

CiviCare: An AI-Powered Smart Water Governance and Grievance Resolution System for Urban Local Bodies in India

Tanishka Ashish Shah¹, Dhanashri Jamdar Pingale^{1*}, Purva Hanumant Pawar¹, Sakshi Santosh Tupe¹, Sweety Dhiraj Mohite²

Abstract

Water supply operations in many Indian Urban Local Bodies (ULBs) continue to rely on manual processes that lack transparency, efficiency, and accountability. Citizens often have limited access to information regarding supply schedules, connection status, and billing details. Grievances are frequently reported through informal channels, resulting in poor traceability and lack of resolution assurance. This paper introduces CiviCare, a full-stack AI-enabled web platform designed to digitize and optimize municipal water governance for Indian ULBs. The system manages the complete lifecycle of a water connection, including application submission with document verification, site inspection, administrative approval, Consumer Number generation, and rule-based annual billing. A rule-driven Natural Language Processing (NLP) module is implemented to automatically classify and prioritize citizen complaints, which are then assigned to field plumbers through generated work orders with defined Service Level Agreements (SLAs). Water supply information is recorded daily by municipal officers and presented transparently through ward-level dashboards. The platform further integrates a Gemini AI-based chatbot for citizen interaction and Twilio SMS services for proactive notifications. Evaluation results demonstrate improvements in complaint resolution visibility, fairness in billing, and efficiency in managing water connections when compared to existing municipal systems.

Keywords: Municipal water management, ULB digitization, grievance management, NLP classification, smart governance, billing transparency, citizen services, India

INTRODUCTION

India comprises more than 4,000 Urban Local Bodies (ULBs), including municipal corporations, municipal councils, and nagar panchayats, which together serve an urban population of over 500 million. Although initiatives such as the Jal Jeevan Mission aim to ensure universal access to tap water, the administrative systems responsible for managing water services in many small- and medium-sized ULBs remain largely manual and paper-based [1].

*Author for Correspondence

Dhanashri Jamdar Pingale
E-mail: pingaledhanashri4@gmail.com

¹Student, Department of Computer Engineering, PES's College of Engineering Phaltan, Maharashtra, India

²Assistant Professor, Department of Computer Engineering, PES's College of Engineering Phaltan, Maharashtra, India

Received Date: April 03, 2026

Accepted Date: May 11, 2026

Published Date: June 07, 2026

Citation: Tanishka Ashish Shah, Dhanashri Jamdar Pingale, Purva Hanumant Pawar, Sakshi Santosh Tupe, Sweety Dhiraj Mohite. CiviCare: An AI-Powered Smart Water Governance and Grievance Resolution System for Urban Local Bodies in India. Journal of Web Engineering & Technology. 2026; 13(2): 15–23p.

For citizens, obtaining a new water connection is often a time-consuming process involving multiple visits to municipal offices, the submission of physical documents, and uncertainty regarding inspection schedules. The allocation of Consumer Numbers typically requires in-person follow-up. Similarly, billing processes are maintained through manual records, offering little clarity or transparency regarding how the charges are calculated. Complaint reporting is equally

unstructured, with issues such as supply interruptions, pipeline failures, or billing disputes commonly communicated through verbal means or informal messaging platforms, resulting in the absence of tracking mechanisms, acknowledgements, or defined resolution timelines.

Existing studies on complaint management systems primarily focus on large urban municipalities equipped with established IT infrastructure [2] or smart water monitoring solutions that depend on IoT-based systems requiring significant financial investment [3]. These approaches are not well suited to smaller ULBs, where water metering is often unavailable, digital systems are limited, and citizens exhibit varying levels of digital literacy.

