्हानेही आहेत. योग्य नियोजन, नैतिक वापर आणि पारंपरिक संवर्धन पद्धतींसोबत AI चा समन्वय साधल्यास ऐतिहासिक वारसा स्थळांचा शाश्वत विकास अधिक प्रभावीपणे साध्य होऊ शकतो.

मुख्य शब्द (Keywords): कृत्रिम बुद्धिमत्ता (AI), शाश्वत विकास, ऐतिहासिक स्थळे, सांस्कृतिक वारसा, संवर्धन, स्मार्ट पर्यटन, डिजिटल वारसा.

१. प्रस्तावना (Introduction)

किल्ले, मंदिरे, लेणी, गुहा, स्मारके, पुरातत्त्वीय स्थळे आणि ऐतिहासिक शहरे ही आपल्या समृद्ध सांस्कृतिक वारशाची साक्ष देतात. ही स्थळे केवळ भूतकाळाची आठवण नसून ती शिक्षण, पर्यटन आणि आर्थिक विकासासाठीही महत्त्वाची आहेत. ऐतिहासिक स्थळांमुळे स्थानिक रोजगार निर्माण होतो आणि राष्ट्रीय अर्थव्यवस्थेला चालना मिळते. असे असले तरी वाढते प्रदूषण, हवामानातील बदल, लोकसंख्येचा ताण आणि अयोग्य मानवी हस्तक्षेप यामुळे अनेक ऐतिहासिक स्थळांचे नुकसान होत आहे. त्यांचे संवर्धन करण्यासाठी पारंपरिक संवर्धन पद्धती खर्चिक आणि वेळखाऊ ठरतात. या पार्श्वभूमीवर कृत्रिम बुद्धिमत्ता आधारित आधुनिक तंत्रज्ञानाचा वापर करून ऐतिहासिक वारसा स्थळांचा शाश्वत विकास करणे बदलत्या काळाची महत्त्वाची गरज बनली आहे.

२. अभ्यासाची उद्दिष्टे (Objectives)

या संशोधन लेखाची प्रमुख उद्दिष्टे पुढीलप्रमाणे आहेत:

- 1) कृत्रिम बुद्धिमत्तेचा इतिहास समजून भविष्यातील संधींचा वेध घेणे.
- 2) ऐतिहासिक स्थळांच्या शाश्वत विकासाची संकल्पना अभ्यासणे.
- 3) कृत्रिम बुद्धिमत्तेची ऐतिहासिक स्थळांच्या संवर्धनात भूमिका समजून घेणे.
- 4) ऐतिहासिक स्थळांच्या संवर्धनात AI च्या उपयोगांचा अभ्यास करणे.
- 5) पर्यटन, निरीक्षण आणि शिक्षणामधील AI चा प्रभाव विश्लेषित करणे.
- 6) AI वापरताना येणाऱ्या अडचणी आणि मर्यादा समजून घेणे.



३. संशोधन पद्धती (Research Methodology):

सदर संशोधन हे वर्णनात्मक व विश्लेषणात्मक स्वरूपाचे आहे.

- डेटाचा प्रकार: दुय्यम माहिती (Secondary Data)
- माहितीचे स्रोत:
 - संशोधन जर्नल्स
 - कृत्रिम बुद्धिमत्ता व वारसा संवर्धन विषयक पुस्तके
 - UNESCO आणि शासकीय अहवाल
 - शैक्षणिक संकेतस्थळे आणि ऑनलाइन लेख

संकलित माहितीचे तुलनात्मक व विश्लेषणात्मक अध्ययन करण्यात आले आहे व ऐतिहासिक संशोधन पद्धतीचा वापर करण्यात आला आहे.

४. ऐतिहासिक स्थळांचा शाश्वत विकास : संकल्पना

ऐतिहासिक स्थळांचा शाश्वत विकास म्हणजे अशा पद्धतीने संवर्धन करणे की,

- सांस्कृतिक मूल्यांचे संरक्षण होईल.
- पर्यावरणाचा समतोल राखला जाईल.
- आर्थिक लाभ मिळून विकासाला हातभार लावला जाईल.
- पुढील पिढ्यांसाठी वारसा सुरक्षित राहील.

शाश्वत विकासामध्ये स्थानिक समुदायाचा सहभाग, जबाबदार पर्यटन आणि तंत्रज्ञानाचा योग्य वापर यांना महत्त्व दिले जाते.

५. कृत्रिम बुद्धिमत्ता : एक आढावा:

कृत्रिम बुद्धिमत्ता म्हणजे अभूतपूर्व तंत्रज्ञानाचा अद्भूत आविष्कार आहे. या तंत्रज्ञानात विलक्षण क्षमता आहे. जगाच्या व्यवहारामध्ये या क्षमतांचा उपयोग करून घेतला तर अमुलाग्र परिवर्तन होऊ शकते. आपल्या दैनंदिन जीवनात सुद्धा अनेक पातळ्यांवर विविध प्रकारचे बदल होऊ शकतात. आपले दैनंदिन जीवन अधिक आरामदायक, सुखकर आणि आनंददायक होऊ शकते. त्याचा अनुभव कृत्रिम बुद्धिमत्तेचा वापर करून आपण घेतला असेलच. कृत्रिम बुद्धिमत्ता म्हणजे संगणक किंवा मानवी बुद्धिमत्तेसारखी विचार, विश्लेषण आणि निर्णय घेण्याची क्षमता विकसित करणे. AI मधील प्रमुख तंत्रज्ञान पुढीलप्रमाणे आहेत:

- मशीन लर्निंग (Machine Learning)



- संगणकीय दृष्टी (Computer Vision)
- नैसर्गिक भाषा प्रक्रिया (Natural Language Processing)
- पूर्वानुमान विश्लेषण (Predictive Analytics)
- ड्रोन व रोबोटिक्स

५.१ आर्टिफिशियल इंटेलिजन्सचा इतिहास:

१९४३ दुसऱ्या महायुद्धाचा कालखंड होता. एका बाजूला युद्ध चालू असताना दुसरीकडे या आधुनिक तंत्रज्ञानाची सुरुवात झाली. वॉरन मॅक क्युलोच (Warren McCulloch) आणि वॉटर पिट्स (Walter Pitts) यांनी 1943 मध्ये एक अत्यंत महत्त्वाचा पेपर लिहिला. त्यात त्यांनी **मानवी मेंदूतील न्यूरॉन्सवर आधारित गणिती/तार्किक मॉडेल** मांडले. हे मॉडेल आज **Artificial Neuron** किंवा **McCulloch-Pitts Neuron** म्हणून ओळखले जाते. आर्टिफिशियल न्यूरल नेटवर्क्स (ANN) ची पायाभरणी मेंदूला लॉजिक आणि गणिताच्या स्वरूपात समजावून सांगण्याचा प्रयत्न या दोन शास्त्रज्ञांनी केला.

५.२ इलेक्ट्रॉनिक ब्रेन, चॅटबॉट

इलेक्ट्रॉनिक ब्रेन हा शब्द प्रयोग करण्याचे श्रेय १९४५ ते ५० याकाळात प्रारंभिक संगणकांवर लिहिणाऱ्या पत्रकारांना आणि लोकप्रिय विज्ञान लेखकांना द्यावे लागेल. वॉरन मॅक क्युलोच हा मेंदू आणि शरीर शास्त्राचा संशोधक होता. तर वॉटर पिट्स हा तर्कशास्त्र, मज्जासंस्था यांचा डॉक्टर असून तो संगणक तज्ञ होता. १९४३ मध्ये त्यांनी कृत्रिम बुद्धिमत्तेची पायाभरणी केली. इलेक्ट्रॉनिक ब्रेन म्हणजे इलेक्ट्रॉनिक मेंदूच्या निर्मितीची कल्पना या वरील दोन शास्त्रज्ञांनी मांडली. A logical calculus of ideas immanent in nervous activity. असा एक निबंध त्यांनी लिहिला. इलेक्ट्रॉनिक मेंदूचा विचार पुढे आला. १९६४ मध्ये जोसेफ वाईझनबाम या संगणक तज्ञाने एलिझा हा संगणक प्रोग्राम विकसित केला परिणामी आपण संगणकाबरोबर बोलू लागलो. आपण शब्द उच्चारला की संगणक ते समजून घेऊ लागला आणि तो उत्तरे देऊ लागला याला चॅटबॉट म्हणतात.

कृत्रिम बुद्धिमत्तेचा विचार १९५० मध्ये ब्रिटिश गणित तज्ञ एलन ट्युरिंग यांनी देखील मांडला. संगणकाकडे मानवा सारखीच बुद्धिमत्ता असते आणि तो संगणक मानवासारखा विचार करू शकतो त्याची बुद्धिमत्ता मानवाच्या बुद्धिमत्ते इतकीच कुशाग्र असते. संगणकाचा बौद्धिक वर्तन हे मानवाच्या बौद्धिक वर्तनासारखेच असते हे त्यांनी दाखवून दिले. त्यांनी जो लेख लिहिला त्याचे नाव होते कम्प्युटिंग मशिनरी आणि इंटेलिजन्स. मराठीत त्याचा अर्थ आहे संगणकाची



बुद्धिमत्ता आणि त्या बुद्धिमत्तेचे होऊ शकणारे उपयोग. आज आर्टिफिशियल इंटेलिजन्सच्या क्षेत्रात जे ज्ञानाचे दरवाजे खुले झाले आहेत त्याची सुरुवात ५० वर्षांपूर्वी झाली आहे. त्यांनी १९६४ मध्ये गणितातील प्रमेय सोडवू शकण्याची यंत्रणा संगणकात उभी केली गेली. संगणक माणसाप्रमाणे बोलू लागला. तो आपल्या आवाजाला प्रति आवाज देऊन प्रतिसाद करू लागला.

१९७४ साल उजाडले हंस मोराव्हॅक यांनी मानवी मेंदू आणि संगणकाच्या क्षमतेची तुलना केली असून, सुरुवातीच्या संगणकांची क्षमता मानवी बुद्धिमत्तेपेक्षा खूप कमी असल्याचे मत मांडले. ते John McCarthy यांच्या प्रभावाखाली AI क्षेत्रात संशोधन करत होते. त्यांच्या या एकाच वाक्याने आर्टिफिशियल इंटेलिजन्सचा बाजार कोसळला. ज्या कंपन्यांनी या संशोधनाच्या क्षेत्रात पैसा गुंतवला होता त्यांनी हात आखडता घेतला. कृत्रिम बुद्धिमत्तेसाठी हा कालखंड खडतर होता. आर्टिफिशियल इंटेलिजन्स विंटर असे त्यास संबोधले. मराठीत त्याला कृत्रिम बुद्धिमत्तेचा हिवाळा असे म्हणतात. १९८२ साली जपान सरकारने MITI मार्फत Fifth Generation Computer Systems हा प्रकल्प सुरू केला. या प्रकल्पासाठी सुमारे ५७ अब्ज येन (अंदाजे ४५०-५०० मिलियन डॉलर) इतके अनुदान देण्यात आले. जगातील विविध भाषांमध्ये संगणक बोलू लागला अनुवाद करू लागला यासाठी ते अनुदान होते.

२०२१ मध्ये एलोन मस्क Elon Musk यांच्या Neuralink कंपनीने एक इलेक्ट्रॉनिक चिप विकसित केली.

मेंदू - संगणक इंटरफेससाठी प्रायोगिक तत्त्वावर ती एका माकडाच्या मेंदूत बसवण्यात आली आणि त्या माकडाने मेंदूतील सिग्नल्स वापरून संगणकावर व्हिडिओ गेम खेळला. ही कंपनी **मेंदू - संगणक इंटरफेससाठी इलेक्ट्रॉनिक चिप** विकसित करते. ही चिप मेंदूतील सिग्नल्स संगणकांशी जोडते आणि भविष्यात न्युरोलॉजिकल आजार व अर्धाग्यवायू सुधारण्यासाठी याचा उपयोग होऊ शकतो.

