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AI for Sanitation Equity: A Review of Artificial Intelligence Applications in Monitoring and Mitigating Open Defecation in Marginalized Indian Communities

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Abstract

This paper reviews the application of artificial intelligence (AI) in addressing open defecation within marginalized Indian communities. Despite large-scale sanitation campaigns, significant disparities persist, especially among Scheduled Castes, Scheduled Tribes, and slum populations. AI technologies—such as satellite image analysis, mobile data collection, IoT-enabled smart toilets, and GIS-based spatial modeling—offer new pathways for real-time monitoring, predictive risk mapping, and behavior change. However, gaps remain in ethical deployment, inclusion of marginalized groups, and integration with social learning frameworks. Through a systematic synthesis of academic studies, government data, and pilot projects, this review evaluates the readiness, limitations, and equity impact of AI interventions. It highlights the need for participatory AI design, stronger data governance, and interdisciplinary collaboration to ensure responsible innovation. By centering community agency, this review outlines a roadmap for equitable AI adoption in India's sanitation ecosystem, aligning with Sustainable Development Goal 6 on clean water and sanitation for all.

Keywords: Artificial Intelligence, Open Defecation, Sanitation Equity, Marginalized Communities, India, Behavior Change

Introduction

Contextual Background

Open defecation continues to be one of the most persistent public health and social equity challenges in India. The practice not only reflects infrastructural gaps but also entrenched socio-cultural norms that undermine toilet adoption. Public health consequences are severe: fecal contamination of soil and water remains widespread, with direct links to diarrheal diseases, intestinal parasitic infections, cholera, typhoid, and other gastrointestinal illnesses that disproportionately affect children (Dandabathula et al., 2019). Research also demonstrates associations between open defecation exposure and stunting, undernutrition, and increased infant mortality across high-density regions (Spears et al., 2020).

Policy Initiatives: Swachh Bharat Mission

Recognizing sanitation as both a developmental and political priority, the Government of India launched the Swachh Bharat Mission (SBM) on 2 October 2014 with the ambitious aim of making India "open-defecation free" (ODF) by October 2019. By 2019, over 90 million household latrines were constructed nationwide, alongside school and community facilities. Awareness campaigns—using celebrity endorsements, mass media, and community mobilization through Swachhagrahis (sanitation volunteers)—further reinforced the behavioral dimensions of the mission (Exum et al., 2020).

Early assessments of SBM's impact indicated measurable reductions in diarrheal disease and improvements in self-reported sanitation access across rural districts (Majeed & Vellakkal, 2024; VerKuilen et al., 2023). For example, longitudinal survey data found that toilet-owning households were less likely to report waterborne diseases compared to non-owners, and that sanitation-related morbidity declined in several states where latrine coverage increased (Dandabathula et al., 2019). Nonetheless, the robustness of "open-defecation free" declarations has been contested. The challenges underscore the limitations of infrastructure-driven approaches that neglect behavioral, cultural, and equity-based dimensions.

Marginalization and Inequity

Sanitation inequity in India is deeply structured by caste, class, and geography. In many cases, latrine construction and use are limited not by lack of physical infrastructure but by stigma surrounding pit-emptying, which is culturally associated with "polluting" manual scavenging (Coffey et al., 2017). Studies document that Dalit households are often left out of toilet construction programs, or when included, they face challenges in maintaining sanitation facilities due to poverty, poor service delivery, and social exclusion (Jain et al., 2020).

Urban informal settlements and slums add another layer of inequity. Migrant populations and urban poor frequently lack access to household sanitation due to insecure land tenure, overcrowding, and weak municipal service provision (Roy, Kumar, & Singh, 2023). Public toilets, where available, are often unsafe and poorly maintained (Dandabathula et al., 2019). Thus, sanitation inequity is not merely an infrastructure gap but reflects intersecting vulnerabilities tied to social stratification, economic deprivation, and governance deficits.