To address these challenges, this study introduces CiviCare, a practical and scalable web-based platform tailored to the needs of Indian ULBs. The system offers several key contributions: (1) end-to-end digitization of the water connection lifecycle with document submission and multistage approval workflows, (2) transparent rule-based billing without dependence on water meters, (3) an NLP-based complaint classification and prioritization system with automated assignment and SLA tracking, (4) improved supply transparency through integration of dam-level data, (5) proactive communication with citizens using SMS notifications, and (6) a multilingual AI-powered chatbot for user assistance.

PROBLEM STATEMENT

Although the Government of India continues to promote digital governance initiatives, a large number of small and medium Urban Local Bodies (ULBs) still depend on traditional paper-based processes for managing water connections, billing operations, and grievance redressal processes. These practices result in limited transparency, slower service delivery, delays in resolving citizen complaints, and reduced public engagement. Many existing digital solutions are either dependent on costly IoT-based infrastructure or are not designed to accommodate the practical limitations of smaller municipalities. Consequently, these solutions are difficult to implement effectively in such environments. Hence, there is a clear requirement for an affordable, scalable, and intelligent solution capable of digitizing water governance processes, automating complaint handling, and enhancing transparency in service delivery without relying on complex or high-cost infrastructure.

RELATED WORK

DiCarlo et al. [4] analyzed complaint management practices in community water systems in the United States and observed that many smaller utilities do not maintain digital complaint records. Additionally, only a portion of larger utilities utilize complaint data to identify broader operational trends. This highlights the need for structured complaint analytics, which CiviCare addresses through ward-level trend monitoring dashboards.

Shama et al. [2] introduced CitySolution, a deep learning-driven civic complaint management platform featuring separate dashboards for citizens and municipal authorities, along with automated complaint routing. Although the system demonstrates effective AI-based classification, it is designed as a general-purpose civic solution and does not incorporate water-specific functionalities, such as connection lifecycle handling, billing mechanisms, or supply schedule tracking.

Alenezy et al. [5] developed Fix-It, a public complaint reporting system that integrates mobile applications, location mapping, and web interfaces. However, the system lacks intelligent features such as machine learning-based classification, priority assignment, SLA-based tracking, and water supply related capabilities.

Afify and Kadry [6] proposed an E-CCMS, a role-based digital platform for registering and monitoring complaints. Although the system provides a structured framework for grievance handling, it remains domain-independent and does not include AI-driven processing or specialized modules for water service management.

Soares et al. [7] reviewed smart water management technologies and concluded that most existing solutions emphasize IoT-enabled systems, such as smart metering and leakage detection, which require substantial hardware investment. Similarly, Bonilla and Brentan [8] highlighted the limited availability of digital solutions specifically designed for small municipalities, thereby reinforcing the need for a practical and scalable platform such as CiviCare.

SYSTEM ARCHITECTURE

CiviCare was designed using a three-tier client-server architecture consisting of presentation, application, and data layers. The presentation layer was developed using React.js with Vite, enabling browser-based access to multiple role-specific portals. The application layer was built in Python using FastAPI, which provides RESTful API endpoints secured through JWT-based authentication. The data layer utilizes PostgreSQL as a relational database, with SQLAlchemy ORM handling database interactions.

Modules

- *Connection management*: Handles the complete workflow, including application submission, document upload via Cloudinary, inspection processing, administrative approval, and Consumer Number generation.
- *Billing engine*: Performs annual billing calculations based on parameters such as pipe size, connection category, construction type, pending dues, and a 2% compound penalty on arrears.
- *Grievance management*: Incorporates an NLP-based classification system with priority scoring, automated work order creation, assignment to field plumbers, SLA tracking, and PDF-based complaint receipt
- *Supply transparency*: Maintains daily water supply logs recorded by officers for each ward, integrates dam-level data, and displays the information through a public dashboard.
- *Service requests*: Supports additional user requests, such as ownership transfer, temporary or permanent disconnection, reconnection, and pipe size modification
- *Communication*: Provides notification services through Twilio SMS for announcements and integrates a Gemini AI chatbot to handle citizen queries.

