BMS INSTITUTE OF TECHNOLOGY & MANAGEMENT

BANGALORE-560019

Students Mini Project Assessment and Review Committee

Mini Project: Review 2

Batch No: 16	Guide Name: Dr. MANOJ H M	Submission Date: 10/01/2025
Mini Project Title: IoT and ML-Driven Water Forensics for Illegal Dumping Detection		

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Mini Project Category		Research, Environmental and Societal

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BMS INSTITUTE OF TECHNOLOGY & MANAGEMENT

Yelahanka, Bangalore – 560 019

Department of Artificial Intelligence and Machine Learning

Mini Project work

"IoT and ML-Driven Water Forensics for Illegal Dumping Detection"

Submitted By:

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Under the Guidance of

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2024-2025

Semester: V

BAI506- Mini Project Work Review I & II

Mini Project Work Review I & II Course Outcome

CO1: Design and construct a solution for an identified real-life problem with societal importance using software engineering approach ethically.

CO2: Make use of programming skills to manage as an individual or in a team, in development of technical projects using appropriate tools.

CO3: Develop effective presentation and communication skills in presenting project related activities.

CO4: Build quality document of project work for publications, patenting, and final thesis.

CO-PO-PSO MAPPING

CO No.	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2
CO1	3	3	3	3	-	-	3	-	1	-	-	3	3
CO2	1	2	1	-	3		2	2	3	3	-	3	-
CO3	-	-	-	-	-	1	2	2	3	-	2	3	1
CO4	3	3	3	2	3	1	1	-	3	3	2	3	2
Average	1.75	2	1.75	1.25	1.5	0.5	2	1	2.5	1.5	1	3	1.5

SDG (Sustainable Development Goals) Mapping

The relevant SDG (Sustainable Development Goals) are:

SDG 3: Good Health and Well-Being

- **Justification**: By preventing hazardous chemical dumping and water contamination, the project protects human health. Contaminated water can lead to severe diseases, including those caused by heavy metals, toxic chemicals, and pathogens.
- **Impact**: Ensures access to safer water supplies, reducing the burden of waterborne diseases and improving overall community well-being.

SDG 6: Clean Water and Sanitation

- **Justification**: Focuses on monitoring and maintaining water quality to prevent pollution.
- **Impact**: Promotes access to clean and safe water for sustainable human and ecosystem health.

SDG 9: Industry, Innovation, and Infrastructure

- **Justification**: Utilizes advanced IoT and machine learning technologies for real-time water monitoring and anomaly detection.
- **Impact**: Encourages sustainable industrial practices and innovation in environmental monitoring systems.

SDG 11: Sustainable Cities and Communities

- **Justification**: Contributes to building sustainable and environmentally responsible urban systems by addressing illegal dumping in water sources.
- **Impact**: Improves the livability and resilience of communities.

SDG 13: Climate Action

- **Justification**: Reduces pollution in water bodies, which is crucial for mitigating the effects of climate change on ecosystems and communities.
- **Impact**: Supports proactive climate-related water resource management.

SDG 14: Life Below Water

- **Justification**: Protects aquatic ecosystems by detecting and preventing harmful pollutants in water.
- **Impact**: Enhances marine biodiversity and the health of water bodies.

SDG 15: Life on Land

- **Justification**: Prevents contaminants in water from impacting terrestrial ecosystems and agricultural lands.
- **Impact**: Supports biodiversity conservation and sustainable land management.

ABSTRACT

Illegal dumping is a severe environmental issue with harmful impacts on water, soil, and air quality due to the release of hazardous chemicals. Pollutants from these dumps pose significant risks to human health and ecosystems, contaminating natural resources over time. Traditional monitoring methods, such as manual inspections and lab tests, are reactive, costly, and labor-intensive, making them challenging to scale across vulnerable water bodies. This project addresses this gap with an IoT-based system that monitors water quality in real-time. By deploying sensors in high-risk areas near water bodies, the system continuously tracks water composition, providing data that is wirelessly transmitted to a central platform. Machine learning algorithms analyze this data to detect anomalies, identify contamination signs through deviations from normal water quality parameters, and alert authorities to potential illegal dumping. Additionally, integrating Geographic Information Systems (GIS) allows spatial analysis, accurately mapping pollution sources for quick response. Over time, the collected data and GIS integration support predictive analytics, revealing trends to forecast future dumping patterns. This proactive, scalable, and cost-effective solution enables real-time monitoring and enhances environmental protection efforts by allowing authorities to respond swiftly to illegal dumping in water bodies.

METHODOLOGY

Details the approach for data collection, ML-based anomaly detection, GIS mapping, and alerting to support effective, real-time monitoring:

1. **Data Collection:**

   IoT sensors deployed in vulnerable water bodies gather real-time data on pH, turbidity, dissolved oxygen, and specific chemical concentrations. This data collection forms the basis of the anomaly detection process, providing the system with the necessary input to monitor water quality continuously.