Role of Artificial Intelligence in Sanitation Monitoring

Given the persistent challenges in sanitation adoption and equity, artificial intelligence (AI) is emerging as a potential complement to conventional monitoring systems. Traditional survey-based data collection on sanitation practices is subject to underreporting, courtesy bias, and administrative pressure to demonstrate programmatic success (Vyas et al., 2019). AI technologies—ranging from satellite imagery classification to IoT-enabled sensors—offer new possibilities for more accurate, granular, and timely monitoring of sanitation behaviors and infrastructure.

Remote sensing techniques combined with machine learning have been used to detect sanitation coverage patterns at settlement and village scales. Similarly, AI-enabled mobile data analytics can process geotagged photographs of toilets submitted through SBM platforms to verify construction quality and actual usage (Ministry of Housing and Urban Affairs, n.d.).

These innovations can reduce dependence on self-reported survey data and enhance accountability in large-scale sanitation campaigns.

Beyond infrastructure monitoring, AI-powered communication platforms offer novel avenues for behavior change. Such tools, if adapted to sanitation campaigns, can deliver culturally tailored nudges in vernacular languages, addressing social barriers and stigma that hinder latrine use. AI can also support predictive modeling, using socio-demographic and environmental datasets to forecast areas most at risk of sanitation lapses, thereby enabling targeted interventions for marginalized communities (Roy et al., 2023).

At the same time, scholars warn against uncritical adoption of AI in sanitation. Ethical concerns like privacy and bias are significant in marginalized communities (Narayan, Mehta, & Vyas, 2022). For example, AI-based surveillance of public spaces must avoid stigmatizing or criminalizing individuals practicing open defecation out of necessity rather than choice (Deshmukh & Iyer, 2020). These debates highlight the need for community-centric AI models that are participatory, transparent, and aligned with principles of dignity and equity (Chattopadhyay, Sahoo, & Pandey, 2021).

Purpose of the Review

This paper aims to systematically examine the role of AI in addressing sanitation inequities in India, with a specific focus on open defecation among marginalized communities. The objectives are fourfold. First, to synthesize AI applications in sanitation monitoring. Second, to analyze the ethical and social equity implications of these technologies, paying attention to issues of bias, privacy, and participatory design. Third, to critically assess the limitations and contextual challenges—such as data quality, infrastructural divides, and cultural resistance—that shape the effectiveness of AI in low-resource settings. Fourth, to highlight case studies demonstrating AI's potential and pitfalls.

By situating AI within the broader socio-political context of sanitation inequity, the review underscores the importance of responsible innovation that integrates technical feasibility with community realities. The ultimate aim is to offer policy recommendations and research directions that align AI deployment with Sustainable Development Goal 6—"clean water and sanitation for all"—ensuring that technological advancements contribute to equitable and inclusive outcomes.

Literature Review

Public Health Interventions Using AI

Over the past decade, artificial intelligence (AI) has become increasingly central to India's public health landscape. Predictive modeling, machine learning, and natural language processing (NLP) tools have been deployed to forecast disease outbreaks, improve diagnostic efficiency, and identify high-risk populations by combining demographic, epidemiological, and environmental datasets (Thanveer et al., 2023). In the Indian context, similar applications are being adapted to monitor local epidemics, from vector-borne diseases to waterborne illnesses (Narayan, Ramesh, & Sinha, 2022).

Alongside predictive analytics, conversational and NLP-driven platforms have shown promise in addressing health communication gaps. WashKaro, a multilingual mobile application developed during the COVID-19 pandemic, applied machine learning to deliver verified, contextualized health information in regional languages (Pandey, Litoriya, & Pandey, 2020). By countering misinformation and customizing outreach, such platforms demonstrated the potential for AI-enhanced behavioral communication, which can be extended to sanitation and hygiene campaigns.

However, despite this momentum, AI applications in sanitation equity remain underdeveloped compared to their use in disease surveillance, maternal health, or chronic disease management (Majeed & Vellakkal, 2024). Literature focuses more on health system strengthening than sanitation-specific AI, indicating a gap.

AI Applications in Rural Infrastructure

Infrastructural innovation has been a key entry point for AI adoption in rural India, particularly in sanitation and water systems. These systems help monitor hygiene and usage for better maintenance (Parkar, Deshmukh, & Jain, 2024). Such innovations hold promise for rural and peri-urban contexts, where maintenance failures often deter toilet usage.