Technology Stack

The table summarizes the principal technologies employed across the frontend, backend, database, authentication, storage, document generation, messaging, AI, and dam-data components Table 1.

Table 1. Technology stack.

Layer	Technology
Frontend	React.js, Vite, CSS3
Backend	Python 3.11, FastAPI, Uvicorn
Database	PostgreSQL, SQLAlchemy ORM
Authentication	JWT (python-jose), bcrypt
File Storage	Cloudinary (free tier)
PDF Generation	ReportLab
SMS	Twilio Programmable SMS
AI Chatbot	Google Gemini 1.5 Flash API
Dam Data	Maharashtra WRD (web scraping)

User Roles and Access Control

CiviCare defines five primary user roles, each associated with a dedicated interface and controlled access permissions enforced through JWT-based role authorizations.

- *Citizen*: Allows users to apply for water connections by uploading Aadhaar and property-related documents; monitors application progress across all lifecycle stages; accesses and downloads annual bills and payment receipts in PDF format; submits complaints with supporting images; requests services such as ownership transfer, pipe size modification, and reconnection; and interacts with the multilingual AI chatbot for assistance.
- *Officer*: responsible for reviewing submitted applications, conducting and recording site inspections with relevant property details, approving or rejecting requests, and generating Consumer Numbers (format: PMC-YYYY-NNNNN). They also handle complaint assignments to plumbers, record daily ward-level water supply data, send targeted SMS notifications, and generate billing records.
- *Plumber*: Accesses assigned work orders (WO-NNNNNN) through a dedicated interface; updates complaint status (e.g., in progress or resolved) along with resolution details; restricted to viewing only the complaints assigned to them
- *Corporator*: Provides a read-only dashboard for monitoring ward-level water supply data, complaint resolution metrics, and billing status; acts in an oversight role without permission to modify system data
- *Admin*: Oversees overall system configuration, including management of billing rates, creation of staff accounts, and ward administration, and has unrestricted access to all modules along with audit logs.

SYSTEM DESIGN

Data Flow Diagram—Level 0

The Level 0 Data Flow Diagram (DFD), also known as the context diagram, represents CiviCare as a unified system that processes inputs from four external entities: Citizen, Officer, Plumber, and Corporator. The system also interacts with two external services: the Maharashtra Water Resources Department for dam-level data and Twilio for SMS communication. This high-level representation illustrates the overall data exchange between users and the system without detailing the internal processes (Figure 1).

Use Case Diagram

CiviCare defines four primary actors that interact with the system. Table 2 details the use cases associated with each actor in Figure 2.

IMPLEMENTATION

Connection Lifecycle

The water connection workflow in CiviCare is designed to replicate the standard municipal procedure outlined in the Maharashtra Municipal Councils Act [9], as follows: Citizens initiate the process by submitting an online application along with the required documents, including Aadhaar identification and proof of property ownership (such as a 7/12 extract or sale deed), which are uploaded through Cloudinary.

Municipal officers then verify the submitted documents and arrange site inspections. During the inspection, relevant details such as the pipe diameter, construction category, number of taps, and number of floors were recorded. Based on the inspection findings, the application is either approved or rejected. If approved, the system automatically generates a unique Consumer Number (format: PMC-YYYY-NNNNN) and creates a user account for the applicant. The Consumer Number is initially assigned as the default password, which the user must update upon first login. This digital workflow significantly reduces the need for repeated physical visits to municipal offices [10].