५.३ ChatGPT:

Artificial Intelligence चा आधुनिक विकास ChatGPT, Neuralink आणि Turing Test या तीन महत्त्वाच्या घटकांमुळे स्पष्ट दिसतो. **ChatGPT**, नोव्हेंबर २०२२ मध्ये OpenAI ने लॉन्च केलेले AI-आधारित भाषिक मॉडेल आहे, जे संगणक किंवा मोबाईलवर प्रश्न विचारल्यावर उत्तर देते आणि संवाद साधू शकते. हे पूर्णपणे स्वायत्त बुद्धिमत्ता नसले तरी, इंटरनेट आणि प्रशिक्षण डेटा वापरून कार्य करते. **Neuralink** ही Elon Musk ची कंपनी आहे जी मेंदू-संगणक इंटरफेससाठी इलेक्ट्रॉनिक चिप विकसित करते, जी मेंदूतील सिग्नल्स वाचून संगणक



किंवा उपकरण नियंत्रित करते; सध्या ही प्रायोगिक टप्प्यात आहे आणि AI सोबत वापरता येऊ शकते.

Turing Test, Alan Turing (1950) यांनी मांडलेली एक पद्धत आहे, जी मशीन मानवासारखी बुद्धिमत्ता दाखवते का ते तपासते. या तिन्ही घटकांचा संगम आधुनिक AI च्या उपयोगाची आणि विकासाची सविस्तर कल्पना देते. Neural Network ही संगणकात मज्जातंतू सारखी संरचना आहे, ज्यामधील Nodes इनपुटवर प्रक्रिया करून आउटपुट तयार करतात.

Large Language Models (LLMs) अनेक भाषा समजतात आणि नियमबद्ध, तर्कशुद्ध उत्तर देतात. AI चा वापर क्रीडा विश्लेषण, डेटा प्रक्रिया आणि भविष्यात ऐतिहासिक वारसा स्थळांच्या संवर्धनासाठी सहाय्यक होऊ शकतो. AI समस्यांचे निराकरण करताना प्रशिक्षण डेटा, गणित, इतिहास आणि तर्कशास्त्र यावर आधारित निर्णय घेते. त्यामुळे AI ला दिलेली माहिती अचूक आणि नियमबद्ध असणे महत्त्वाचे आहे.

६. ऐतिहासिक स्थळांच्या शाश्वत विकासामध्ये कृत्रिम बुद्धिमत्तेची भूमिका:

६.१ स्मारकांचे संवर्धन व पुनर्संचयन:

AI आधारित संगणकीय दृष्टी तंत्रज्ञानाच्या साहाय्याने स्मारकांमधील भेगा, झीज, रंग बदल आणि संरचनात्मक कमकुवतपणा ओळखू शकते. 3D स्कॅनिंग आणि प्रतिमा विश्लेषणामुळे नुकसान लवकर ओळखता येईल. तसेच जुन्या छायाचित्रे व ऐतिहासिक नोंदी वापरून डिजिटल पुनर्संचयन करता येवू शकते, ज्यामुळे त्यांचे मूळ स्वरूप जतन होईल.

६.२ निरीक्षण व धोका व्यवस्थापन:

AI प्रणाली सेन्सर्स, उपग्रह आणि ड्रोनच्या साहाय्याने ऐतिहासिक स्थळांचे सातत्याने निरीक्षण करू शकते. त्यामुळे -

- पूर, भूकंप, हवामान बदल यांचा अंदाज
- प्रदूषण पातळीचे निरीक्षण
- तोडफोड व अतिक्रमण ओळखणे

सुलभ होईल आणि वेळेआधी उपाययोजना करता येवू शकेल.

६.३ शाश्वत पर्यटन व्यवस्थापन:

अतिपर्यटनामुळे ऐतिहासिक स्थळांचे नुकसान होते. AI आधारित प्रणाली -

- पर्यटकांची संख्या नियंत्रित करणे,
- गर्दीचा अंदाज लावणे,



• स्मार्ट तिकीट प्रणाली विकसित करणे
यामध्ये मदत करू शकतात तसेच व्हर्च्युअल टूर मुळे प्रत्यक्ष स्थळांवरील ताण कमी होवू शकतो.

६.४ डिजिटल दस्तऐवजीकरण व जतन:

AI तंत्रज्ञानामुळे -

- स्मारकांचे 3D मॉडेल तयार करणे,
- हस्तलिखिते, शिलालेखांचे डिजिटायझेशन,
- प्राचीन लिपींचे भाषांतर

करणे शक्य होणार आहे. तसेच यामुळे ऐतिहासिक माहिती कायमस्वरूपी सुरक्षित राहू शकते.

६.५ शिक्षण व जनजागृती:

AI आधारित -

- व्हर्च्युअल रिऍलिटी (VR)
- ऑगमेंटेड रिऍलिटी (AR)
- आभासी मार्गदर्शक (Virtual Guides)

यामुळे इतिहास शिक्षण अधिक रंजक आणि प्रभावी होईल तसेच वारसा संवर्धनाबाबत जनजागृती वाढेल.

७. फायदे: ऐतिहासिक स्थळांच्या शाश्वत विकासासाठी कृत्रिम बुद्धिमत्तेचा वापर केल्यास अनेक महत्त्वाचे फायदे मिळतील. हे फायदे पुढीलप्रमाणे आहेत -

७.१ अचूक व प्रभावी संवर्धन:

कृत्रिम बुद्धिमत्तेच्या साहाय्याने स्मारकांमधील भेगा, झीज, ओलावा, वायू प्रदूषणामुळे होणारे नुकसान लवकर ओळखता येईल. यामुळे वेळेआधी दुरुस्ती करून मोठे नुकसान टाळता येवू शकते आणि संवर्धन कार्य अधिक अचूक व प्रभावी करता येवू शकते.

७.२ खर्च आणि वेळेची बचत:

पारंपरिक संवर्धन पद्धतींमध्ये मोठ्या प्रमाणावर मनुष्यबळ, वेळ आणि खर्च लागतो. AI आधारित प्रणाली स्वयंचलित निरीक्षण व विश्लेषण करू शकेल, ज्यामुळे खर्च कमी होवू शकतो आणि काम कमी वेळेत पूर्ण करता येवू शकते.

७.३ सातत्यपूर्ण निरीक्षण शक्य:

AI प्रणाली २४x७ ऐतिहासिक स्थळांचे निरीक्षण करू शकते. ड्रोन, सेन्सर्स आणि उपग्रहांच्या साहाय्याने सतत माहिती गोळा केली जावू शकते, ज्यामुळे अचानक होणारे बदल किंवा धोके त्वरित लक्षात येवू शकतात.



७.४ मानवी जोखीम कमी होते: काही ऐतिहासिक स्थळे धोकादायक किंवा अवघड ठिकाणी असतात. अशा ठिकाणी AI आधारित ड्रोन आणि रोबोट्सचा वापर केल्यास मानवी जीविताला धोका न होता निरीक्षण आणि संवर्धन कार्य अधिक प्रभावी करता येवू शकते.

७.५ पर्यटन व्यवस्थापन सुधारते:

AI तंत्रज्ञानामुळे पर्यटकांची संख्या नियंत्रित करता येईल, गर्दीचे नियोजन करता येईल आणि तिकीट व्यवस्था अधिक पारदर्शक होवू होईल. यामुळे ऐतिहासिक स्थळांचे संरक्षण करणे शक्य होईल. तसेच पर्यटकांना चांगला अनुभव मिळू लागेल.

७.६ डिजिटल जतन व दीर्घकालीन संरक्षण:

AI च्या मदतीने ऐतिहासिक स्थळांचे 3D मॉडेल, डिजिटल नोंदी, हस्तलिखिते व शिलालेख जतन करता येवू शकते. भविष्यात नैसर्गिक आपत्ती किंवा नुकसान झाल्यास ही माहिती उपयोगी ठरेल.

७.७ शिक्षण व जनजागृती वाढते:

AI आधारित व्हर्चुअल टूर, आभासी मार्गदर्शक आणि संवादात्मक माध्यमांमुळे लोकांमध्ये इतिहासाबद्दलची रुची वाढेल. तसेच ऐतिहासिक वारशाच्या संवर्धनाचे महत्त्व समाजापर्यंत पोहोचेल.

७.८ शाश्वत विकासाला चालना:

कृत्रिम बुद्धिमत्ता सांस्कृतिक, पर्यावरणीय आणि आर्थिक या तिन्ही घटकांमध्ये संतुलन राखण्यास मदत होईल. त्यामुळे ऐतिहासिक स्थळांचा शाश्वत विकास साध्य होवू शकतो.

८. मर्यादा व आव्हाने:

जरी ऐतिहासिक स्थळांच्या शाश्वत विकासासाठी कृत्रिम बुद्धिमत्ता अत्यंत उपयुक्त ठरत असली, तरी तिच्या वापरास काही महत्त्वाच्या मर्यादा व आव्हाने आहेत. ही आव्हाने लक्षात घेणे आवश्यक आहे, कारण त्यांचा परिणाम संवर्धनाच्या प्रक्रियेवर होऊ शकतो.

८.१ तंत्रज्ञानाचा उच्च खर्च:

कृत्रिम बुद्धिमत्तेवर आधारित प्रणाली, सेन्सर्स, ड्रोन, 3D स्कॅनिंग उपकरणे आणि सॉफ्टवेअर यांचा खर्च खूप जास्त असतो. अनेक ऐतिहासिक स्थळे ग्रामीण किंवा कमी निधीच्या भागात असल्याने अशा ठिकाणी आधुनिक तंत्रज्ञानाचा वापर करणे कठीण जाईल.



८.२ प्रशिक्षित मनुष्यबळाची कमतरता: AI प्रणाली प्रभावीपणे वापरण्यासाठी तांत्रिक ज्ञान असलेले तज्ञ आवश्यक असतात. मात्र ऐतिहासिक संवर्धन क्षेत्रात AI तज्ञांची कमतरता असल्यामुळे तंत्रज्ञानाचा पूर्ण उपयोग होऊ शकणार नाही.

८.३ डिजिटल पायाभूत सुविधांचा अभाव: काही ऐतिहासिक स्थळे दूरवर किंवा दुर्गम भागात असल्यामुळे इंटरनेट, वीजपुरवठा आणि डिजिटल सुविधा अपुऱ्या असतात. अशा परिस्थितीत AI आधारित प्रणाली कार्यक्षमपणे राबवणे आव्हानात्मक ठरेल.

८.४ डेटा गोपनीयता व सुरक्षिततेचे प्रश्न:

AI प्रणाली मोठ्या प्रमाणावर डेटा संकलन करतात. यात पर्यटकांची माहिती, स्थानिक माहिती आणि संवेदनशील वारसा माहितीचा समावेश असतो. या डेटाच्या गोपनीयतेबाबत आणि सुरक्षिततेबाबत धोके निर्माण होऊ शकतात.

८.५ सांस्कृतिक संवेदनशीलतेचा अभाव:

कृत्रिम बुद्धिमत्ता ही तांत्रिक प्रणाली असल्याने ती सांस्कृतिक भावना, धार्मिक मूल्ये आणि स्थानिक परंपरा पूर्णपणे समजू शकत नाही. चुकीच्या वापरामुळे ऐतिहासिक स्थळांचे मूळ स्वरूप किंवा सांस्कृतिक महत्त्व कमी होण्याचा धोका निर्माण होवू शकतो.

८.६ तंत्रज्ञानावर अतीअवलंबन:

AI वर पूर्णपणे अवलंबून राहिल्यास पारंपरिक ज्ञान, स्थानिक कौशल्ये आणि तज्ज्ञ अनुभव दुर्लक्षित होऊ शकतात. त्यामुळे संवर्धन प्रक्रियेत संतुलन राखणे आवश्यक आहे.