Similarly, municipal bodies are experimenting with AI-powered computer vision to improve waste management and sewer monitoring. For example, AI-driven visual recognition tools mounted on sanitation vehicles detect waste segregation and bin collection events, offering real-time accountability in solid waste operations (Business Standard, 2025). While these applications primarily address broader sanitation infrastructure rather than open defecation directly, they highlight the potential for transferable AI frameworks in hygiene monitoring.

While some initiatives have demonstrated measurable health impacts, peer-reviewed evaluations of sanitation-specific outcomes remain sparse. Most projects remain in pilot stages, with limited independent assessments of their impact on open defecation reduction or sanitation equity.

Traditional Approaches to Open Defecation Tracking

Monitoring open defecation in India has historically relied on household surveys, government reporting, and community-based interventions. The Community-Led Total Sanitation (CLTS) approach, pioneered in South Asia, sought to "trigger" communities through participatory mapping and collective action, often relying on public pledges and social pressure to reduce open defecation (Kar & Chambers, 2008).

Government-led sanitation campaigns—including the Total Sanitation Campaign (1999), Nirmal Bharat Abhiyan (2012), and the Swachh Bharat Mission (2014 onwards)—have largely emphasized large-scale latrine construction. Programs expanded coverage but often failed to ensure sustained use, creating persistent gaps (Coffey et al., 2017; Jain, Wagner, Snell-Rood, & Ray, 2020). Reports of inflated declarations of "open defecation free" status underscore the limitations of self-reporting and the need for independent, technology-driven monitoring (Exum et al., 2020).

Tech-Enabled Innovations for Open Defecation Monitoring

Recent advances in AI and remote sensing offer innovative methods to track open defecation behavior and sanitation gaps. Satellite imagery combined with deep learning models has been employed to identify informal settlements, degraded land patches, and environmental correlates of open defecation at fine spatial scales (Maiya & Babu, 2018). Geographic Information System (GIS)-based spatial modeling has also been used to forecast sanitation risks by integrating household survey data with demographic, environmental, and social variables (Roy, Kumar, & Singh, 2023). These methods demonstrate the feasibility of identifying sanitation hotspots and targeting interventions with greater precision.

Predictive analytics has further enabled the exploration of social determinants. Such approaches illustrate how AI can move beyond infrastructure tracking to model behavioral and cultural dynamics.

Robotic automation has reduced hazards for sanitation workers, though its impact on open defecation is indirect (Mani et al., 2022). While these technologies enhance worker dignity and safety, their indirect impact on open defecation monitoring remains limited.

Gaps in the Literature

Several gaps persist in the current research landscape. Real-time monitoring is limited; few studies detect open defecation directly. This limits the capacity for rapid response and targeted intervention.

Marginalized communities are underrepresented, with few disaggregated outcomes reported. This omission risks reinforcing structural inequities by overlooking the unique barriers faced by marginalized groups (Coffey et al., 2017; Jain et al., 2020).

Behavioral aspects remain underexplored; AI applications rarely include nudges or participatory interventions. Early pilots like WashKaro indicate potential, but sanitation-specific adaptations are limited (Pandey et al., 2020).

Ethical concerns like bias, privacy, and surveillance remain under-addressed (Suresh & Guttag, 2021). Few studies assess community consent processes or the perceptions of AI deployments among marginalized populations, raising concerns about autonomy, dignity, and fairness.

AI systems often ignore social learning and community norms critical for sustained sanitation (Kar & Chambers, 2008; Routray et al., 2017). Yet, most AI tools function independently of such frameworks, limiting their long-term impact and relevance to local socio-cultural contexts.

Methodology for the Review

Criteria for Selecting Studies, Projects, and Technologies Reviewed

This systematic review synthesizes peer-reviewed and grey literature on AI and ML applications addressing open defecation in India. Inclusion criteria were as follows:

1. **Technological Focus**: Studies must employ AI or ML methods applied to public health, sanitation, or rural infrastructure contexts.
2. **Relevance to Open Defecation**: Works should be specific to open defecation monitoring or mitigation, or offer transferable insights to that domain.