2. **Machine Learning:**

   Train an anomaly detection model, such as Isolation Forest or One-Class SVM, using baseline data from clean water samples. The trained model will detect deviations in sensor data, flagging abnormal readings that may indicate contamination.

3. **Alert Mechanism:**

   Set up a cloud-based alert system using Firebase or Google Cloud. When contamination thresholds are exceeded, the system triggers alerts, notifying authorities via preferred channels (SMS, email, or mobile app), ensuring they are immediately informed.

4. **GIS Integration:**

   Utilize QGIS or ArcGIS to map contamination data, allowing authorities to visualize and analyse contamination trends over time. GIS mapping supports efficient resource allocation, as it highlights high-risk zones in need of immediate intervention.

5. **Testing and Validation:**

   Conduct extensive testing and validation to ensure the model's accuracy and reliability. Use both real and simulated contamination data to assess the system's ability to detect anomalies and send timely alerts, refining the model and alert thresholds as needed.

IMPLEMENTATION

Lists the hardware, software, and network components essential for implementing and deploying the proposed system:

1. HARDWARE REQUIREMENTS:

- **ESP32 Microcontroller:** A versatile, low-power microcontroller unit (MCU) equipped with Wi-Fi and Bluetooth capabilities, used for gathering data from water quality sensors and wirelessly transmitting it to a cloud server. Its low cost and energy efficiency make it suitable for remote monitoring in areas without stable power sources.
- **Water Quality Sensors:**
    - **pH Sensor:** Measures the acidity or alkalinity of water, which can indicate contamination from industrial discharge or chemical dumping.
    - **Dissolved Oxygen (DO) Sensor**: Measures the concentration of oxygen dissolved in water, as reduced DO levels often signify organic waste pollution or chemical contamination.
    - **Turbidity Sensor:** Determines water clarity, where high turbidity can indicate suspended particles from waste or soil runoff.
    - **Chemical Sensors** (e.g., Nitrate, Phosphate, Heavy Metals): Detect specific contaminants such as nitrates from agricultural runoff, phosphates from detergents, and heavy metals from industrial waste, providing detailed data on pollution levels.
- **Computer or Server:** Required for managing and processing the data, running machine learning models, and integrating with the cloud. This setup will handle the training, testing, and deployment of the anomaly detection model, as well as data analysis and storage integration.

2. SOFTWARE REQUIREMENTS:

- **Programming Language (Python):**
    - **Tools and Libraries**:
        - **pandas** and **numpy** for data manipulation.
        - **matplotlib** and **seaborn** for data visualization.
        - **requests** library for API calls, enabling cloud data integration.
- **Machine Learning Libraries (scikit-learn):**
    - **scikit-learn**: Provides algorithms like Isolation Forest or One-Class SVM, essential for anomaly detection in water quality data.

    - **joblib** or **pickle** for model serialization and deployment.
    - **TensorFlow** or **PyTorch** (optional): In case more advanced, deep learning models are considered in future development

- **Cloud Platform:** ThingSpeak for storing sensor data, visualizing trends, and triggering real-time alerts.
- **GIS Software:** QGIS or alternatives like folium/geopandas for basic contamination mapping and data visualization.