८.७ पर्यावरणीय परिणाम:

AI प्रणाली, विशेषतः मोठ्या डेटा प्रक्रिया केंद्रांमुळे, अधिक ऊर्जा वापर करतात. यामुळे कार्बन उत्सर्जन वाढू शकते, जे शाश्वत विकासाच्या उद्दिष्टांशी विसंगत ठरू शकते.

८.८ कायदेशीर व नैतिक अडचणी:

AI वापराबाबत स्पष्ट कायदे आणि मार्गदर्शक तत्वांचा अभाव असल्यामुळे जबाबदारी निश्चित करणे कठीण जाते. तसेच निर्णय प्रक्रियेत पारदर्शकतेचा अभाव नैतिक प्रश्न निर्माण करू शकतात.

९. निष्कर्ष:

एकूणच, कृत्रिम बुद्धिमत्तेचा वापर करताना वरील मर्यादा आणि आव्हानांचा विचार करून योग्य धोरणे, प्रशिक्षण आणि नैतिक मार्गदर्शक तत्वे तयार करणे आवश्यक ठरणार आहे. AI



चा वापर पारंपरिक संवर्धन पद्धतींच्या पूरक स्वरूपात केल्यास ऐतिहासिक वारसा स्थळांचा शाश्वत विकास अधिक प्रभावीपणे साध्य होऊ शकतो.

ऐतिहासिक वारसा स्थळांच्या शाश्वत विकासामध्ये कृत्रिम बुद्धिमत्ता तेव्हाच महत्त्वाची भूमिका बजावू शकते जेव्हा स्पष्ट कायदे आणि मार्गदर्शक तत्त्वांचा अवलंब काटेकोरपणे केला जाईल. येणाऱ्या काळात ऐतिहासिक वारसा स्थळांचे संवर्धन, निरीक्षण, पर्यटन व्यवस्थापन, डिजिटल जतन आणि शिक्षण या सर्व क्षेत्रांमध्ये AI प्रभावी ठरणार आहे. योग्य नियोजन, नैतिक वापर आणि सर्वसमावेशक धोरणांच्या माध्यमातून AI चा वापर केल्यास आपल्या सांस्कृतिक वारशाचे दीर्घकालीन संरक्षण शक्य होईल. त्यासाठी कृतिशील ध्येयधोरणे आखून व्यापक स्तरावर त्यांची अमलबजावणी होणे आवश्यक आहे.

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कृत्रिम बुद्धिमत्तेवरील मानवी विश्वास : एक सामाजिक-

मानसशास्त्रीय अभ्यास

डॉ. सुरेश प्रकाश पाटील

सहाय्यक प्राध्यापक

मानसशास्त्र विभाग,

मत्स्योदरी कला, विज्ञान व वाणिज्य महाविद्यालय

अंबड, जि.जालना

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सारांश (Abstract) :

समाजातील निर्णयप्रक्रिया, सेवा वितरण आणि मानवी वर्तनावर प्रभाव टाकणारी महत्त्वाची तंत्रज्ञानाची शक्ती बनली आहे. तथापि, AI प्रणालींचा प्रभावी वापर आणि स्वीकार हा फक्त तांत्रिक क्षमतेवर अवलंबून नसून मानवी विश्वासावर देखील अवलंबून असतो. प्रस्तुत अभ्यासात सामाजिक-मानसशास्त्रीय दृष्टिकोनातून AI वरील मानवी विश्वासाचा सखोल अभ्यास केला आहे. वर्णनात्मक संशोधन पद्धतीचा अवलंब करून 120 प्रतिसादकांकडून प्रश्नावलीद्वारे डेटा संकलित केला. SPSS विश्लेषणानुसार जागरूकता, पारदर्शकता आणि सामाजिक मान्यता AI वरील विश्वास वाढवतात, तर AI Anxiety (भीती/असुरक्षितता) आणि जोखीम समज विश्वास कमी करतात. हा अभ्यास AI विकास व धोरणनिर्मितीसाठी मानसशास्त्रीय दृष्टिकोन समजून घेण्यास उपयुक्त ठरतो.

कीवर्ड्स: कृत्रिम बुद्धिमत्ता, विश्वास, सामाजिक मानसशास्त्र, AI Anxiety, तंत्रज्ञान स्वीकार

प्रस्तावना :

२१व्या शतकात तंत्रज्ञानाने मानवी जीवनात अभूतपूर्व बदल घडवून आणले आहेत. त्यातील प्रमुख बदलांपैकी कृत्रिम बुद्धिमत्ता (AI) मानवी निर्णय, सामाजिक व्यवहार आणि नैतिक चौकटींवर प्रभाव टाकणारी महत्त्वाची साधने बनली आहे. AI आज वैद्यकीय निदान, डिजिटल प्रशासन, शिक्षणातील वैयक्तिकृत अध्यापन, बँकिंग व्यवहार, तसेच सोशल मीडियामध्ये अल्गोरिदम नियंत्रणात महत्त्वाची भूमिका बजावत आहे. तथापि, लोकांचा विश्वास नसल्यास सर्वात प्रगत AI प्रणाली देखील प्रभावी ठरत नाही. सामाजिक मानसशास्त्राच्या दृष्टिकोनातून विश्वास हा अनुभव, सामाजिक वातावरण, जोखीम समज, भावनिक प्रतिक्रिया आणि सांस्कृतिक मूल्यांवर आधारित असतो. AI ही मानवी नसलेली बुद्धिमत्ता असल्याने लोकांमध्ये उत्सुकता, अपेक्षा, भीती आणि संशय यांसारख्या भावना एकत्र दिसतात. त्यामुळे AI वरील मानवी विश्वासाचा सामाजिक-मानसशास्त्रीय अभ्यास अत्यंत आवश्यक ठरतो.



कृत्रिम बुद्धिमत्तेची व्याख्या:

AI म्हणजे संगणक प्रणालींना शिकणे, विचार करणे, निर्णय घेणे आणि समस्या सोडवणे यास सक्षम करणे. मशीन लर्निंग, डीप लर्निंग, न्यूरल नेटवर्क्स आणि नैसर्गिक भाषा प्रक्रिया (NLP) ही AI ची मुख्य शाखा आहेत.

सामाजिक मानसशास्त्रातील विश्वास:

सामाजिक मानसशास्त्रात, विश्वास म्हणजे एखाद्या घटकाकडून अपेक्षित आणि सकारात्मक वर्तन मिळेल अशी व्यक्तीची मानसिक अपेक्षा होय. हे केवळ व्यक्तीच्या अनुभवानुसार नाही तर सामाजिक संदर्भ, अनुभव आणि मूल्यांवरही अवलंबून असते. विश्वास निर्माण होण्यासाठी तीन मूलभूत घटक आवश्यक मानले जातात:

(१) क्षमता (Competence) - घटक किंवा प्रणाली आवश्यक कार्यक्षमतेसह कार्य करण्यास सक्षम असावी, (२) नैतिकता (Integrity) - तिचे वर्तन नैतिक आणि प्रामाणिक असावे, आणि

(३) कल्याणभावना (Benevolence):

कृत्रिम बुद्धिमत्ता (AI) बाबतीत ही तीनही घटक लोकांच्या मनात प्रश्नांकित होतात, कारण AI प्रणाली मानवी भावना, नैतिक विचार किंवा कल्याणाच्या अंतर्निहित उद्देशाने प्रेरित नसतात. परिणामी, AI वरील विश्वास हा केवळ तांत्रिक क्षमतेवर अवलंबून नसून, सामाजिक आणि मानसशास्त्रीय मूल्यांच्या आधारावर ठरतो.

AI वरील मानवी विश्वास: सामाजिक-मानसशास्त्रीय परिमाण:

३.१ सामाजिक स्वीकार:

लोक एखाद्या तंत्रज्ञानाला कितपत मान्यता देतात हे त्यांच्या विश्वासावर परिणाम करते. सामाजिक मान्यता मिळालेल्या AI प्रणालीवर लोक जास्त विश्वास ठेवतात.

३.२ भावनिक घटक :

AI ला मानवी भावना नसल्यामुळे लोकांना भावनिक नाते निर्माण करणे कठीण जाते, ज्यामुळे विश्वास मर्यादित राहतो.

३.३ जोखीम समज व Anxiety :

डेटा गोपनीयता, गैरवापर, चुकीचे निर्णय यामुळे लोकांमध्ये AI विषयी असुरक्षितता (Anxiety) वाढते, ज्याचा परिणाम विश्वासावर होतो.

४ .साहित्यपरिशीलन (Review of Literature):

Davis (1989) यांनी Technology Acceptance Model (TAM) मध्ये तंत्रज्ञान स्वीकारण्यामागील मानसशास्त्रीय घटक स्पष्ट केले. Lee आणि See (2004) यांनी ऑटोमेशनवरील विश्वास योग्य प्रमाणात असावा असे सांगितले. Glikson आणि Woolley (2020) यांच्या अभ्यासानुसार AI वरील विश्वास सामाजिक संदर्भ, अनुभव आणि पारदर्शकतेवर अवलंबून



असतो. भारतीय संदर्भात डिजिटल दरी, AI साक्षरतेचा अभाव आणि नैतिक चौकटींचा अस्पष्टता हे विश्वास निर्माण होण्याचे मुख्य अडथळे आहेत.

संशोधन उद्दिष्टे

1. AI वरील मानवी विश्वासाचा स्तर मोजणे
2. AI Awareness आणि विश्वास यातील संबंध तपासणे
3. AI Anxiety चा विश्वासावर परिणाम समजून घेणे

गृहितके

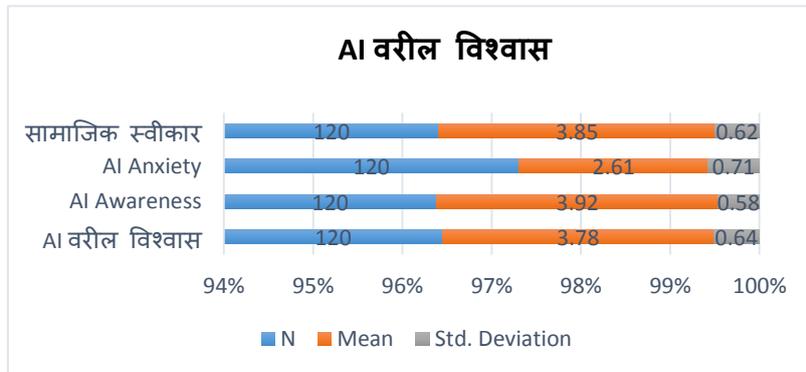
1. AI विषयी अधिक जागरूकतेचा विश्वासावर सकारात्मक परिणाम होतो.
2. AI Anxiety वाढल्यास विश्वासावर नकारात्मक परिणाम होतो.

संशोधन पद्धती:

सध्याचा अभ्यास वर्णनात्मक संशोधन पद्धतीवर आधारित आहे, ज्यात 120 प्रतिसादक (विद्यार्थी, शिक्षक, कर्मचारी) निवडले गेले. साध्या यादृच्छिक नमुन्याद्वारे डेटा संकलित केला गेला आणि 5-बिंदू Likert Scale प्रश्नावली वापरली गेली. डेटा विश्लेषणासाठी SPSS मध्ये वर्णनात्मक सांख्यिकी, सहसंबंध व प्रतिगमन पद्धती वापरण्यात आल्या.