3. **Geographic Context**: Research must focus on Indian settings or include comparative examples from similar low-resource, marginalized communities.
4. **Methodological Rigor**: Studies should provide sufficient methodological and empirical detail—e.g., algorithms used, data sources, deployment context, and results—to allow for critical analysis.

Studies were excluded if they lacked empirical evaluation, used non-AI tools, or addressed sanitation without linking to open defecation.

To mitigate selection bias, two researchers independently screened titles, abstracts, and full texts. Discrepancies were resolved through discussion or involvement of a third reviewer, and inter-rater reliability was assessed via Cohen's κ until substantial agreement was reached ($\kappa > 0.80$).

Sources of Data

Data were drawn from academic databases (Scopus, PubMed, Web of Science, IEEE Xplore), government portals (Swachh Bharat Mission Dashboard, Ministry of Jal Shakti), NGO/technical reports (e.g., Wadhwani AI, IIIT Delhi), and pilot project case studies or publicly available grey literature with sufficient methodological detail.

Inclusion/Exclusion Criteria and Screening Process

Phase 1: Title and Abstract Screening: Titles and abstracts were screened; items unrelated to AI, sanitation, or focused only on infrastructure were excluded.

Phase 2: Full-Text Eligibility Screening: Full texts were assessed against inclusion criteria; items lacking empirical evaluation or relevance to open defecation/marginalized communities were excluded.

Phase 3: Quality Assessment: Studies were assessed for methodological rigor; only high and medium quality works were included, with low-quality sources noted in appendices.

Throughout phases, dual-review was conducted and Cohen's κ was calculated at each stage to ensure reproducibility and minimize interpretation drift.

Thematic Analysis Framework

Thematic analysis was applied to synthesize findings across qualitative and quantitative sources. The framework followed Braun and Clarke's six-phase approach, adapted for this mixed-methods review:

Two analysts independently read texts, coded AI modalities, data sources, sanitation outcomes, behavioral and equity aspects, and clustered codes into validated themes. Themes were refined and defined precisely (e.g., "Infrastructure monitoring via IoT," "Sentiment-driven behavioral nudges," "Algorithmic bias in marginalized contexts"). Themes were linked to research questions, synthesizing technology type, target populations, challenges, equity implications, and knowledge gaps. Thematic analysis was paired with summary tables of study metadata, AI methods, populations, and outcomes.

Scope and Limitations

This review focused on AI interventions directly addressing open defecation; broader sanitation applications were included only if relevant to defecation mapping or access. Studies focused on India or similar low-resource settings; global models were included only if transferable. Only English-language literature was considered, possibly omitting some regional reports. Publication bias is acknowledged for pilot or proprietary AI projects. Despite this, the methodology ensures transparency, reproducibility, and equity sensitivity from search to synthesis.

Applications of AI in Sanitation Monitoring

Remote Sensing and Satellite Imagery

Advancements in remote sensing and satellite technology have enabled the identification of sanitation-related risks at granular geographic scales. Platforms like ISRO's Bhuvan provide imagery to detect informal settlements and markers of open defecation hotspots (NRSC, 2023). Deep learning models, such as convolutional neural networks, have been applied to segment slum areas using satellite data, classifying land use patterns and degraded patches, thereby offering scalable tools for monitoring sanitation challenges (Maiya & Babu, 2018).

Machine learning techniques, particularly Land Cover and Change Detection (LCCD) frameworks, have been integrated with AI to classify regions into sanitation-relevant categories, such as built-up versus open land (Gu et al., 2023). Though few studies map open defecation directly, poverty-mapping models suggest potential for identifying sanitation deficits (Abascal et al., 2024). By applying these frameworks, researchers can flag high-risk blocks and districts where targeted interventions are urgently required.

Mobile and IoT-Based Data Collection

Community health workers in India are increasingly utilizing mobile-based decision-support tools that incorporate AI-driven analytics. Direct sanitation applications are limited, but WASH initiatives demonstrate potential. For example, GPS-enabled mobile apps supported by basic classifiers can help frontline workers submit geotagged reports on latrine usage and identify probable non-use patterns. Pilot platforms remain experimental but offer a framework for behavior monitoring (Pandey et al., 2020).