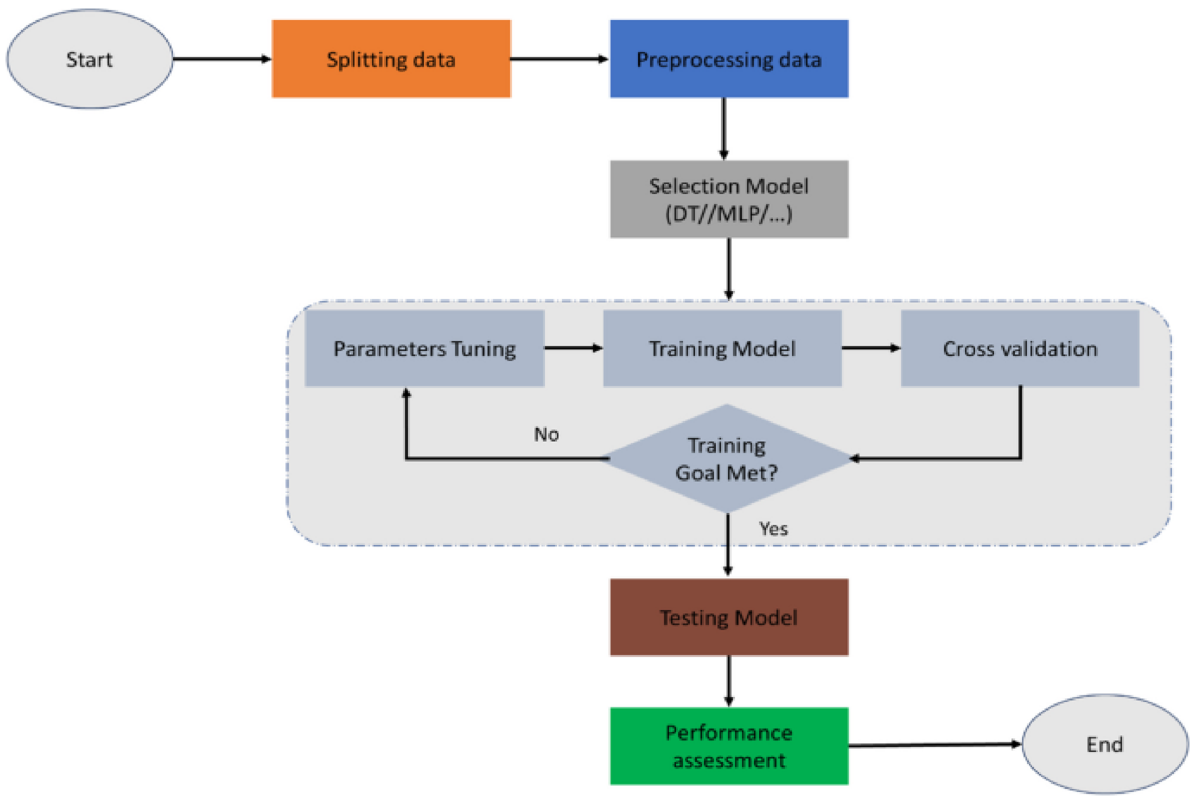


Fig 1: Flowchart of machine learning modeling

Fig 1. outlines a machine learning workflow: data is split, pre-processed, and used to select and train a model through parameter tuning and cross-validation until a goal is achieved, followed by testing and performance assessment.

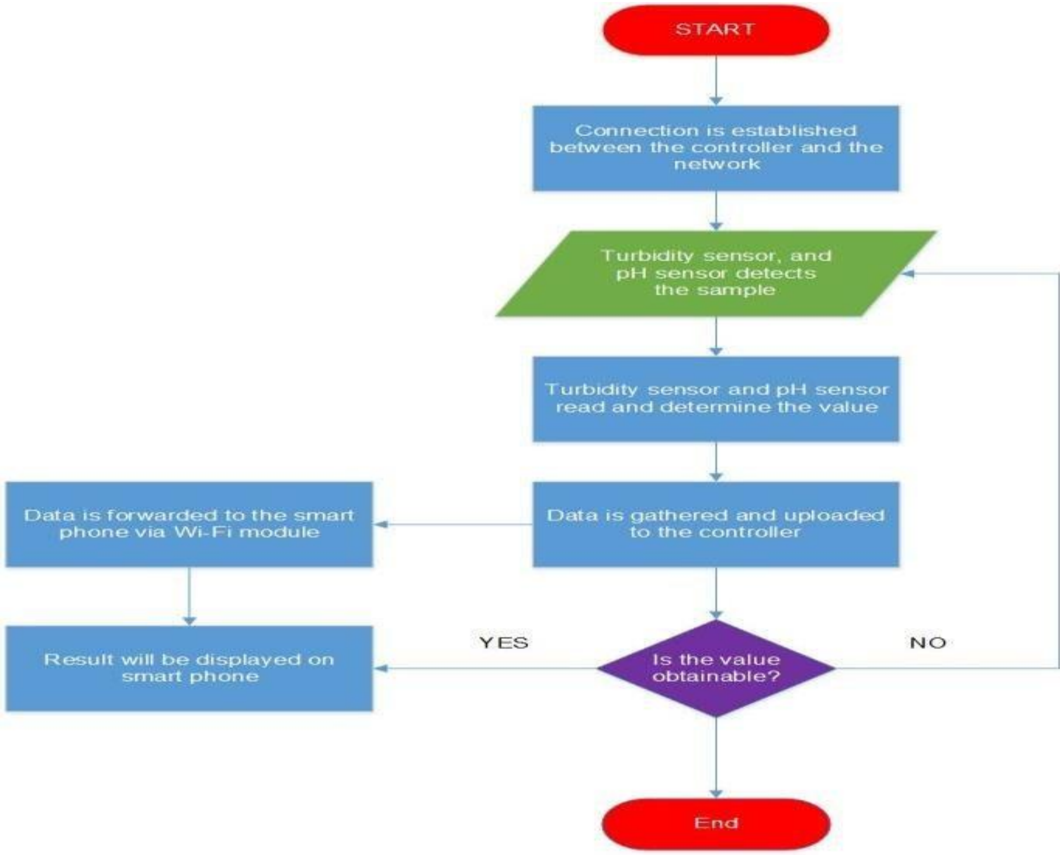


Fig 2: Flowchart of IoT water monitoring system

Fig 2. shows an IoT-based water monitoring system: sensors detect and read water parameters, transmit data to a controller, and, if valid, forward results to a smartphone for real-time monitoring.