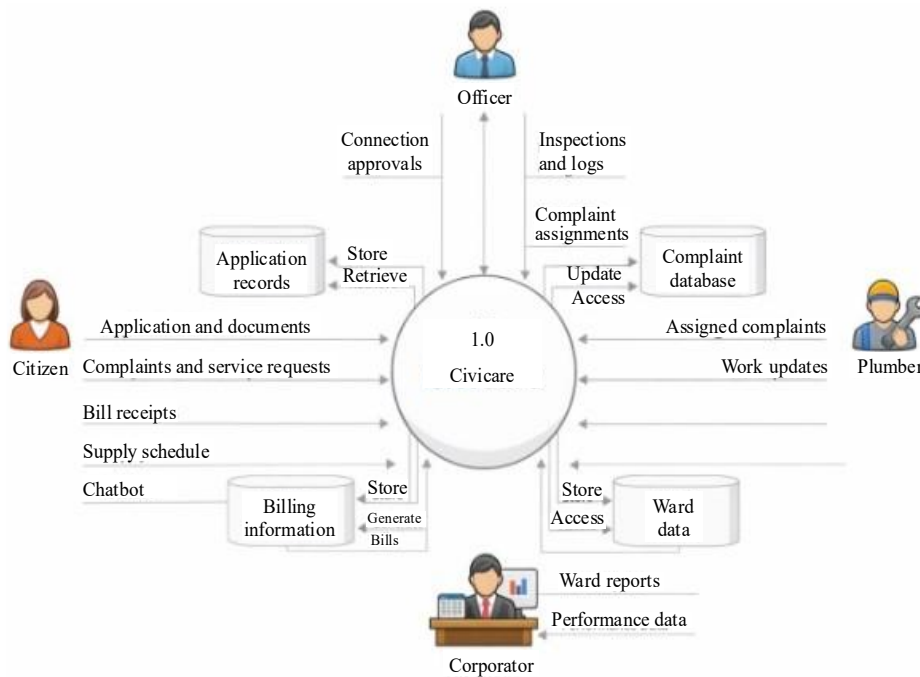


Figure 1. DFD Level 0 - CiviCare context diagram.

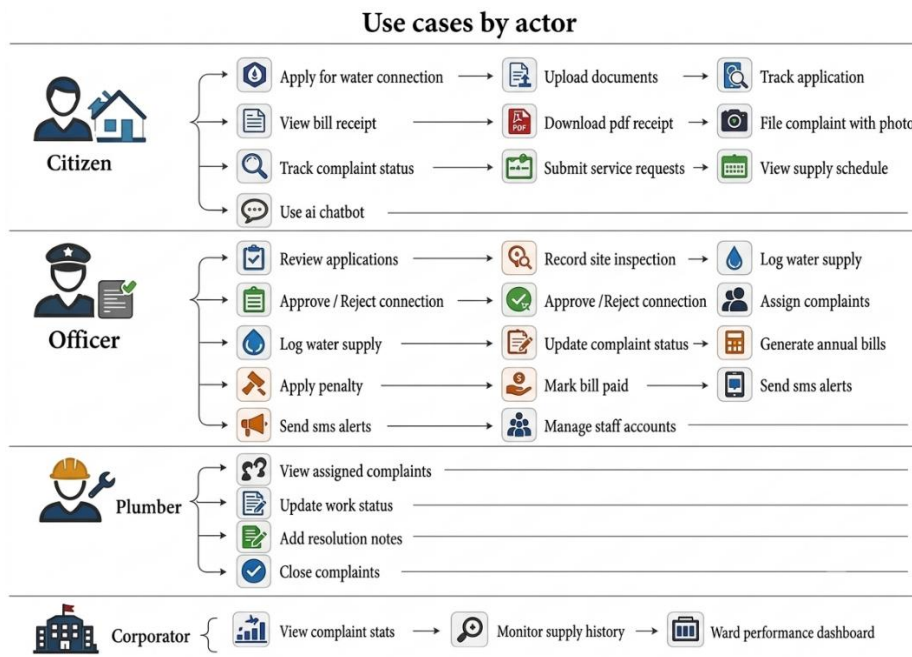


Figure 1. Use case diagram.