The deployment of Internet of Things (IoT)-enabled "smart public toilets" is being piloted in several Indian cities. In Indore, municipal authorities announced plans to retrofit more than 350 community toilets with sensors to track visitor flow, odor levels, water availability, and cleanliness indicators (Indore Municipal Corporation [IMC], 2025). Similarly, Hyderabad's LooCafe model integrates odor sensors and facility analytics, supported by a revenue-linked public toilet model. These are mainly industry-led pilots rather than peer-reviewed studies. Academic contributions, such as Deshmukh et al.'s intelligent sanitation prototype with infrared occupancy sensors and AI-based predictive maintenance, demonstrate a growing scholarly interest in sensor-driven sanitation monitoring (Parkar et al., 2024). These systems provide indirect usage insights, but do not measure open defecation directly.

GIS and Spatial Prediction Models

Geographic Information System (GIS) and AI classifiers have been developed to map sanitation risk zones. For instance, Roy et al. (2023) identified sanitation clusters in the Middle Ganges Plain using survey data alongside environmental covariates such as groundwater contamination. Similarly, Ashraf et al. (2023) demonstrated that communities with higher caste fractionalization exhibit distinct sanitation behaviors, indicating the importance of embedding socio-cultural variables into predictive frameworks. AI spatial models integrating environmental, demographic, and caste data can identify high-risk marginalized clusters.

By integrating census data on caste and poverty distributions with sanitation infrastructure maps, AI-enabled GIS systems can visualize inequities across villages and urban wards. Most Indian applications are still pilot-stage but align with best practices in equity-sensitive spatial analysis (Singh et al., 2022).

AI in Behavior Tracking and Change

Natural Language Processing (NLP)-based sentiment analysis has been employed in India to study public attitudes toward health campaigns (Pandey et al., 2020). Extending this to sanitation could allow authorities to track misinformation, stigma, and public acceptance of programs such as the Swachh Bharat Mission in marginalized communities. Few sanitation-focused studies exist, but pilots capture real-time public perceptions.

Interactive platforms such as chatbots and nudge-based apps can deliver targeted sanitation messages in local languages. WashKaro, for example, demonstrated how machine learning frameworks can provide multilingual, contextualized health communication during COVID-19 (Pandey et al., 2020). Translating this model to sanitation would involve nudging rural households to use toilets and reinforcing behavioral norms through SMS or voice bots. These early-stage trials show promise for AI-mediated behavioral interventions.

AI applications in sanitation monitoring in India encompass a diverse range of modalities, including satellite imagery, machine learning classification, IoT-based data collection, GIS spatial prediction, and behavior change interventions. Though innovative, most technologies remain pilots with limited evaluation, highlighting the need for validation, contextual adaptation, and equity-focused research.

Key Challenges and Limitations of AI in Sanitation Monitoring in India

AI holds promise for improving sanitation monitoring in India, especially for marginalized communities, but deployment faces challenges in data, technology, ethics, and policy that require careful consideration.

Data Limitations

A fundamental challenge in applying AI to sanitation monitoring is the paucity and quality of data, especially in rural and informal urban settings. Many datasets are incomplete, noisy, or not representative of the populations most in need (Kant, 2020). Health and survey data often contain missing values or inaccuracies, especially in remote areas (WHO, 2024). Open-source datasets may underrepresent marginalized groups, undermining model generalizability (Mathiyazhagan, 2024; Sonavane, 2023).

In satellite and remote-sensing contexts, ground truth data—such as verified open defecation sites—are rarely available. Without robust geolabelled validation, computer vision models may misclassify or overlook informal defecation hotspots, especially in heterogeneous rural landscapes (Wired, 2025).

Technological Barriers

The deployment of AI technologies in marginalized areas is frequently hindered by infrastructure and connectivity constraints. Many rural communities lack reliable electricity, internet connectivity, or IoT-compatible mobile devices, making remote sensing dashboards or sensor-enabled toilets aspirational rather than practical (Times of India, 2025). In urban informal settlements, uneven smartphone or sensor access limits timely data collection (Kant, 2020). The cost of IoT infrastructure, installation, and maintenance can be prohibitive, particularly for underfunded municipal or NGO-run sanitation projects. As highlighted by digital sanitation pilots in Kenya and urban India, smart toilets require continuous upkeep, calibration, and technical maintenance—resources often absent in low-income settings (Giesen et al., 2024).