SYSTEM TESTING

Test Environment Description:

The implemented system is tested in a simulated environment resembling real-world scenarios to ensure comprehensive validation. The test environment includes:

1. Hardware Setup:
   - ESP32 microcontroller with connected pH, dissolved oxygen (DO), turbidity, and chemical sensors.
   - Cloud server integration for real-time data transfer and storage (e.g., Firebase or Google Cloud).
   - Test water samples with varying contaminant levels (e.g., industrial waste, agricultural runoff, and organic pollutants).
2. Software Setup:
   - Python programming environment with libraries like pandas, numpy, matplotlib, scikit-learn, and QGIS.
   - Machine learning models (e.g., Isolation Forest or One-Class SVM) pre-trained on baseline water quality data.
3. Network Setup:
   - A stable internet connection for IoT sensors and cloud services.
   - Backup local storage in case of network interruptions.
4. GIS Integration:
   - Tools like QGIS or ArcGIS to analyze geographic data and validate spatial mapping of pollution sources.
5. Assumptions:
   - Water samples are representative of real-world contamination.
   - The deployed IoT sensors are calibrated and functioning within specified tolerances.

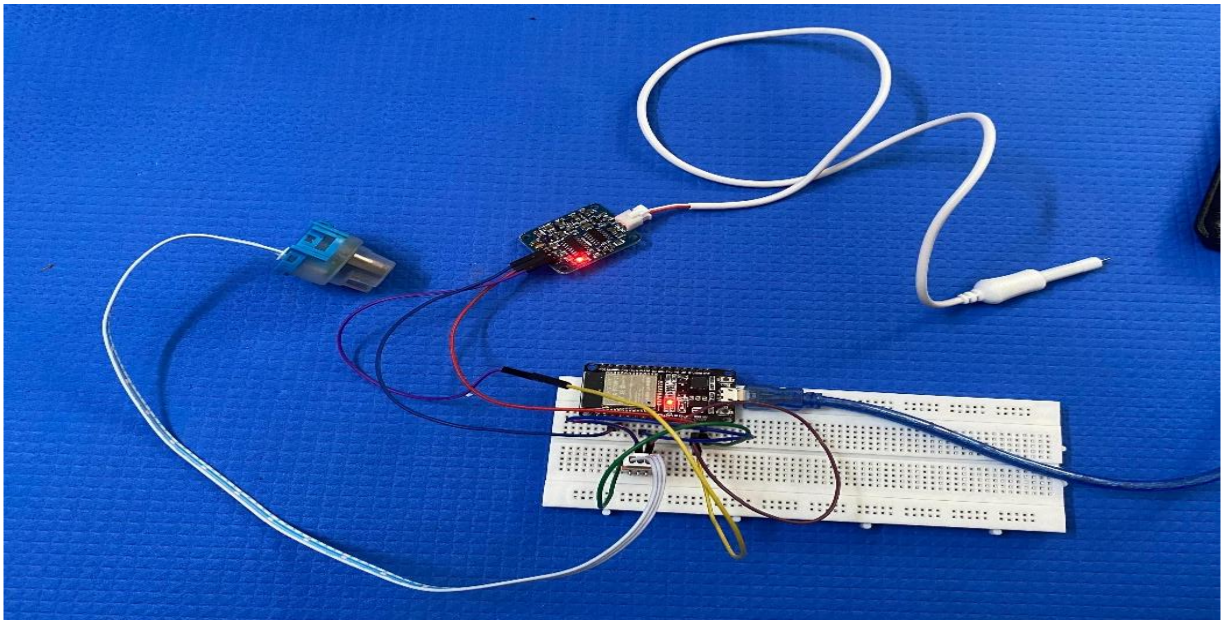
Possible Test Cases:

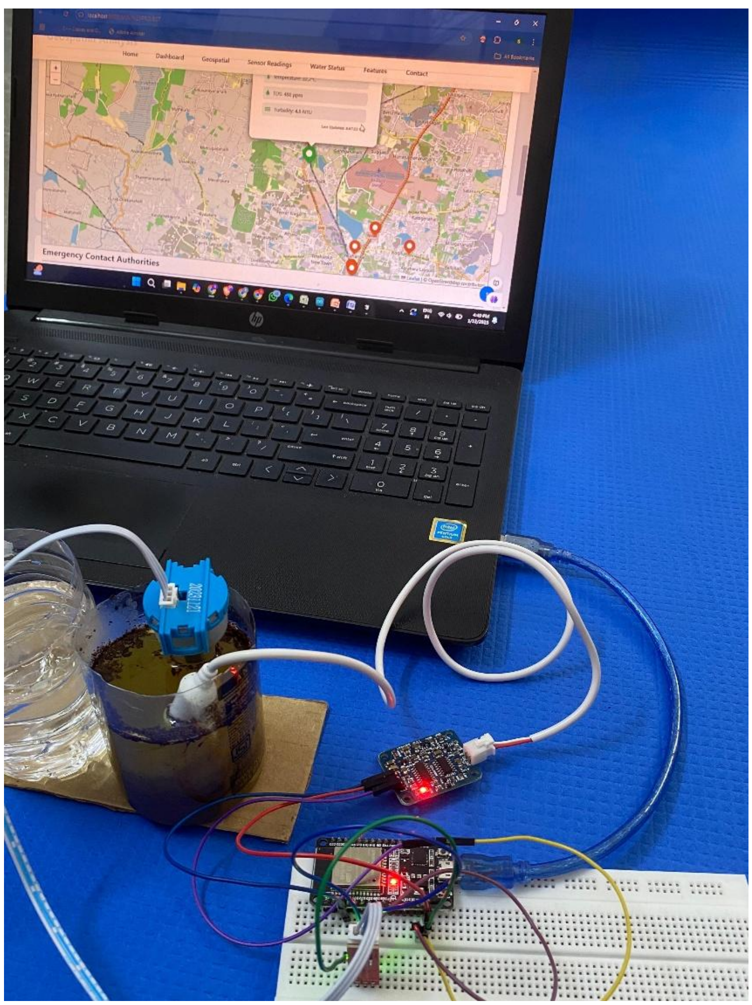
The project will be tested against various scenarios and inputs, ensuring robustness and accuracy. Test cases include:

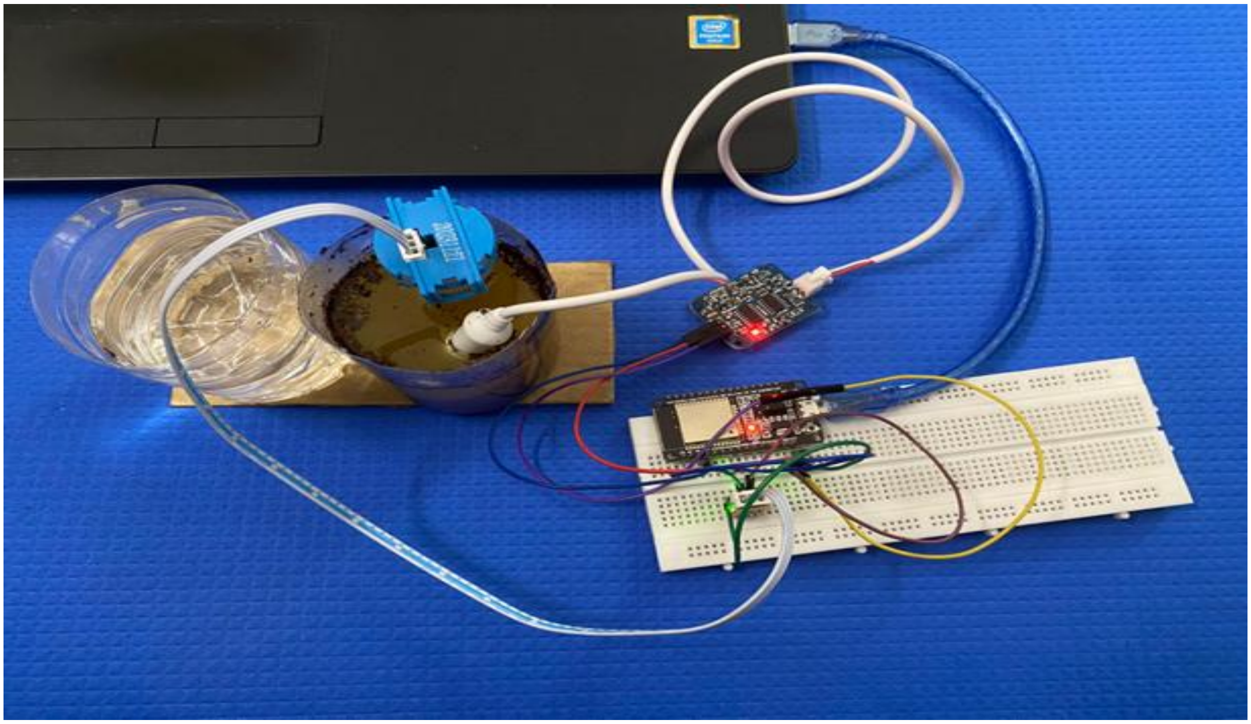
1. Functional Testing:
   - Sensor Data Accuracy: Validate that sensors correctly measure pH, DO, turbidity, and specific chemicals within acceptable ranges.
   - Data Transmission: Ensure seamless data transfer from sensors to the cloud.
   - Anomaly Detection: Test machine learning models with both normal and contaminated water data to confirm correct anomaly identification.