८. डेटा विश्लेषण व निष्कर्ष:

घटक	N	Mean	Std. Deviation
AI वरील विश्वास	120	3.78	0.64
AI Awareness	120	3.92	0.58
AI Anxiety	120	2.61	0.71
सामाजिक स्वीकार	120	3.85	0.62

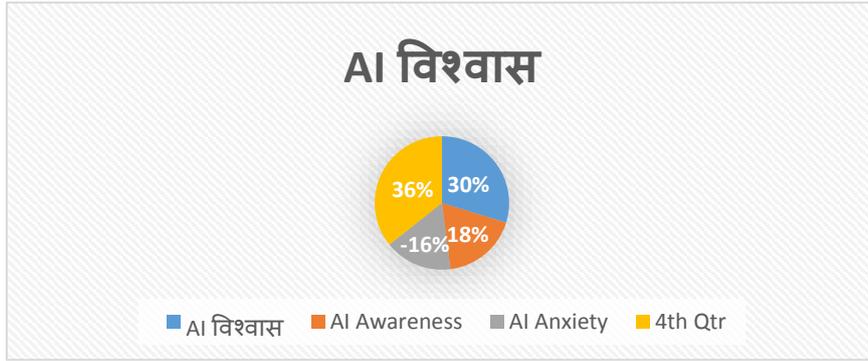


Interpretation: विश्वास, जागरूकता आणि सामाजिक स्वीकार जास्त असून AI Anxiety तुलनेने कमी आहे.



घटक	AI विश्वास	AI Awareness	AI Anxiety
AI विश्वास	1.000	0.612	-0.548
AI Awareness	0.612	1.000	-0.421
AI Anxiety	-0.548	-0.421	1.000

($p < 0.01$)

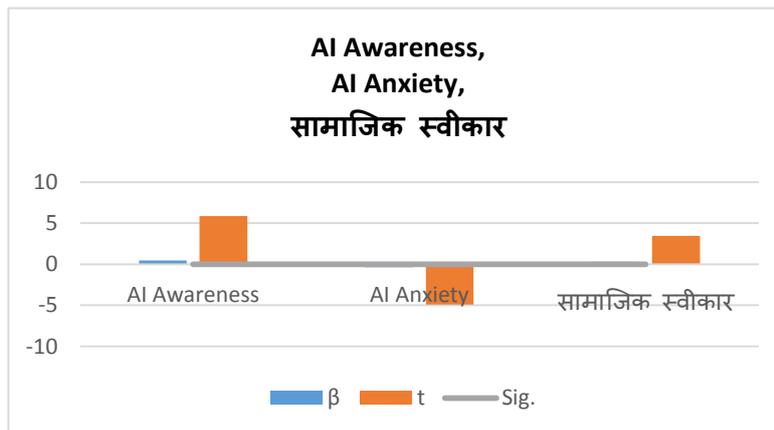


Interpretation: जागरूकता व AI विश्वास यामध्ये सकारात्मक, तर AI Anxiety व विश्वास यामध्ये नकारात्मक संबंध आहे.

प्रतिगमन विश्लेषण (Regression Analysis):

घटक	β	t	Sig.
AI Awareness	0.463	5.87	0.000
AI Anxiety	-0.382	-4.91	0.000
सामाजिक स्वीकार	0.298	3.44	0.001

$R^2 = 0.56$





Interpretation: जागरूकता व सामाजिक स्वीकार सकारात्मक, तर AI Anxiety नकारात्मक प्रभाव टाकते.

९. संशोधन निष्कर्ष

संपूर्ण विश्लेषणानुसार, काही महत्वाचे निष्कर्ष स्पष्ट होतात. प्रथम, AI जागरूकता (Awareness) हा विश्वास वाढविणारा प्रमुख घटक आहे. जे लोक AI विषयी अधिक माहिती आणि समजूतदार आहेत, ते AI प्रणालींवर अधिक विश्वास ठेवतात. दुसरे, AI Anxiety किंवा AI विषयीची असुरक्षितता हा विश्वास कमी करणारा घटक आहे. जेव्हा लोकांना डेटा सुरक्षितता, गोपनीयता, चुकीचे निर्णय किंवा नैतिक अडचणींबाबत चिंता असते, तेव्हा त्यांच्या AI वरील विश्वासावर नकारात्मक परिणाम होतो. तिसरे, सामाजिक स्वीकार (Social Acceptance) हा विश्वास वाढवण्यास सहाय्यक घटक आहे. समाजात AI प्रणालींचा व्यापक स्वीकार आणि सामाजिक मान्यता असल्यास व्यक्तींचा विश्वास अधिक मजबूत बनतो.

एकत्रितपणे, हे निष्कर्ष सूचित करतात की AI वरील मानवी विश्वास हा केवळ तांत्रिक क्षमता किंवा तंत्रज्ञानाच्या कार्यक्षमतेवर अवलंबून नसून सामाजिक-मानसशास्त्रीय घटकांवरही अवलंबून असतो. जागरूकता, सामाजिक मान्यता आणि नैतिक पारदर्शकता यांचा समन्वय विश्वास वाढवण्यास महत्वाचा ठरतो, तर असुरक्षितता आणि चिंता यांचा नकारात्मक प्रभाव होतो. त्यामुळे AI स्वीकार आणि धोरणात्मक निर्णयांसाठी मानसशास्त्रीय आणि सामाजिक घटकांचा विचार करणे आवश्यक आहे.

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इतिहास लेखन व संशोधन प्रक्रियेतील निवडक AI साधनांचे योगदान

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सारांश (Abstract) :

कृत्रिम बुद्धिमत्ता (AI) शिक्षण, अध्ययन व संशोधनाच्या पारंपरिक पद्धतींमध्ये महत्त्वाचा बदल घडवून आणते. इतिहास हा समाजाच्या विविध प्रक्रियांचा अभ्यास असल्याने, AI साधने जसे की Mapflow.AI, Google Earth Engine, GeoWGS84.AI, AI Storyteller, Glance AI Writer, Preserv AI, YOLO (You Only Look Once), Kraken OCR, Eden AI, peparpal, Hyper Write, IoT एज सेन्सर्स आणि Chat GPT यांचा वापर करून लिखित, मौखिक, दृश्य व भौगोलिक स्रोतांचे संकलन व विश्लेषण अधिक प्रभावी आणि अचूक करण्यास मदत होते. हा संशोधन निबंध AI च्या शैक्षणिक मूल्यांचे आणि महत्त्वाचे पैलू यांचे स्पष्टीकरण देतो. AI आधारित साधनांच्या वापरामुळे ऐतिहासिक माहितीचे आणि स्रोतांचे संकलन, वर्गीकरण आणि करता येते. याशिवाय दृश्यीकरण व मांडणी अधिक वेगवान, अचूक व प्रभावी बनत चालली आहे. प्रस्तुत संशोधन निबंधाचा उद्देश इतिहासाच्या अध्यापन-अध्ययन व संशोधन प्रक्रियेत AI साधनांचा उपयोग, त्यांचे शैक्षणिक मूल्य आणि त्यातील चिकित्सक पैलूंचा सखोल अभ्यास करणे हा आहे.

मुख्य शब्द: (Keywords): कृत्रिम बुद्धिमत्ता, इतिहास अध्यापन, इतिहास संशोधन, डिजिटल इतिहास, AI साधने.

संशोधनाची गरज:

1. इतिहास शिक्षणात तंत्रज्ञानाधारित साधनांचा वाढता वापर समजून घेणे
2. AI मुळे इतिहास संशोधनाच्या पद्धतींमध्ये झालेल्या बदलांचा अभ्यास करणे
3. शिक्षक व विद्यार्थ्यांसाठी AI साधनांचे शैक्षणिक मूल्य स्पष्ट करणे
4. AI च्या मर्यादा व नैतिक प्रश्नांवर चिकित्सक चर्चा करणे



संशोधनाची उद्दिष्टे:

1. इतिहास अध्यापन-अध्ययनात AI साधनांचा उपयोग विशद करणे.
2. विविध AI साधनांचे कार्यपद्धतीनिहाय विश्लेषण करणे.
3. इतिहास संशोधनातील AI च्या योगदानाचे मूल्यमापन करणे.
4. AI वापरातील मर्यादा व आव्हाने अधोरेखित करणे.
5. मानवी इतिहासकार व AI यांच्यातील समन्वयाची भूमिका स्पष्ट करणे.

संशोधन पद्धती:

प्रस्तुत अभ्यासासाठी वर्णनात्मक व विश्लेषणात्मक पद्धतींचा अवलंब करण्यात आला आहे. द्वितीयक स्रोतांमध्ये संशोधन लेख, पुस्तके, अहवाल, डिजिटल डेटाबेस व AI साधनांची अधिकृत माहिती यांचा वापर करण्यात आला आहे. तसेच तुलनात्मक विश्लेषणाच्या साहाय्याने विविध AI साधनांचे इतिहासातील उपयोग स्पष्ट करण्यात आले आहेत.

AI आणि इतिहास : संकल्पनात्मक पार्श्वभूमी:

21 शतकात, ज्ञाननिर्मिती व ज्ञानप्रसार प्रक्रियेत तंत्रज्ञान, विशेषतः कृत्रिम बुद्धिमत्ता, महत्त्वाची भूमिका बजावत आहे. AI आधारित साधने इतिहासातील कालरेषा, भौगोलिक विस्तार, सामाजिक बदल आणि सांस्कृतिक परस्परसंवादाच्या नवीन पद्धतींमध्ये आकलनास मदत करताना त्याची मर्यादा, पक्षपात, स्रोतांची विश्वसनीयता, व मानवी विवेकांची भूमिका लक्षात घेतली पाहिजे. त्यामुळे AI चा इतिहासातील वापर एका चिकित्सक आणि विचारशील दृष्टिकोनातून पाहिला गेला आहे. “These are broadly defined, in terms of the fundamental characteristics that shape a society– particularly one weaving AI into its fabric.”¹

अशा समाजाची निर्मिती की जो कृत्रिम बुद्धिमत्तेला प्राधान्य देतो.

इतिहास विषयात AI चा वापर मुख्यतः चार क्षेत्रांत होतो: (१) स्रोत प्रक्रिया व विश्लेषण, (२) भौगोलिक व दृश्यीकरण, (३) कथन व लेखन, आणि (४) वारसा संवर्धन. या पार्श्वभूमीवर पुढील विभागात विविध AI साधनांचे सविस्तर विश्लेषण करण्यात येईल.

AI साधननिहाय सविस्तर स्पष्टीकरण:

1. Mapflow.AI:

इतिहास विषयाच्या अभ्यासात हे एक अत्यंत उपयुक्त AI-आधारित भौगोलिक साधन आहे. Mapflow processes imagery and extracts vector objects from it”² या साधनाद्वारे उपग्रह प्रतिमांद्वारे रस्ते, इमारती, वसाहती व शहरी रचना ओळखणे शक्य होते, ज्याने विविध ऐतिहासिक



कालखंडांतील शहरांचा विकास समजून घेणे सोपे होते. प्राचीन, मध्ययुगीन आणि आधुनिक शहररचना, वसाहतवादी काळातील पायाभूत सुविधांचा अभ्यास आणि शहरी विस्तार दृश्य स्वरूपात करता येतो, यामुळे इतिहास अधिक स्पष्ट होते. औद्योगिकीकरण, युद्धे, व्यापारमार्ग आणि साम्राज्यांच्या विस्ताराचा भूगोलावर झालेला परिणाम नकाशांच्या माध्यमातून विश्लेषित केला जातो. त्यामुळे, Mapflow.AI हे ऐतिहासिक भूगोल व नगरइतिहासाच्या अभ्यासासाठी एक प्रभावी व आधुनिक साधन म्हणून महत्त्वाचे ठरते.