Formula-Based Billing

CiviCare provides a transparent approach to annual billing without relying on water meters, aligning with the flat-rate billing model commonly used by small Indian ULBs. The billing calculation is defined as follows:

$$\text{Annual Bill} = (\text{Base Rate} \times \text{Construction Multiplier}) + \text{Additional Tap Charge} + \text{Arrears} + \text{Penalty}$$

The base rate is determined based on the pipe size and connection category, as specified in Table 3. Construction multipliers are assigned as follows: RCC (pucca) = 1.0×, semi-pucca = 0.75×, and kutchra/patra = 0.5×.

For overdue payments, a penalty of 2% compound interest per month is applied, in accordance with standard municipal regulations. If a user fails to pay for two consecutive billing cycles, a warning notification of disconnection is issued. After three consecutive defaults, the connection is marked for disconnections.

Users can access and download their annual bills and payment receipts in PDF format, which are generated on the server side using the ReportLab library.

NLP Complaint Classification and Priority Scoring

CiviCare incorporates a rule-based Natural Language Processing (NLP) mechanism to automatically categorize complaints and assign priority levels. When a complaint is submitted, the system identifies its category using a predefined taxonomy, including no supply, low pressure, pipe burst, dirty water, and billing issues. It further analyzes the complaint description to detect urgency indicators such as keywords like “burst,” “hospital,” “flooding,” or “since days.” A weighted priority score ranging from 1 to 5 was calculated using the following expression:

$$Priority = \min(5, BaseScore[type] + \min(2, \sum UrgencyKeywordMatches))$$

Each complaint category is assigned a base score: pipe burst (5), dirty water and no supply (4), low pressure (3), and billing (2). Additional urgency keywords could increase the score by a maximum of two points.

Once processed, the system generates a unique work order ID (format: WO-NNNNNN) and assigns a Service Level Agreement (SLA) deadline based on the complaint type. For example, pipe burst issues are assigned a 4-hour resolution window, whereas low-pressure complaints allow up to 24 h. The assigned officer forwards the complaint to a designated plumber who can access and update only their allocated tasks through the plumber portal.

This rule-based model also serves as a baseline for future enhancements using transformer-based NLP techniques as labeled complaint datasets become available [11].

Supply Transparency and Dam Level Integration

Municipal officers record daily water supply details for each ward, including the supply start time, duration, operational status (such as supply, maintenance, shortage, or pipe burst), and the corresponding reason. This information is consolidated into a publicly accessible dashboard that displays the current supply conditions, a 30-day supply performance score for each ward, and related complaint statistics.

Additionally, water level data from Veer Dam were periodically retrieved from the Maharashtra Water Resources Department portal through scheduled web scraping implemented using Python’s BeautifulSoup library. This integration provides contextual insights into water availability, supporting informed decision-making regarding supply distribution.

Communication Engine

CiviCare includes an integrated communication system for disseminating official announcements to the public. When an officer publishes a notification for a specific ward or multiple wards, the system sends SMS alerts to registered citizens using the Twilio Programmable SMS API [12]. Contact details collected during the application process enabled targeted message delivery, replacing informal communication channels with a structured and auditable mechanism. The platform also features an AI-powered chatbot built using the Google Gemini 1.5 Flash model, which is accessed via the REST API. The chatbot is configured with a system-level context covering connection procedures, billing policies, and complaint workflows, allowing users to interact in natural language for queries related to services and processes. To ensure reliability, a rule-based fallback mechanism is implemented to handle user queries in cases where the Gemini API is unavailable, thereby maintaining uninterrupted assistance for the citizens.

RESULTS AND DISCUSSION

CiviCare was tested using a controlled dataset consisting of 13 wards, six active consumer connections, 25 previously recorded complaints, 30 days of water supply logs, and six billing entries. The system was deployed in a local environment using FastAPI and PostgreSQL on a standard machine configured with Windows 11, 8 GB of RAM, and an Intel Core i5 processor.