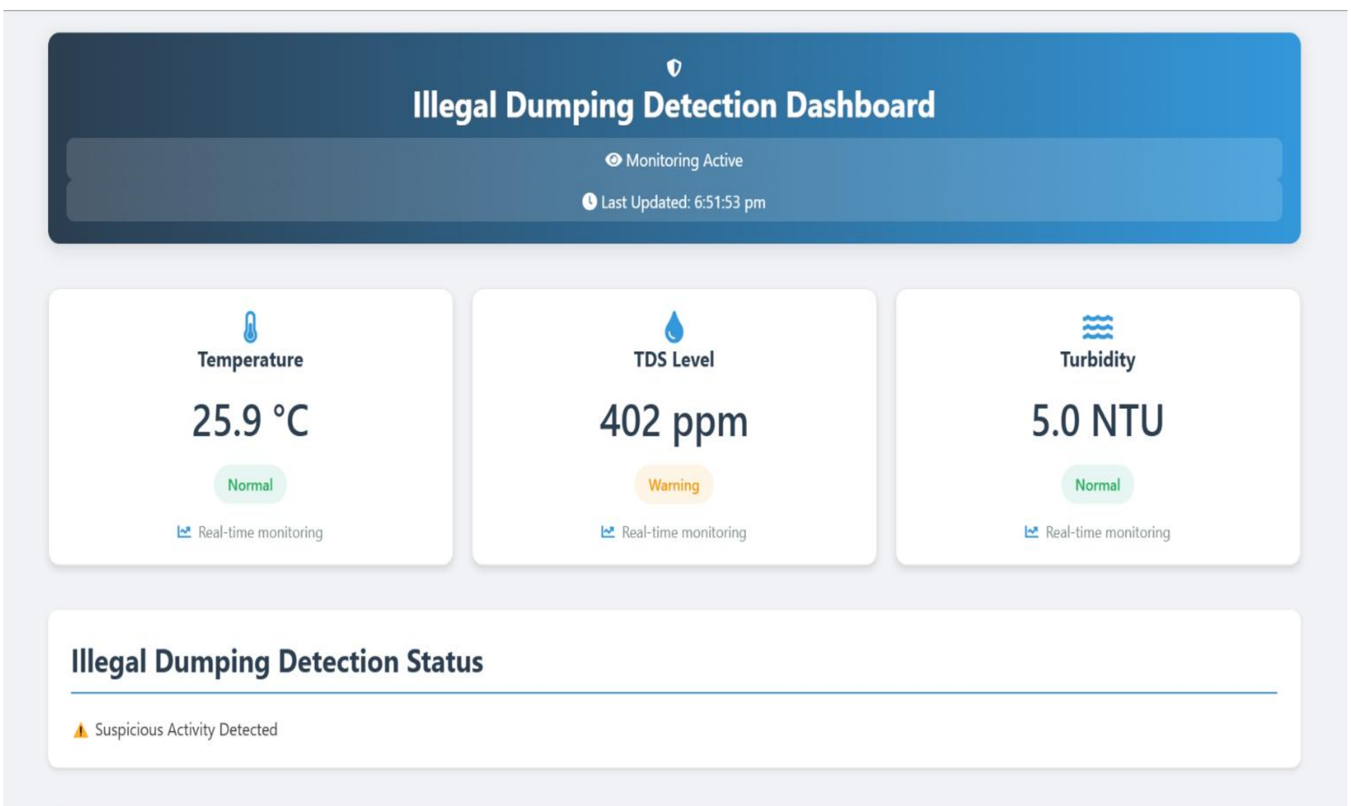
2. Performance Testing:
   - Real-Time Processing: Measure the system's ability to process and analyze data within a defined time limit.
   - Alert Responsiveness: Test the delay between anomaly detection and notification delivery to authorities.
3. Integration Testing:
   - Verify seamless integration between IoT sensors, cloud servers, and machine learning models.
   - Validate GIS mapping accuracy for real-time contamination visualization.
4. Boundary Testing:
   - Evaluate system performance with extreme values, such as highly acidic or alkaline water samples.
   - Test sensor functionality in varied environmental conditions, including high turbidity or high pollutant concentrations.
5. Security Testing:
   - Assess the system's resistance to data breaches during transmission and storage.
   - Validate user authentication and data access control mechanisms.
6. Scalability Testing:
   - Simulate the addition of multiple sensors to evaluate system performance under increased data loads.
7. Usability Testing:
   - Ensure the user interface is intuitive, providing easy access to real-time data, alerts, and GIS visualizations.
8. Predictive Analytics Testing:
   - Validate the predictive model's accuracy in forecasting future contamination trends using historical data.