2. GeoWGS84.AI:

इतिहासामध्ये नकाशाला महत्त्वाचे स्थान असते. एखाद्या साम्राज्याच्या सीमा, राष्ट्रनिर्मिती आणि सीमा वादाचा अभ्यास करण्यासाठी इतिहासामध्ये सदरील साधनाचा उपयोग होतो. नकाशा आधारित इतिहास संशोधनांमध्ये सदरील साधनाचा उपयोग झाल्याने विद्यार्थ्यांना एखाद्या साम्राज्याचा नकाशा आणि त्या राज्याच्या असणाऱ्या कक्षा समजून आल्याने इतिहासाची वैचारिक व्याप्ती वाढण्यासाठी या साधनाचा उपयोग होतो.

3. Google Earth Engine:

सदरील साधनाच्या माध्यमातून इतिहास अध्ययन करण्यासाठी मदत होते. इतिहास शिकवताना नद्यांचे बदललेले मार्ग, शहरीकरण आणि पुरातत्त्व शास्त्रातील प्रतिमा अभ्यासण्यासाठी या साधनाचा उपयोग होतो. सिंधू संस्कृतीच्या न्हासाचे महत्त्वपूर्ण कारण सांगितले जाते की नद्यांनी मार्ग बदलल्यामुळे सिंधू संस्कृतीचा न्हास झाला. या नद्यांनी मार्ग बदललेल्या परिस्थितीचा अभ्यास करण्यासाठी सदरील साधनाचा आपणास उपयोग होतो. याशिवाय विद्यार्थ्यांना वर्गामध्ये अध्यापन करत असताना दुष्काळाविषयी आणि पाण्याच्या दुर्भिक्षाविषयी माहिती सांगायची झाल्यास गुगल अर्थ इंजिन या साधनाचा उपयोग होतो. पर्यावरणीय इतिहासाची संरचना करण्यासाठी देखील या साधनाचा उपयोग होतो. या साधनांमुळे एखाद्या पर्यावरणीय घटका विषयी काला अनुक्रमाने माहिती आपणास घेता येते.

4. AI Storyteller:

हे एक नैसर्गिक भाषा प्रक्रिया (NLP) वापरणारे कथानिर्मिती AI साधन असून दिलेल्या सूचनावरून आधारित कथन तयार करते. एखाद्या विद्यार्थी ऐतिहासिक पात्राच्या माध्यमातून कथा लिहू शकतो. सदरील साधनांच्या माध्यमातून ऐतिहासिक कल्पनाशक्ती आणि लेखन कौशल्य वाढण्यासाठी मदत होते.

5. Toolsaday Story:



सदरील साधनाच्या माध्यमातून एखादे ऐतिहासिक कथानक किंवा एखादी रचना यावर कथालेखन करण्यासाठी उपयोग होतो. एखाद्या तथ्याचे कथात्मक सादरीकरण शिकवण्यासाठी शिक्षकांना याची मदत होऊ शकते. एखाद्या संशोधकाला डिजिटल इतिहास प्रकल्प तयार करायचा असेल तर हे साधन अतिशय उपयुक्त ठरते. या साधनांमुळे इतिहासामध्ये आवड नसणाऱ्या व्यक्तीला देखील इतिहास सहजपणे समजू शकतो आणि त्यामुळे त्याची इतिहासामध्ये आणि इतिहास संशोधनामध्ये अधिक प्रमाणात रुची वाढू शकते.

इतिहास कथा रूपाने सांगितला की तो प्रत्येकाला आवडू लागतो. इतिहासाची गोडी निर्माण व्हावी आणि सृजनशील इतिहास लेखन व्हावे यासाठी या साधनाचा प्रामुख्याने उपयोग होतो. इतिहासामध्ये एखादा कंटाळवाणा वाटणारा किंवा स्मृतीच्या कवेत न येणारा एखादा प्रसंग असेल तर या साधनाच्या माध्यमातून त्याला मनोरंजक आणि शैक्षणिक कथांमध्ये परिवर्तित केले जाऊ शकते आणि आणि इतिहास वाचनीय होऊ शकतो. छत्रपती शिवाजी महाराजांचा काळ आणि त्यांनी स्वराज्यासाठी दिलेला लढा यामध्ये पात्रांची मांडणी आणि प्रकरणांची आखणी आपणास करता येऊ शकते. एखादी ऐतिहासिक व्यक्तिरेखा समजून घेण्यासाठी या साधनाचा उपयोग करून घेता येतो आणि विद्यार्थी एखाद्या ऐतिहासिक पात्राच्या भूमिकेत शिरून कथा लिहू शकतात. उदाहरणार्थ "मी छत्रपती शिवाजी महाराज बोलत आहे." या साधनाचा महत्त्वपूर्ण उपयोग असा की कथात्मक स्वरूपाने इतिहास प्रगटीकरण केल्यामुळे विद्यार्थ्यांना अधिक काळ स्मरणात राहण्यास मदत होते आणि अध्ययन अध्यापन कार्यात सुलभता निर्माण होते.

6. Glance AI Writer:

या या टूलचा वापर लेखन रचना करण्यासाठी अत्यंत उपयुक्त आहे. एखादा मजकूर लिहित असताना त्यामध्ये काही सुधारणा सुचवणे, शैक्षणिक लेखन मार्गदर्शनासाठी सहकार्य करणे, इतिहास लिखाणाचे गुणवत्ता वाढवणे, पुरविण्यात आलेली माहिती अत्यंत समर्पक शब्दात मांडणे, एखादी माहिती विशिष्ट क्रमाने मांडणे आणि विशिष्ट पद्धतीने मांडणे हे काम सोपे करण्याचे कार्य सदरील टूलच्या माध्यमातून करता येते. संशोधनकार्यासाठी देखील या साधनाचा उपयोग होऊ शकतो संशोधनातील क्रमवार संगती लावून निष्कर्ष आणि प्रथम भाग यांचा एकमेकांशी सहसंबंध जोडून सांगण्याचे कार्य देखील या साधनांच्या माध्यमातून होते. संशोधन क्षेत्रामध्ये एका डिजिटल संपादकाप्रमाणे कार्य करून संशोधनातील गुंतागुंतीचे मुद्दे वाचकांना सहस समजतील अशा भाषेमध्ये

7. Preserv AI:

साधन काय आहे: सांस्कृतिक वारसा जतनासाठीचे डिजिटल AI व्यासपीठ, या साधनाच्या माध्यमातून सांस्कृतिक वारसा जतन करण्यासाठी मदत होते. एखाद्या ऐतिहासिक वारशाचे थ्रीडी



स्कॅनिंग सेंसर आणि भविष्यवाणी विश्लेषण करण्यासाठी या साधनाचा उपयोग होतो. विद्यार्थ्यांना एखादे आभासी संग्रहालय दाखवायचे असल्यास यातून ते दाखवले जाऊ शकते. एखाद्या किल्ल्याचे किंवा लेण्याचे हुबेहूब डिजिटल मॉडेल तयार करून मूळ वास्तूचे स्वरूप समजून घेता येते आणि भविष्यात त्यामध्ये काही बदल झाल्यास तो देखील टिपता येतो. वर्गात बसूनच जगातील कोणतेही कोपऱ्यातील ऐतिहासिक वारसा स्थळाला आपण भेट देऊ शकतो आणि आपली समज विकसित करू शकतो. “The fastest and most accurate mapping application for creating 3D digital twins of urban infrastructure.”³

या संसाधनाचा उपयोग करून एखादी मूर्ती जीर्ण अथवा खराब झाले असेल तर ती तिच्या मूळ स्वरूपात कशी असू शकेल याविषयीची कल्पना देखील निर्माण करता येऊ शकते.

सांस्कृतिक वारसा व्यवस्थापन: युनेस्को (UNESCO) सारख्या जागतिक संस्थांसाठी हे साधन ऐतिहासिक स्थळांचे आयुष्य वाढवण्यासाठी अत्यंत महत्त्वपूर्ण ठरते.

8. YOLO (You Only Look Once)

सदरील साधनाच्या माध्यमातून पुरातत्वीय वस्तूंचे वर्गीकरण करता येते किंवा डेटा आधारित पुरातत्त्व शिकता येते यामुळे संशोधन कार्य करत असताना वेळ आणि श्रम वाचतो. पुरातत्त्व शास्त्र आणि वस्तू संग्रहालय शास्त्र या दोन विषयांमध्ये येवलोच्या माध्यमातून महत्त्वपूर्ण बदल घडून येत आहे.

एखाद्या उत्खननस्थळी कॅमेऱ्याच्या माध्यमातून जमिनीतून मिळणाऱ्या वस्तूची ओळख चटकन पाठविण्यासाठी हे साधन उपयुक्त आहे. समजा एखाद्या उत्खननस्थळी अनेक प्रकारचे भांडे नाणी आणि इतर वस्तू सापडल्या आहेत अशावेळी सदरील साधन त्या सर्वांना वेगवेगळे करून दाखवते. आपणास इतिहास काळातील वेगवेगळ्या प्रकारचे नाणे सापडले आहे अशावेळी त्या नाण्याचे वेगवेगळ्या गटात वर्गीकरण करून सांगण्याचे कार्य या साधनाच्या माध्यमातून होते. या साधनाचे महत्त्वाचे वैशिष्ट्य म्हणजे मानवी डोळ्याने ओळखता येणारे आणि अतिशय सूक्ष्म असणारे साधने किंवा वस्तू यादेखील व्यवस्थित वर्गीकृत केल्या जातात.

09. Kraken OCR

या साधनांच्या माध्यमातून ऐतिहासिक हस्तलेखन साठी आणि त्याच्या वाचनासाठी सहाय्य होते. अतिशय जुनी आणि दुर्मिळ असणारी हस्तलिखिते देखील वाचणे बनवण्याचे कार्य सदरील साधनांच्या माध्यमातून होते. “kraken is a turn-key OCR system optimized for historical and non-Latin script material”⁴

याशिवाय संग्रहालय व संग्रहालयातील विविध अभिलेख अभ्यासण्यासाठी देखील या साधनाचा उपयोग प्रामुख्याने होतो. त्यामुळे प्राथमिक संसाधनाचा वापर संशोधनासाठी उपयुक्त



ठरतो.हे सॉफ्टवेअर विशेषता ऐतिहासिक संसाधनाच्या आणि कागदपत्राच्या पडताळणीच्या अनुषंगाने बनवण्यात आलेले असल्याने ते इतिहासातील अत्यंत महत्त्वपूर्ण संसाधन जुन्या कागदपत्रावर खडबडीत असणारा मजकूर ओळखण्याचे समर्थ प्रस्तुत AI साधनांमध्ये आहे. हे एक विनामूल्य असणारे सॉफ्टवेअर असून मोडी लिपी, जुन्या कालखंडातील मराठी आणि देवनागरी मध्ये तज्ञता वाढवण्यासाठी उपयुक्त आहे. जुन्या लिप्यांचा अभ्यास करण्यासाठी आणि जुने हस्तलिखित शोधणे योग्य मजकुरात रूपांतरित करण्यासाठी सदरील साधनाचा वापर होतो. 10.

Eden AI

प्रस्तुत साधन हे एखादा मजकूर किंवा प्रतिमा ओळखणारे आणि त्याचे विश्लेषण करणारे एक साधन आहे. ते ऐतिहासिक छायाचित्रे व चित्रांचे विश्लेषण करतात.

या साधनाचे प्रमुख वैशिष्ट्य म्हणजे या साधनांमध्ये ऐतिहासिक चित्रातील वस्तू, पेहराव आणि वास्तूकला यांची देखील ओळख करता येते. एखाद्या ऐतिहासिक पात्राच्या चेहऱ्यावरील हावभाव इतिहासाला समजून घेण्यासाठी मदत करते. एखाद्या चित्रकार आणि चित्रित केलेले चित्र हे त्या काळाचे प्रतिबिंब असल्यामुळे तत्कालीन कालखंडातील सामाजिक परिस्थिती आणि चित्रकाराचा असणारा दृष्टिकोन देखील समजण्यास मदत होते. एखादे छायाचित्र कोणत्या काळातील आहे हे समजून घेण्यासाठी देखील या साधनाचा उपयोग होऊ शकतो.