NLP Complaint Classification

The performance of the rule-based NLP module was assessed using a test set of 50 manually annotated complaints covering all the predefined categories. The system achieved an accuracy of 88% in correctly identifying complaint types and 92% in assigning appropriate priority scores.

Most errors were observed in cases where the complaint descriptions were either vague or involved multilingual inputs, particularly Marathi-English code-mixed text. These limitations highlight the need for future improvements in transformer-based models with better support for Indic languages.

Billing Accuracy

The accuracy of the billing module was assessed using six representative connection profiles covering a range of pipe diameters and connection categories. For each case, the generated bill closely aligned with the expected values derived from the Maharashtra ULB tariff schedule, with a maximum deviation limited to ₹1 due to rounding. Furthermore, the penalty computation, based on a 2% monthly compound interest rate, was validated against manual calculations for overdue periods of 1, 3, 6, and 12 months. The results showed no observable discrepancies, confirming the correctness of the implementation.

System Performance

The system performance was evaluated by measuring the API response times across key endpoints using 100 consecutive requests. The complaint submission endpoint, incorporating NLP-based classification, exhibited an average response time of 42 ms. Similarly, the bill generation endpoint recorded an average of 38 ms, whereas the public dashboard endpoint averaged 95 ms. All endpoints consistently responded within 200 ms under a single-user workload, satisfying the typical performance benchmarks for web-based applications in the intended deployment setting (Table 4).

Table 1. Annual base rates (INR) by pipe size and connection type.

Pipe size	Domestic	Commercial	Industrial	Religious/govt.
½ inch (0.5")	₹720	₹1,800	₹3,600	₹600
¾ inch (0.75")	₹1,080	₹2,700	₹5,400	₹900
1 inch (1.0")	₹1,800	₹4,500	₹9,000	₹1,500
1.5 inch (1.5")	₹3,600	₹9,000	₹18,000	₹3,000

Table 2. Complaint evaluation accuracy.

Complaint type	Precision	Recall	F1-score
No Supply	0.91	0.95	0.93
Pipe Burst	0.94	0.90	0.92
Low Pressure	0.85	0.82	0.83
Dirty Water	0.88	0.86	0.87
Billing Issue	0.90	0.88	0.89
Weighted Avg	0.90	0.88	0.89

Table 3. System performance.

Endpoint	Avg. response (ms)	Max. response (ms)
POST /complaints/	42	78
POST /billing/generate	38	65
GET /dashboard/public	95	142
POST /connections/approve	61	98
GET /billing/my	28	51

Comparison with Related Work

Compared with existing solutions, CiviCare demonstrates several domain-specific enhancements. Although CitySolution [3] offers a comprehensive feature set, it lacks dedicated functionalities tailored to water utility management. CiviCare addresses this gap by incorporating features such as end-to-end connection lifecycle management, rule-based billing aligned with the tariff structures, and integration of dam-level monitoring data.

Similarly, Fix-It [2], primarily designed for general grievance handling, does not include advanced capabilities such as automated NLP-based complaint classification, service-level agreement (SLA) monitoring, or integrated SMS-based communication, all of which are implemented in CiviCare. Moreover, neither CitySolution nor Fix-It adequately addresses billing transparency, which is a critical requirement for municipal water users in India. Notably, CiviCare distinguishes itself as the first system, within the scope of the reviewed literature, to fully digitize the water connection approval process in Indian Urban Local Bodies (ULBs), including multi-stage document verification and workflow management.

CONCLUSION AND FUTURE WORK

This study introduces CiviCare, an AI-enabled platform for municipal water governance and grievance management tailored to the needs of Indian Urban Local Bodies (ULBs). The proposed system effectively addresses the key limitations observed in conventional municipal frameworks, including the lack of a structured digital workflow for water connection management, limited transparency in billing mechanisms, reliance on informal complaint-handling practices, and insufficient mechanisms for proactive citizen engagement.