Social and Ethical Issues

AI systems that monitor sanitation behavior—such as mobile tracking by community workers or facial recognition for attendance—can easily cross the line into non-consensual surveillance. Notably, biometric monitoring tools deployed in sanitary worker management have drawn criticism from users—especially Dalit workers—who report being forced to wear devices during private or personal activities, with little recourse or opt-out options (Sonavane, 2023). This raises serious ethical concerns around autonomy, dignity, and potential punitive surveillance (Siddiqui, 2024).

AI tools may unintentionally reinforce stigma or exclusion. Models trained on unbalanced datasets can misidentify marginalized groups, leading to misallocation of sanitation resources and reinforcing existing inequities under the guise of data-driven decision-making (Mathiyazhagan, 2024; Sonavane, 2023). Biometric and computer-vision systems may perform poorly on darker-skinned individuals, reproducing inequities (Siddiqui, 2024).

Policy Gaps

India currently lacks a coherent regulatory or governance framework for AI deployment in public sector sanitation systems. Laws such as the Digital Personal Data Protection Act (DPDP Act, 2023) do not adequately enforce provisions for high-risk AI use or guarantee explainability in decision-making (Gupta & Roy, 2025). Biometric systems in public services lack clear grievance and audit mechanisms (Gupta & Roy, 2025).

Furthermore, there is a disconnect between AI initiatives and grassroots sanitation realities. Many pilot projects are technology-driven, with inadequate involvement of end-user communities in design or consent processes. This leads to deployments that overlook local norms, maintenance, and resource constraints (Kant, 2020; WHO, 2024). Policies rarely emphasize community participation or caste- and gender-sensitivity, limiting uptake and legitimacy (Siddiqui, 2024).

Linking Technologies to Case Studies

This review identifies four key technological modalities in AI applications for sanitation monitoring: (i) computer vision and satellite-based remote sensing, (ii) mobile and IoT-enabled monitoring, (iii) GIS-based spatial prediction, and (iv) natural language processing (NLP) for behavioral insights. These modalities are key AI research directions for public health in low-resource contexts (Abascal et al., 2024; Gu et al., 2023; Pandey et al., 2020; Singh et al., 2022), but translating them into sanitation initiatives in India faces infrastructural, social, and institutional constraints.

Many AI interventions in India are documented in grey literature. Mobile and IoT-enabled toilets, remote sensing, and GIS-based spatial models show potential in detecting sanitation risk clusters, but academic evaluation and integration into government frameworks remain limited (Parkar et al., 2024; Maiya & Babu, 2018; Roy et al., 2023).

Computer vision and satellite-based models have effectively detected environmental markers of sanitation risk. Convolutional neural networks segment slums, identify degraded patches, and infer human activity, supporting intervention prioritization, though accuracy requires geospatial validation and community input (Maiya & Babu, 2018; Roy et al., 2023).

Mobile and IoT-enabled monitoring provides near real-time data for operational planning. Smart toilets and GPS-enabled mobile apps track usage, water availability, and hygiene, allowing frontline workers to submit geotagged reports. Though mostly reported via NGOs, these tools show practical adaptation of AI to field conditions (Parkar et al., 2024).

GIS-based spatial prediction combines demographic, environmental, and socio-economic data to identify high-risk zones, supporting targeting of marginalized communities, though adoption is limited by data gaps (Singh et al., 2022). NLP sentiment analysis can reveal perceptions and barriers to toilet use; pilots show potential for behavioral nudges, but evaluation in India remains nascent (Pandey et al., 2020).

Case studies illustrate operational deployment: LooCafe's sensor-enabled toilets track hygiene and usage; SHRI pilots integrate occupancy sensors into monitoring dashboards; startups such as IndoAI and TrackingPath develop AI-driven anomaly detection for sanitation; robotic interventions like Homosep Atom are tested for public facility hygiene. These initiatives, while primarily pilot or industry-based, provide insights into practical adaptation, operational challenges, and scaling considerations.