RESULTS AND DISCUSSION





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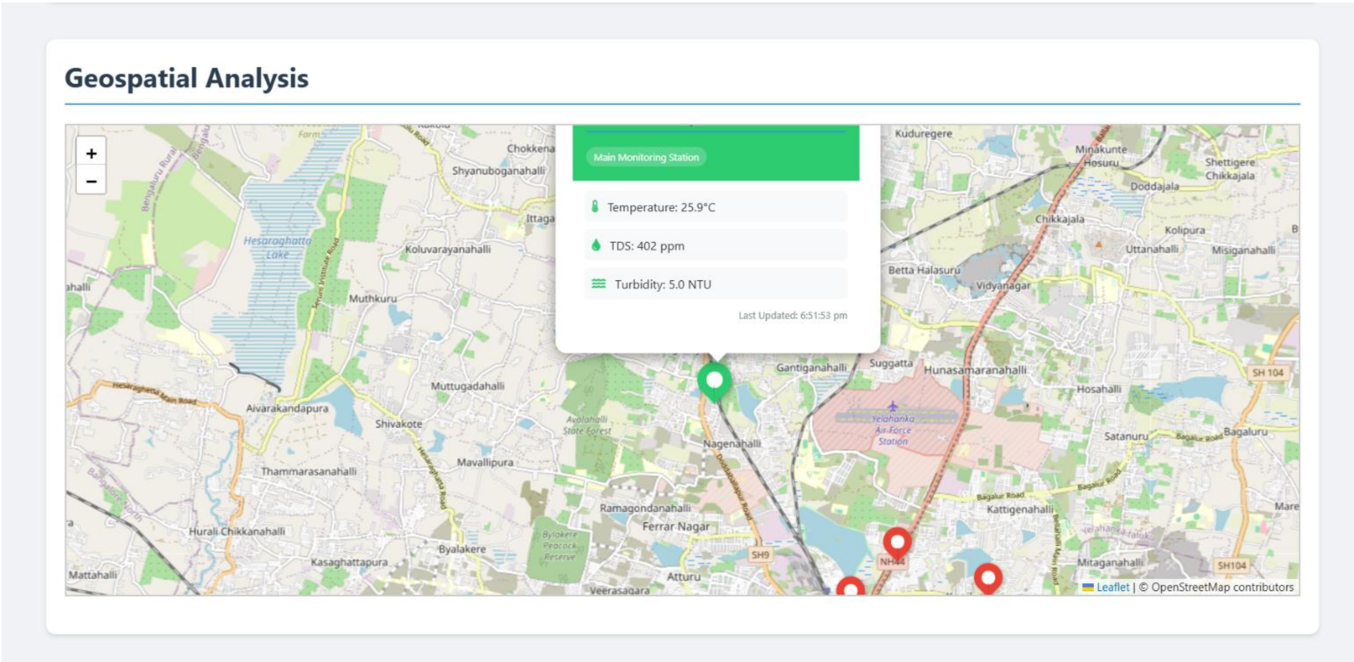
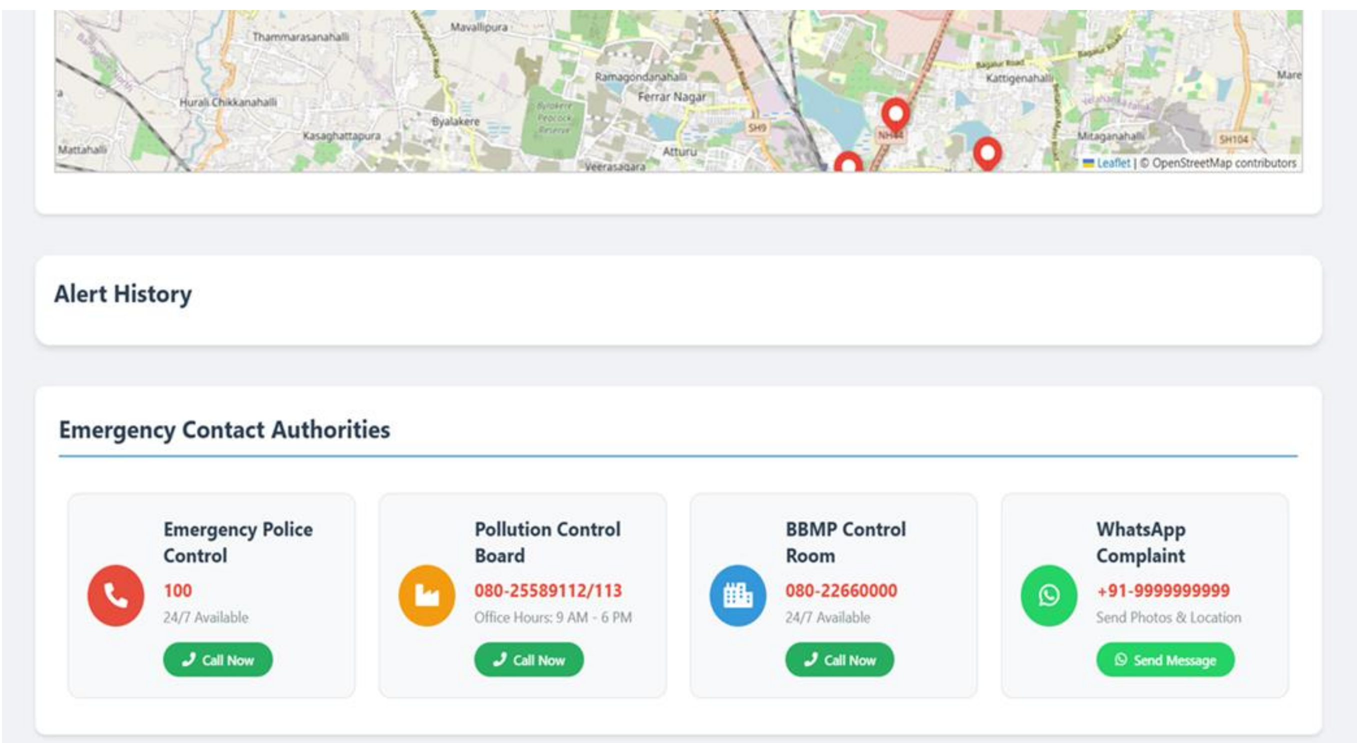
25.9 °C
Normal
Real-time monitoring
TDS Level
402 ppm
Warning
Real-time monitoring
Turbidity
5.0 NTU
Normal
Real-time monitoring
Illegal Dumping Detection Status
Suspicious Activity Detected