The findings highlight that impactful digital transformation in municipal services can be achieved without dependence on a costly IoT infrastructure. By leveraging existing administrative data sources, such as connection records, inspection reports, and supply logs, CiviCare enables improved transparency, operational accountability, and intelligent service delivery through integrated AI components.

Future enhancements to the system will focus on expanding its analytical and operational capabilities to improve its performance. These include the adoption of transformer-based models for multilingual complaint classification, implementation of duplicate complaint detection using cosine similarity techniques, and identification of supply distribution anomalies across wards through Z-score-based statistical analyses. Additional directions involve the development of a mobile application for field personnel, integration with state-level ULB platforms for unified data exchange, and incorporation of real-time dam-level data through APIs to support the predictive analysis of water supply stress.

Acknowledgment

The authors express their sincere gratitude to Prof. S. D. Mohite, Department of Computer Engineering, PES's College of Engineering, Phaltan, for her continuous guidance, constructive feedback and support throughout the course of this work. The authors also acknowledge the contributions of open-source communities whose tools and frameworks, including FastAPI, React,

PostgreSQL, and the *docx* library, played a significant role in the development and implementation of the system.

REFERENCES

1. Pegu K, Samal KP. Navigating India's legal governance in water sector: a scrutiny into national performance under SDG framework for clean and wastewater management in India. *J Sustain Dev Law Policy*. 2025;16:210.
2. Shama F, Aziz A, Deya LB. CitySolution: a complaining task distributive mobile application for smart city corporation using deep learning. *SoftwareX*. 2024 Sep;27:101829.
3. Pérez-Padillo J, Puig F, Morillo JG, Montesinos P. IoT platform for failure management in water transmission systems. *Expert Syst Appl*. 2022 Aug;199:116974.
4. DiCarlo M, Berglund EZ, Kaza N, Grieshop A, Shealy L, Behr A. Customer complaint management and smart technology adoption by community water systems. *Utilities Policy*. 2023 Feb;80:101465.
5. Alenezy FA, Akhlaq M. Fix-it: design and implementation of a public complaint management system. In: 2023 International Conference on Computer Science, Information Technology and Engineering (ICCoSITE); 2023 Feb 16. p. 858–862. IEEE.
6. Afify EA, Kadry MA. Electronic-customer complaint management system (e-CCMS)—a generic approach. *Int J Adv Netw Appl*. 2019 Jul;11(1):4125–4141.
7. Soares Ascensão É, Melo Marinangelo F, Meschini Almeida CF, Kagan N, Dias EM. Applications of smart water management systems: a literature review. *Water*. 2023 Oct 6;15(19):3492.
8. Bonilla C, Brentan B, Montalvo I, Ayala-Cabrera D, Izquierdo J. Digitalization of water distribution systems in small cities, a tool for verification and hydraulic analysis: a case study of Pamplona, Colombia. *Water*. 2023 Nov;15(21):3824.
9. Directorate of Municipal Administration. The Maharashtra Municipal Councils, Nagar Panchayats and Industrial Townships Act, 1965. Directorate of Municipal Administration; 2025. Available from: https://mahadma.maharashtra.gov.in/en/services/the-maharashtra-municipal-councils-nagar-panchayats-and-industrial-townships-act-1965/?dma_tab=regional
10. Bureau of Indian Standards. Indian standard: IS 10500:2012, drinking water—specification. New Delhi: Bureau of Indian Standards; 2012. Available from: <https://www.scirp.org/reference/referencespapers?referenceid=2203259>
11. Esperança M, Freitas D, Paixão PV, Marcos TA, Martins RA, Ferreira JC. Proactive complaint management in public sector informatics using AI: a semantic pattern recognition framework. *Appl Sci (Basel)*. 2025 Jun 13;15(12):6673.
12. Twilio Developer Education Team. Programmable Messaging [Online]. Twilio; 2026. Available from: <https://www.twilio.com/docs/messaging>