In conclusion, the review highlights a gap between theoretical AI potential and operational reality. While academic research is methodologically strong, large-scale deployments are mostly in grey literature. Bridging this gap requires evaluation, community-centered design, ethical oversight, and municipal integration to ensure AI enhances sanitation equity.

Case Studies and Indian Initiatives

Example 1: Government and Startup-Led AI in Sanitation Mapping

The Swachh Bharat Mission (SBM) has pioneered the use of AI for large-scale sanitation monitoring through its geo-tagged photo portal. Citizens can upload images of constructed Individual Household Latrines (IHHLs) via mobile applications, which are subsequently analyzed by an AI model designed to detect latrine seats and verify beneficiary presence. Applied to nearly 40 million images, this represents a large-scale public sector AI application for sanitation verification (Ministry of Housing and Urban Affairs, n.d.).

In the private sector, industry-led initiatives such as TrackingPath, operated by AVSG Info Systems Pvt. Ltd., have introduced AI-driven visual intelligence platforms primarily for municipal solid waste management. The system, mounted on garbage collection vehicles, employs computer vision algorithms to analyze events such as bin lifting, waste segregation, and loading operations (Business Standard, 2025). Though focused on waste management, the technology could monitor public toilet networks and sanitation hotspots.

IndoAI, a technology startup operating in several Indian smart cities, provides another illustrative example. Its camera-based AI system detects anomalies such as illegal waste disposal or loitering in public spaces, sending geo-tagged alerts to municipal sanitation teams. Documentation comes mainly from industry reports; the platform illustrates potential for monitoring hygiene compliance (IndoAI, 2025).

Example 2: NGO-Led AI Interventions for Toilet Access and Use

Civil society organizations are increasingly experimenting with AI for sanitation monitoring. The non-profit Sanitation and Health Rights India (SHRI), in collaboration with its technology partner Dalgo, has implemented an automated dashboard in Jharkhand to track the condition and usage of community toilets. The system records daily data on cleanliness, water availability, and user footfall, which are processed and visualized for facility managers in real time. Reports from SHRI indicate improvements in maintenance and satisfaction, though based on NGO evaluations (Project Tech4Dev, 2025).

LooCafe provides an example of a market-based model integrating technology and service delivery. The organization operates container-based public toilets equipped with IoT-enabled sensors, including odor detectors, water-level monitors, and usage counters. Revenue generated through an attached café model sustains facility upkeep while sensor data supports operational decision-making. Over 350 units are reportedly operational across Telangana, Tamil Nadu, and Jammu & Kashmir (LooCafe, 2023).

Comparative Insights from Low-Resource Countries

International examples offer additional insights relevant to low-resource contexts. In East Africa, the mWater platform enables utilities to crowdsource sanitation data in informal settlements through mobile surveys. Collected datasets could inform future machine learning models for sanitation risk mapping (Patrissi, 2024). Similarly, WASHtsApp, a WhatsApp-based chatbot piloted in rural African settings, uses a retrieval-augmented generation (RAG) approach to deliver context-specific hygiene and sanitation guidance in local languages. Pilot results suggest high acceptance and behavior change, offering a blueprint for AI-mediated sanitation in India (Kloker et al., 2024).

Opportunities and Future Directions

Opportunities and Future Directions

One of the key opportunities for enhancing sanitation equity with artificial intelligence (AI) lies in designing **community-centric systems** that actively involve local stakeholders. Marginalized populations in India—including Scheduled Castes, Scheduled Tribes, and residents of urban informal settlements—often face barriers in accessing or trusting digital technologies. Marginalized populations—Scheduled Castes, Scheduled Tribes, and residents of informal settlements—face barriers; AI interventions must be co-designed with communities via ASHAs, volunteers, and Panchayati Raj institutions (Chattopadhyay et al., 2021). Participatory approaches like co-annotating datasets or validating algorithms enhance fairness and legitimacy (Suresh & Guttag, 2021).