Geospatial Analysis
Main Monitoring Station
Temperature: 25.9°C
TDS: 402 ppm
Turbidity: 5.0 NTU
Last Updated: 6:51:53 pm
Leaflet | © OpenStreetMap contributors


Leaflet | © OpenStreetMap contributors
Alert History
Emergency Contact Authorities
Emergency Police Control
100
24/7 Available
Call Now
Pollution Control Board
080-25589112/113
Office Hours: 9 AM - 6 PM
Call Now
BBMP Control Room
080-22660000
24/7 Available
Call Now
WhatsApp Complaint
+91-9999999999
Send Photos & Location
Send Message

CONCLUSION

The mini-project titled "IoT and ML-Driven Water Forensics for Illegal Dumping Detection" demonstrates the innovative use of cutting-edge technologies like Internet of Things (IoT) and machine learning (ML) to address the pressing environmental issue of illegal waste dumping in water bodies. This project not only highlights the technical prowess of the team but also showcases its dedication to societal and environmental well-being.

The system developed provides real-time monitoring, leveraging IoT devices for data collection and ML algorithms for anomaly detection. This enables swift identification of potential pollution sources, ensuring timely intervention to prevent water contamination. The solution is scalable, allowing its adoption across varied geographies, from urban centers to remote areas.

By focusing on water quality monitoring, the project directly supports multiple Sustainable Development Goals (SDGs):

- SDG 3 (Good Health and Well-Being): Mitigates health risks associated with waterborne diseases.
- SDG 6 (Clean Water and Sanitation): Enhances access to safe and clean water by preventing pollution.
- SDG 13 (Climate Action): Reduces the impact of water pollution on ecosystems, contributing to proactive climate mitigation.
- SDG 14 and 15 (Life Below Water and Life on Land): Protects aquatic and terrestrial ecosystems, promoting biodiversity and sustainable resource management.

The project also emphasizes sustainable urban development by ensuring clean water sources for growing communities. Furthermore, the use of advanced technologies promotes innovation and paves the way for more efficient and automated environmental forensics systems.

In addition to its technical achievements, the project aligns with ethical and societal responsibilities, demonstrating the importance of collaboration between technology and environmental stewardship. It sets a foundation for future research and practical applications in the fields of smart environmental monitoring, resource conservation, and sustainable development.

Overall, the project is a testament to the transformative potential of technology in addressing real-world challenges, showcasing a comprehensive approach to environmental protection and public health improvement.

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