11. Paperpal :

सदरील साधनांच्या माध्यमातून शैक्षणिक आणि संशोधन क्षेत्रात मदत होते. या साधनाच्या माध्यमातून इतिहास अध्ययनातील संशोधन लेखन सुधारण्यास मदत होते. ऐतिहासिक सज्ञा आणि संदर्भ समजून घेण्यास सदरील साधन सहाय्यक आहे. इतिहास लिखाणामध्ये वस्तुनिष्ठता आणि तटस्थता राखणे अत्यंत महत्त्वाचे असते ते प्रस्तुत साधनाच्या माध्यमातून शक्य आहे. या साधनाचे महत्त्वपूर्ण वैशिष्ट्य म्हणजे सदरील साधन हे पल्हाडे पणे न लिहिता विशिष्ट स्वरूपात एखादा मुद्दा प्रतिपादित करते त्यामुळे सूत्रबद्धता निर्माण होण्यास मदत होते. याशिवाय सदरील साधन हे व्याकरणाच्या होणाऱ्या चुका टाळून उत्कृष्ट संशोधनाचा दर्जा राखण्यास उपयुक्त आहे.

12. Hyper Write:

संशोधनाच्या क्षेत्रात नव संशोधकाला लेखन करण्यासाठी सहाय्यकाची ज्या पद्धतीने आवश्यकता असते त्या पद्धतीने सदरील साधन वापरकर्त्यास मदत करते. सदरील साधनांच्या माध्यमातून एखाद्या नवलेखकास लिखाणास प्रोत्साहित करून अनेकदा नवनवे प्रश्न विचारून माहिती देण्याचा प्रयत्न केला जातो. चे केवळ मजकूर लिहिण्याचे कार्य करत नसून लिखाणासाठी सहाय्यक म्हणून कार्य करते. इतिहासात घडणाऱ्या घटनांच्या पाठीमागे कारणाचे अनंत साखळी असते या साखळीला व्यवस्थितपणे मांडण्याचा प्रयत्न सदरील साधनांच्या माध्यमातून होतो.



13. IoT एज सेन्सर्स (वारसा संवर्धन):

ऐतिहासिक स्थळांच्या निरीक्षणासाठी सेन्सर आधारित प्रणाली निर्माण करण्याचे कार्य या साधनांच्या माध्यमातून होते. हवामान बदल आणि तापमान आद्रता इत्यादी वस्तू मोजण्याचे कार्य करून स्मारक अधिकाधिक कालखंड जतन होण्यासाठीची कार्यपद्धती सांगण्यात येते. शाश्वत वारसा व्यवस्थापनासाठी साधनाचा उपयोग होत असून एखाद्या लेण्यातील आद्रता अचानक वाढली किंवा ऐतिहासिक वास्तूला रस्ते वाहतुकीमुळे कंपनी निर्माण झाली तर सावधगिरीचा इशारा देण्याचे कार्य या साधनांच्या माध्यमातून होते.

निष्कर्ष:

1. AI चा वापर इतिहास, पुरातत्व आणि संग्रहालय यांना उपयोगी आहे.
2. इतिहासाच्या अनेक पैलूंना उलगडून दाखवण्याचे सामर्थ्य AI साधनात आहे.
3. इतिहासाच्या प्राध्यापकांना आणि शिक्षकांना AI साधने वापरून अध्ययन आणि अध्यापन उत्तम बनवता येते.
4. ऐतिहासिक वारशांचे जतन करण्यासाठी AI महत्वाची कामगिरी बजावते.
5. AI साधनांचा वापर करतांना त्याची पडताळणी मानवाने करणे आवश्यक आहे.

समारोप:

अशारीतीने AI साधने आणि इतिहास यांची जवळीक निर्माण होणे आवश्यक आहे. इतिहास, पुरातत्व आणि वस्तूसंग्रहालयशास्त्र यांच्या विकासासाठी AI साधने वापरणे काळाची गरज झाली आहे. जगाच्या ज्ञानाची व्याप्ती दिवसेंदिवस वाढत आहे आणि त्यामुळे तंत्रज्ञान विरहीत कृती अधिक वेळ, पैसा आणि मेहनत वाया घालू शकते. त्यामुळे आधुनिक काळात एखादा संदर्भ नोंदविण्यासाठी, एखादा मजकूर लिहण्यासाठी, कातः लेखन आणि ऐतिहासिक घटनांचे कथेत आणि सोप्या भाषेत रुपांतर करण्यासाठी AI साधने आवश्यक आहे. मानव ज्या कृती सहज करू शकत नाही त्या कृती तंत्रज्ञान सहज आणि अचूक करत असल्यास त्याचा वापर केला पाहिजे.

मात्र त्याचवेळी अत्यंत महत्वाची गोष्ट म्हणजे AI साधनांचा वापर काळजीपूर्वक करणे आवश्यक आहे. संशोधन नैतिकता आणि तथ्याचे सत्य स्वरूप मांडले गेले आहे किंवा नाही याची पडताळणी करणे त्या संबंधित व्यक्तीचे कार्य आहे.

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नाट्यलेखन प्रक्रियेत कृत्रिम बुद्धिमत्ता आणि पर्यावरणीय आशयाची पुनर्रचना संशोधक

वळेकर गहिनिनाथ नारायण

विभाग प्रमुख,

नाट्यशास्त्र विभाग,

शिवछत्रपती महाविद्यालय, छत्रपती सांभाजीनगर

प्रस्तावना :-

नाट्यलेखन हे मानवाच्या सर्जनशीलतेचे उत्कृष्ट रूप आहे- व्यक्तिमत्त्वे, संघर्ष, मूल्ये आणि सामाजिक प्रतिमांचे रूपांतर संवादात व रंगभूमीवर केले जाते. परंपरागत नाट्यलेखन प्रक्रियेत मानवी कल्पकता, जीवन अनुभव आणि सांस्कृतिक अर्थ यांचा गहन उपयोग होतो. परंतु अलीकडील दशकात, कृत्रिम बुद्धिमत्ता (Artificial Intelligence - AI) ने सर्जनशील प्रक्रियेतील स्थान वाढविले आहे. AI-आधारित उपकरणे संवाद, पात्रांचे स्वरूप, कथानकाची पुनर्निर्मिती किंवा भावनात्मक रूपे समोर आणणारे संशोधन आता नाट्यलेखनात नमुन्यांमधील बदल करत आहेत. या शोधपत्राचा उद्देश AI चे नाट्यलेखन प्रक्रियेत योगदान, पर्यावरणीय आशयाचे समावेश आणि त्यांच्या संयुक्त परिणामाचे विश्लेषण करणे हा आहे.

१. नाट्यलेखन आणि कृत्रिम बुद्धिमत्ता -परंपरा आणि तंत्र

1.1 नाट्यलेखनाची पारंपरिक प्रक्रिया

नाट्यलेखन म्हणजे कथानकाची निर्मिती, पात्रनिर्माण, संवादलेखन आणि रंगमंच सुनिश्चित करणारी कलात्मक प्रक्रिया. परंपरेनुसार, नाटककार विषयाची कल्पना तयार करतात, पात्रांची अंतर्गत स्थिती समजून घेतात आणि नाट्यभाषेत भावनांचे प्रस्तुतीकरण करतात. मानवी मन, संवेदना आणि सामाजिक संदर्भ यांचा समावेश या प्रक्रियेत प्रामुख्याने असतो.

1.2 AI आणि सर्जनशीलता

कृत्रिम बुद्धिमत्ता ही संगणकीय प्रणाली आहे जी भाषिक मॉडेल, न्यूरल नेटवर्क आणि डेटाप्रक्रियेच्या आधारे कार्य करते. आजकालचे AI उपकरणे संवादलेखन, दृश्य निर्मिती, भावनात्मक विश्लेषण या सर्जनशील प्रक्रियांमध्ये उपयोग केले जात आहेत. AI भाषिक मॉडेल्स



- GPT सारखी भाषा निर्मिती पद्धती - पटकथा लेखन असे काही भाग पारंपरिक सर्जनशील प्रक्रियेत प्रवेश करत आहेत.

२. AI नाट्यलेखनात - तंत्र, उपकरणे आणि दृष्टांत

2.1 THEATRE प्रोजेक्ट आणि AI-लेखन

THEATRE (THEAITROBOOF) हा एक संशोधन प्रकल्प आहे ज्याचा उद्देश AI वापरून नाटकाची पटकथा निर्माण करता येते का हे तपासणे आहे. प्रकल्पात AI आधारित भाषिक मॉडेलने नाटकाच्या अनेक भागांचे स्क्रिप्ट सुचविले, ज्यावर नाटककाराने सुधारणा केली व अंतिम रूप दिले. या प्रयोगात मानवी आणि AI निर्मित संवादांचे संयोजन करून पूर्ण नाटक तयार केले गेले.¹

उदाहरण: "AI: When a Robot Writes a Play" - एक प्रयोगात्मक नाटक ज्याचे ९०% भाग AI-निर्मित होते.²

2.2 AI-आधारित डायनॅमिक डायलॉग आणि पटकथा सर्जन

आधुनिक संशोधनात Theatrical Language Processing नावाच्या पद्धतीने AI ला डायनॅमिक डायलॉग जनरेशन साधन म्हणून वापरले जात आहे. त्यामुळे पात्र संवादाचा विस्तार, अप्रत्याशित परिस्थिती निर्मिती व अभिनेत्यांसाठी नव्या संवाद संयोजनाचे प्रशिक्षण सहज शक्य होते.³

2.3 OPEN-THEATRE आणि अंतःक्रियात्मक नाट्य

OPEN-THEATRE सारख्या टूलकिटचा उपयोग करून AI आधारित संवाद परिस्थिती, पात्रांची वर्तणूक आणि कथा प्रवाहाला नियमन करणारी तंत्रे विकसित केली जात आहेत.⁴

३. AI नाट्यलेखनाचे फायदे आणि आव्हाने

3.1 फायदे

(अ) सर्जनशील वाढ

AI मध्ये मोठ्या भाषिक मॉडेलमुळे पटकथाकारांना विचारांच्या वेगळ्या पैलू समजून देण्यास मदत होते. AI प्रणाली नाट्यलेखनात नवनिर्मितीला प्रेरणा देऊ शकतात.

(ब) अचूक संवाद विश्लेषण

AI विश्लेषणात्मक उपकरणे नाटकातील संवादातील भावनिक स्वरूप, पात्रांमधील संबंध, विषयांचे प्रवाह शोधू शकतात आणि त्या आधारावर पुनर्लेखन सल्ला देतील.⁵



(क) अकादमिक संशोधनासाठी उपयोग

AI आधारित लेखनाचे तुलनात्मक विश्लेषण, भाषा प्रवाह, पात्र स्वरूप विविधता यांचे सार्थक डेटा मिळवता येते, ज्यामुळे AI व मानवी सर्जनशीलतेचा तुलनात्मक अभ्यास करता येतो.⁶

3.2 आव्हाने

(अ) सर्जनशीलता व व्यक्तिमत्व

AI सर्जनशीलतेची भूमिका वाढली असली तरी मानवी अनुभूती, भावनात्मक बुद्धिमत्ता आणि भाषेची गुंतागुंत AI मध्ये कमी प्रमाणात असते.⁷

(ब) नैतिकता आणि प्रामाणिकपणा

AI निर्मित संवाद किंवा पात्रांचा वापर करताना कॉपीराइट, नैतिकता आणि साहित्यिक स्वामित्व यासारख्या विषयांचे प्रश्न निर्माण होतात.