Satellite-based models identifying high-risk sanitation zones (Roy, Kumar, & Singh, 2023) can be paired with local campaigns led by Swachhagrahis or ASHAs to encourage latrine adoption. Such hybrid approaches ensure that AI-generated insights translate into tangible behavioral change (Jadhav, Weidman, & Kanungo, 2020). Scalability also requires training models on diverse datasets—including household surveys, census records, and geospatial indicators—so that predictions remain sensitive to both rural and urban contexts (Gu, Wang, Li, & Zhang, 2023).

Existing frameworks like SBM and Jal Jeevan Mission offer entry points for AI integration. Current monitoring dashboards emphasize infrastructure counts, often overlooking behavioral or equity-sensitive indicators. AI could predict where toilets are likely to fall into disuse, identify marginalized clusters at risk of exclusion, or track sanitation-related discourse in local-language social media (Narayan, Ramesh, & Sinha, 2022). Implementing bias audits, community consultations, and algorithmic transparency standards would ensure ethical deployment and equity-focused outcomes (Jobin, Ienca, & Vayena, 2019). Public–private partnerships and government-supported innovation sandboxes could facilitate pilot testing of IoT toilets or sensor-based systems while maintaining accountability (Majeed & Vellakkal, 2024, grey literature).

Finally, interdisciplinary and international collaboration is essential. Public health specialists, technologists, and social scientists should jointly develop AI systems that align technical accuracy with cultural appropriateness. Lessons from low-resource countries such as Bangladesh, Kenya, and Nigeria demonstrate how chatbot-based hygiene interventions or mobile data platforms can inform Indian contexts (Kloker, Luyima, & Bazanya, 2024, grey literature). Collectively, participatory design, integrated behavioral strategies, policy alignment, and collaborative learning offer a pathway for AI to advance equitable and context-sensitive sanitation solutions.

Conclusion

Summary of Key Findings

This review has explored the expanding role of artificial intelligence (AI) in addressing open defecation in marginalized Indian communities. Evidence indicates that AI technologies—including satellite imagery and computer vision, mobile- and IoT-based monitoring, GIS-based spatial prediction, and natural language processing for behavioral insights—offer new possibilities for sanitation monitoring and intervention (Abascal et al., 2024; Gu et al., 2023; Pandey, Litoriya, & Pandey, 2020; Singh, Ranjan, & Banerjee, 2022). Remote sensing enables identification of sanitation-vulnerable zones at fine geographic scales, while IoT-enabled toilets and mobile applications allow frontline workers to collect real-time usage and facility maintenance data. GIS and AI classifiers further facilitate the mapping of high-risk populations by integrating demographic, environmental, and socio-cultural variables. AI-driven sentiment analysis and nudge-based applications additionally offer tools for influencing sanitation-related behaviors, providing a mechanism to translate data into actionable interventions (Roy, Kumar, & Singh, 2023; Pandey et al., 2020).

AI's Potential for Sanitation Equity

AI has significant potential to bridge gaps in India's sanitation ecosystem by supporting evidence-based, scalable, and adaptive decision-making. When deployed with inclusive design principles, AI can enhance community engagement, amplify marginalized voices, and inform local governance (Chattopadhyay, Ahmed, & Ghosh, 2021; Suresh & Guttag, 2021). Initiatives under the Swachh Bharat Mission and other national programs can benefit from AI-supported dashboards that not only track infrastructure but also predict areas at risk of disuse or exclusion. However, realizing this potential requires attention to the social, cultural, and economic contexts of marginalized populations, including caste, gender, and poverty dynamics (Lloyd, 2018; Chadha, Singh, & Mehta, 2022).

Responsible Innovation and Ethical Considerations

The deployment of AI in sanitation must be guided by ethical principles, transparency, and participatory approaches. Data should be representative, anonymized, and collected with informed consent, while algorithms must be auditable and explainable to both policymakers and affected communities (Jobin, Ienca, & Vayena, 2019). Cross-sectoral collaboration between AI developers, public health specialists, social scientists, and sanitation workers is crucial to ensure that technical innovations align with community needs and equity goals.

Final Reflection

AI is not a silver bullet, but responsible integration can improve health, dignity, and social equity. By combining technological innovation with community participation and robust governance, India can develop inclusive AI strategies that leave no one behind in the fight against open defecation.

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