(क) मानव-तंत्रज्ञान संतुलन

एक भाग मानवी लेखनावर आधारित ठेऊन AI चा उपयोग करण्याची गरज आहे; पूर्णपणे AI-निर्मित नाटक मानवी अनुभूतीची जागा घेऊ शकणार नाही अशी चिंता नाटककारांमध्ये आहे.⁸

४. पर्यावरणीय आशयाचा नाट्यलेखनात समावेश

4.1 पर्यावरणीय विषय: एक सामाजिक तसेच नाट्य विषय

जागतिक तापमानवाढ, संसाधनांची हानी, प्रदूषण आणि प्रदूषित पाणी यांसारख्या पर्यावरणीय समस्या जगभर चर्चा विषय आहेत. नाटककार हे सामाजिक विचार आणि प्रतिक्रिया रंगभूमीवर आणण्यासाठी सक्षम असतात. या संदर्भातील कथानक मानवांना जागरूक करतात.

५. AI आणि पर्यावरणीय आशय - एकत्रित दृष्टी

5.1 AI विरुद्ध पर्यावरणीय परिणाम

AI चे प्रशिक्षण व चालवण्यास मोठ्या प्रमाणात ऊर्जा व पाण्याची आवश्यकता असते, ज्यामुळे कर्बवायू उत्सर्जन वर परिणाम होतो. उदाहरणार्थ, काही अभ्यासानुसार AI मॉडेल्सच्या ट्रेनिंगमुळे मोठ्या प्रमाणात कार्बन उत्सर्जन होते आणि डेटा सेंटर्सचे ऊर्जा खर्च वाढतो, ज्याचा पर्यावरणावर गंभीर परिणाम होतो.⁹ या संदर्भात नाटकात दोन्ही पैलू एकत्रित करणे आवश्यक



आहे - म्हणजे AI चा उपयोग करून पर्यावरणीय विषयी संदेश देणे आणि AI च्या उपयोगाच्या पर्यावरणीय परिणामांबद्दल जागरूकता वाढवणे.

६. AI-समर्थित पर्यावरणीय आशयाचे नाटक - रूपरेखा

6.1 कथानकाचा आराखडा

एक नाटक तयार करण्याची रूपरेखा पुढीलप्रमाणे असू शकते:

प्रस्तावना: भविष्यातील एक समाज, ज्यात AI ने सर्व निर्णय घेतले आहेत.

- कथानक टर्निंग पॉइंट:** ठळक पर्यावरणीय समस्या निर्माण झाली - प्रदूषण, जंगलतोड, पाण्याचा तुटवडा.
- संघर्ष:** पात्रे AI प्रणालीशी संवाद साधतात - जलसंकट, कर्ब उत्सर्जन, कचरा समस्या यावर निर्णय घेतले जातात.
- उपसंहार:** मानव आणि AI संयुक्त प्रयत्नातून पर्यावरणीय समस्यांचे समाधान शोधतात - नैतिक निर्णय, समाजाचे पुनर्रचनात्मक बदल.

७. AI आणि नाट्यकोश संशोधनातील भविष्यातील संधी

7.1 संशोधन आवश्यकता

- AI आणि मानवी संवाद सर्जनशीलतेमध्ये संतुलन राखणे.
- पर्यावरणीय संदर्भात नाट्यलेखनासाठी AI-आधारित साहित्य निर्मिती.
- नैतिकता, सांस्कृतिक विविधता, विविध सामाजिक परिस्थिती यांचे AI द्वारे लेखनात प्रत्यक्ष उपयोग.

7.2 व्यावसायिक वापर

AI नाटक लेखनाचे विश्लेषण, पात्र भाषा शैली विश्लेषण, थीम आधारित संवाद साधने - या सर्वांचा रंगभूमी उद्योगावर परिणाम होणार आहे. AI आधारित संशोधन पुढे वाढेल आणि कलाकारांना सर्जनशील साधने उपलब्ध करेल.

निष्कर्ष

नाट्यलेखन प्रक्रियेत AI मधील शाश्वत समावेश सामाजिक, सांस्कृतिक आणि तांत्रिक सुधारणा सांगतो. AI ची भूमिका संवाद निर्मिती, पात्र अभिव्यक्ती सर्जनशीलता इ. मध्ये वाढली आहे, परंतु मानवी सर्जनशीलतेचे स्थान अद्याप अपरिहार्य आहे. पर्यावरणीय आशय आता नाट्यलेखनाचा एक महत्वाचा भाग बनत आहे, ज्यामुळे सामाजिक समस्या रंगभूमीवरून



प्रेक्षकांपर्यंत जाऊ शकतात. AI आणि पर्यावरणीय मुद्दे यांचे संतुलन साधून नाटककार नवीन विषय, धडे आणि अनुभव रंगमंचावर प्रेक्षकांना देऊ शकतात.

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Review:

A Review on “Solid Waste Management by Using IoT and AI”

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Abstract:

This systematic review emphasizes on current research, applications, and challenges in deploying IoT and AI technologies for optimizing waste collection, sorting, recycling, and disposal. The study systematically reviews the integration of ‘Internet of Things’ (IoT) and ‘Artificial Intelligence’ (AI) in global waste management, with a focus on a South Korea as an example of best practices in waste management. South Korea’s IoT- and AI-driven system featuring ‘Smart Garbage Bins’ (SGBs), ‘RFID-based Pay-As-You-Throw’ (PAYT), and ‘Dynamic routing algorithms’—is compared with systems in the European Union, United States, and Japan. The study concludes that successful waste digitalization depends on ‘Technology integration, Legislative support, and Public engagement’, offering a replicable model for nations transitioning toward a circular economy.

Keywords: IoT, AI, Smart Waste Management, PRISMA, Comparative Analysis, Circular Economy, South Korea, PAYT

1. Introduction

The rising volume of global waste demands innovative, technology-driven management solutions. Countries worldwide are experimenting with IoT, AI, and automation to improve waste collection, sorting, and recycling efficiency. The exponential growth of global waste generation, driven by urbanization and consumption patterns, presents a critical environmental and operational challenge for municipalities and industries worldwide (2). Traditional waste management systems, often characterized by stationary schedules, inefficient routing, and low recycling rates, are increasingly inadequate, leading to escalating costs, environmental pollution, and public health concerns. In response, the integration of Internet of Things (IoT) and Artificial Intelligence (AI) has emerged as a transformative model for developing smart, data-driven waste management.

This systematic review emphasizes contemporary research on the convergence of IoT and AI in waste management. IoT technologies, through networks of sensors and connected devices, enable the real-time monitoring of waste bin fill-levels, environmental conditions, and asset locations. AI, particularly machine learning and computer vision, controls this data stream to introduce predictive analytics, intelligent automation, and optimized decision-making.



Together, they facilitate applications ranging from dynamic collection routing and automated waste sorting to predictive maintenance of facilities and enhanced recycling chain transparency(4).

By critically examining the technological architectures, demonstrated benefits, and persistent challenges documented in recent literature, this review aims to provide a comprehensive overview of the state-of-the-art. It highlights how the interaction of IoT and AI is foundational to advancing toward efficient, sustainable, and circular waste management systems. South Korea has emerged as a benchmark, integrating these technologies within a supportive policy framework to achieve a circular economy(5).

Multiple studies highlight the use of ultrasonic sensors, microcontrollers (e.g., Arduino Uno), and wireless communication (GSM, LoRaWAN) to monitor bin fill levels in real-time.

- Sohag & Podder (2020) developed an integrated system with automated lids, LCD displays, and GSM-based alerts to optimize collection routes and prevent overflow.
- Lundin et al. (2017) emphasized low-cost, retrofittable sensors (under \$100 per bin) using LoRaWAN for long-range, low-power communication. Their user-centred design involved stakeholders to ensure practicality and scalability.
- Farooq et al. (2022) reviewed companies like Bigbelly, Enevo, and Sensoneo, which offer smart compaction, route optimization, and data analytics to improve operational efficiency.

2. Research Methodology:

Conducted the systematic review following the 'PRISMA 2020 guidelines' to identify, select, and analyse studies on IoT and AI in waste management.

2.1 Identification

Databases Searched: Scopus, Web of Science, IEEE Xplore, ScienceDirect, and Google Scholar.

Search Terms: ('IoT' OR 'Internet of Things') AND ('AI' OR 'Artificial Intelligence') AND ('waste management' OR 'smart waste management techniques') AND ('case study' OR 'South Korea').

Time Frame: 2015–2024.

Initial Records Identified: 1,248 studies.

2.2 Screening:

Duplicates Removed

Title and Abstract Screening

Full-Text Assessed for Eligibility

Excluded After Full-Text Review

Studies Included in Qualitative Synthesis

2.3 Data Extraction and Synthesis:

Data were extracted into a standardized matrix covering:

Technology type (IoT, AI, robotics)

Policy framework



Key performance indicators (KPIs)

3. Integration of IoT and AI

These sources examine the integration of artificial intelligence (AI), machine learning, and the Internet of Things (IoT) to modernize global waste management. Researchers highlight how smart sensors and automated sorting systems improve recycling efficiency, while data-driven routing minimizes the fuel consumption of collection vehicles. Despite these technological advancements, the documents identify significant hurdles, including high equipment costs, a lack of standardized datasets, and a need for greater public awareness. The collective research emphasizes transitioning from traditional linear disposal methods to a circular economy that prioritizes resource recovery. Furthermore, case studies from various countries illustrate how digital platforms and robotics can optimize urban sanitation while reducing environmental pollutants. Ultimately, the literature suggests that achieving long-term sustainability requires a blend of innovative technology, supportive government policy, and active citizen engagement.

The IoT Infrastructure:

Smart Garbage Bins (SGBs) with ultrasonic sensors, load cells, and wireless communication (LoRaWAN, NB-IoT).

Real-time monitoring of fill levels, gas emissions, and bin status.

- **Sensing Capabilities:** These bins are equipped with ultrasonic sensors to measure fill levels and load cells or weight sensors to measure the exact mass of food waste. Additional sensors, such as gas detectors, identify hazardous substances like methane or ammonia to prevent environmental risks.
- **Communication Networks:** SGBs exchange information using wireless mesh networks (WMN), allowing for high reliability and service continuity even across wide service domains. Data is transmitted via CDMA or GPRS modules to centralized servers for analysis.
- **Energy Efficiency:** To ensure mobility and low maintenance, these bins are often battery-powered and utilize energy-efficient sleep modes, only "waking up" during user authentication or data request cycles from a router.

AI and Predictive Analytics:

AI and Predictive Analytics is a powerhouse combination that's transforming decision-making across every industry.

AI enhances predictive analytics by:

- **Handling Unstructured Data:** AI can process text (emails, social media), images (X-rays, product photos), and audio to find predictive signals.
- **Automating Feature Engineering:** AI can automatically discover the most relevant data points (features) that influence outcomes, rather than relying solely on human experts.
- **Continuous Learning:** ML models can continuously improve their predictions as new data flows in.



- Greater Accuracy & Scale: Deep learning models can find complex, non-linear patterns in massive datasets that traditional statistics miss.
- ANN and Random Forest models for waste forecasting
- Dynamic route optimization reducing fuel use
- Robotic sorting systems

4. Robust Policy Framework:

A comprehensive framework requires multiple, reinforcing elements:

A. Regulatory & Legislative Instruments

- Extended Producer Responsibility (EPR): A cornerstone policy. Makes producers financially and/or physically responsible for the end-of-life management of their products (e.g., packaging, electronics, batteries).
- Landfill Bans & Restrictions: Prohibits specific waste types (e.g., organic waste, recyclables) from being landfilled, forcing diversion to higher levels of the hierarchy.
- Product Standards: Mandates durability, repairability (e.g., EU's "Right to Repair"), and recyclability. Bans hazardous materials.
- Mandatory Separate Collection: Laws requiring municipalities or businesses to separately collect key streams like paper, plastic, glass, metals, and organics.
- Permitting & Licensing: Strict environmental permits for waste treatment facilities (landfills, incinerators, recycling plants) to control pollution.

B. Economic & Market-Based Instruments

- Pay-As-You-Throw (PAYT): Households pay for waste collection based on the amount of non-recyclable waste they generate, creating a direct financial incentive to recycle.
- Landfill & Incineration Taxes: Increasing the cost of disposal makes recycling and prevention more economically attractive.
- Deposit-Return Schemes (DRS): Consumers pay a small deposit on beverage containers, refunded upon return. Drastically increases collection rates for high-quality recycling.
- Green Public Procurement (GPP): Governments use their purchasing power to buy recycled-content products, creating a stable market for secondary materials.
- Subsidies & Grants: Support for recycling infrastructure, innovation in waste-to-resource technologies, and circular economy startups.

C. Levels of Policy Action

- International: Basel Convention (controls transboundary movement of hazardous waste), UN Sustainable Development Goals (SDG 12: Responsible Consumption and Production), OECD recommendations.
- Supranational (e.g., European Union): Sets binding directives and targets for member states (e.g., Circular Economy Package, Single-Use Plastics Directive).



- National/Federal: Enacts core laws, sets national targets, and implements schemes like EPR.
- State/Regional: Often responsible for permitting facilities and regional planning.
- Municipal/Local: Directly responsible for household waste collection, operating/local licensing of treatment facilities, and local enforcement (e.g., bin inspections).

D. Major Global Models & Trends

- The European Model: Highly regulated, target-driven, and based on the "polluter pays" principle. Heavily relies on EPR and high landfill taxes. The EU is a global leader in circular economy policy.
- The Japanese Model: Focus on meticulous source separation by citizens (often into 10+ categories), enforced by local communities. Strong emphasis on waste-to-energy (incineration) due to limited land, paired with the "3Rs" (Reduce, Reuse, Recycle) national framework.
- Emerging Economy Challenges & Innovations: Often face issues with informal waste sectors. Effective policies focus on integrating and formalizing waste pickers, building basic collection infrastructure, and leapfrogging to circular solutions (e.g., India's focus on plastic waste EPR and Rwanda's strict ban on non-biodegradable plastic bags).

5. Analysis of waste management:

Waste management system has various criteria on which the success of the system depends, following is the critical analysis of the various criteria and the major leader of waste management.

Criteria	South Korea	European Union	United States	Japan
IoT Adoption	High (nationwide SGBs, RFID, real-time networks)	Moderate (pilots in smart cities)	Low to moderate (private-sector led)	High (focused on Tokyo, Osaka)
AI Integration	Advanced (predictive analytics, robotic sorting)	Growing (AI in sorting, limited in collection)	Emerging (corporate R&D)	Advanced (robotics, vision systems)
Policy Framework	Advanced (predictive analytics, robotic sorting)	Strong (EU Green Deal, circular economy directives)	Fragmented (state-level regulations)	Strong (national waste laws, recycling targets)



Public Engagement	High (PAYT, incentives, strict enforcement)	Moderate (awareness campaigns, variable compliance)	Low to moderate (voluntary programs)	High (cultural emphasis on cleanliness)
Recycling Rate (Food Waste)	95%	50–70% (varies by country)	30–40%	80–85%
Emission Reduction	29–30% (from optimized routing)	15–25%	10–20%	20–25%
Cost Efficiency	High after initial investment	Moderate	Low to moderate	High
Key Technologies	SGBs, RFID, AI routing, robotic sorters	Smart bins, blockchain traceability	Automated trucks, MRF AI	Pneumatic waste pipes, robotic sorting

5. Critical Challenges & Barriers

Technical & Infrastructure

1. Interoperability: Proprietary systems creating data silos
2. Connectivity: Remote/rural areas lacking network coverage
3. Power Supply: Battery life limitations for IoT devices
4. Data Quality: Sensor accuracy and calibration issues

Economic & Operational

1. High Initial Value: Smart bins cost 3-5x traditional bins
2. Return on Investment Uncertainty: Many municipalities lack lifecycle cost analysis
3. Skills Gap: Shortage of AI/data science talent in public sector
4. Maintenance Complexity: Specialized technicians required

Regulatory & Social

1. Data Privacy: Concerns about tracking individual waste patterns
2. Resistance to Change: Union concerns in traditional waste sectors
3. Policy Lag: Regulations not keeping pace with technology
4. Digital Divide: Exclusion of low-income/elderly populations

1. Discussion

The success of IoT and AI with the digitation of the system is depend on Policy and Governance, Technology Deployment and Participation of Stakeholder. The technological development and its integration in the waste management have been the real issue in the developing countries, where as developed countries are now heading towards the complete digitisation of the waste management system.

South Korea's success is attributable to:

1. Holistic system design linking IoT, AI, and policy.
2. Strong legislative backing with circular economy targets.



3. Public compliance mechanisms (RFID, adaptive pricing, fines).
4. Continuous innovation (e.g., Ecube Labs, digital twins).
5. Limitations include high upfront costs and data standardization challenges. The comparative analysis suggests that nations with centralized waste policies and public-private partnerships achieve better outcomes.

7. Conclusion and Recommendations

IoT- and AI-driven waste management system offers a replicable model for sustainable urban waste management. Technology alone isn't sufficient. The most successful implementations (Singapore, Barcelona, Seoul) combine IoT/AI with strong policy frameworks, stakeholder engagement, and business model innovation. The future lies not in "smart waste management" but in "intelligent resource management systems" where waste is eliminated through predictive design and circular flows.

Key recommendations for other nations include:

- Develop national circular economy laws with clear Key Performance Indicators.
- Invest in IoT infrastructure and interoperable data platforms.
- Implement incentive-based PAYT systems to drive public participation.
- Foster innovation through public-private R&D partnerships.

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SEASONAL VARIATION OF FLUORIDE CONCENTRATION IN GROUNDWATER OF JALNA MUNICIPAL AREA, MAHARASHTRA

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Abstract:

Groundwater is the primary source of drinking water in many semi-arid regions of India, including Jalna city in Maharashtra. Fluoride is a naturally occurring constituent of groundwater and its concentration is largely controlled by geological formations and seasonal hydrogeochemical processes. The present study aims to assess fluoride concentration in groundwater of the Jalna Municipal area and to evaluate its seasonal variation during pre-monsoon and post-monsoon periods. Five representative groundwater sampling locations were selected from different parts of the city, and samples were analyzed using standard ion-selective electrode methods. The results indicate that fluoride concentration varies seasonally, with comparatively higher values observed during the pre-monsoon season and lower concentrations during the post-monsoon period due to dilution effects of rainfall recharge. All measured fluoride values were found to be well within the permissible limits prescribed by the World Health Organization (WHO) and Bureau of Indian Standards (BIS). The study concludes that groundwater in Jalna city is presently safe for drinking with respect to fluoride content; however, continuous monitoring is recommended to ensure long-term water quality and public health protection.

Keywords: Groundwater, Fluoride, Seasonal Variation, Jalna, Drinking Water Quality, Semi-Arid Region, BIS Standards, WHO Guidelines

Introduction

Water makes up 71% of the Earth's surface, predominantly in the form of seas and oceans. Approximately 3.4 million individuals (primarily children) perish annually due to diseases linked to water. On our planet, 97.2% of water is saline, while only 2.8% is freshwater, with 20% of that being groundwater. Once groundwater becomes polluted, it cannot be purified by merely halting the source of contamination. The World Health Organization states that roughly 80% of diseases in humans result from contaminated water. [11,12]



Groundwater quality is a key determinant of the suitability of water for drinking and domestic use, particularly in semi-arid regions of India where groundwater serves as the principal source of potable water. Fluoride is a naturally occurring ion in groundwater, released primarily through water–rock interaction involving fluoride-bearing minerals. At low concentrations, fluoride is beneficial in preventing dental caries by strengthening tooth enamel; however, long-term consumption of water containing elevated fluoride levels can lead to dental and skeletal fluorosis, posing significant public health concerns. Several regions of Maharashtra have reported fluoride-related groundwater problems, emphasizing the need for localized assessments. Seasonal variations, especially monsoon rainfall, play a crucial role in modifying groundwater chemistry by influencing recharge, dilution, and mineral dissolution processes, thereby affecting fluoride concentrations. Therefore, evaluating seasonal variations of fluoride in groundwater is essential to understand its spatial and temporal distribution and to ensure the availability of safe drinking water[4,9].

Study Area:

Jalna city is located in the Marathwada region of Maharashtra and experiences semi-arid climatic conditions. The area is characterized by hot summers and moderate rainfall concentrated during the southwest monsoon. Due to limited surface water availability, the population of Jalna depends largely on groundwater sources such as bore wells and dug wells for drinking and domestic purposes. The geological formation of the region mainly consists of Deccan Trap basalt, which plays a crucial role in controlling groundwater quality. Rapid urbanization and increasing water demand have intensified the reliance on groundwater resources. Understanding the groundwater quality of Jalna city is therefore essential for sustainable water management and public health protection.

Objectives:

To determine fluoride concentrations in groundwater samples of the Jalna Municipal area during pre- and post-monsoon seasons and to evaluate seasonal variations in fluoride levels in relation to their suitability for drinking water purposes.

Methodology:

Five groundwater sampling locations were selected within the Jalna Municipal area to represent different land-use patterns and groundwater utilization zones. The selected sites include Old Jalna area (S1), Bus Stand area (S2), Deulgaon Raja Road area (S3), Krishna Nagar



area (S4), and Shivnagar area (S5). These locations were chosen to ensure spatial coverage across the city and to assess variations in fluoride concentration in groundwater used for drinking purposes. Groundwater samples were collected in clean, fluoride-free polyethylene bottles during the pre-monsoon and post-monsoon seasons. The collected samples were analyzed for fluoride concentration using standard laboratory techniques such as the ion-selective electrode method, following prescribed water quality analysis procedures. The analytical results were compared with drinking water standards. According to the World Health Organization (WHO), the guideline value for fluoride in drinking water is 1.5 mg/L. The Bureau of Indian Standards (BIS: IS 10500–2012) prescribes an acceptable limit of 1.0 mg/L and a maximum permissible limit of 1.5 mg/L in the absence of an alternative water source. Fluoride concentration beyond these limits may lead to dental and skeletal fluorosis[1,2,10].

Results and Discussion:

Fluoride Concentration in Groundwater:

The fluoride concentration measured in groundwater samples is presented in Table 1.

Table 1: Fluoride concentration in groundwater samples

Sr. No	Sample ID	Fluoride (mg/L) - Pre-Monsoon	Fluoride (mg/L) - Post-Monsoon
1	S1	0.13	0.03
2	S2	0.18	0.07
3	S3	0.31	0.12
4	S4	0.16	0.11
5	S5	0.21	0.16

Seasonal Variation

The fluoride concentration in all samples was observed to be higher during the pre-monsoon season. This increase may be attributed to reduced groundwater levels and enhanced rock–water interaction during dry periods. Post-monsoon samples showed lower fluoride concentration, likely due to dilution caused by rainfall recharge. Similar seasonal trends have been reported in fluoride studies conducted in various parts of Maharashtra.

Drinking Water Suitability: All recorded fluoride concentrations were significantly below the permissible limit of 1.0–1.5 mg/L for drinking water. This indicates that the groundwater



of Jalna city is presently safe with respect to fluoride concentration. However, continuous monitoring is recommended to detect any future changes influenced by climatic and anthropogenic factors.

Conclusion:

The study reveals that fluoride concentration in groundwater of Jalna Municipal area shows clear seasonal variation, with higher values during pre-monsoon and lower values during post-monsoon. All analyzed samples contain fluoride within acceptable drinking water limits, indicating no immediate fluoride-related health risk. Regular groundwater quality monitoring is suggested to ensure long-term safety and sustainable utilization of groundwater resources in the region.

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