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PREDICTION OF BIOGAS PRODUCTION AND MONITORING USING ML

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A B S T R A C T :

This paper introduces a cloud-based web and mobile application designed to monitor and predict methane gas levels in biodigesters using a pre-trained machine learning model. The system retrieves real-time parameters such as temperature and pH from cloud storage and uses them to generate methane level predictions based on historical data patterns. It features a dynamic dashboard that presents live values, predicted results, and graphical visualizations for better interpretation and trend analysis. A built-in alert mechanism is also integrated to immediately notify users when temperature levels exceed predefined safety thresholds, enabling timely action. The interface is responsive across devices, ensuring easy access and usability. By combining prediction, visualization, and alerts, the application contributes to more effective biogas monitoring and supports safer and more informed waste management practices.

Keywords: Methane Gas Estimation, Biogas Monitoring, Cloud data access, Environmental Parameter Display, Machine Learning-Based Prediction, Alert Notification, Web and Mobile Interface

1. INTRODUCTION:

Methane is a potent greenhouse gas and a key component of biogas produced through the anaerobic digestion of organic waste in biodigesters. Accurate monitoring and management of methane levels is essential for ensuring operational efficiency, safety, and environmental sustainability in biogas systems. As the demand for renewable energy sources grows and decentralized waste-to-energy solutions become more widespread, the need for smart tools that enable real-time gas tracking and prediction has increased.

Traditional monitoring methods often involve manual sampling or expensive hardware systems, which are not feasible for small-scale or community-level biodigester setups. In many cases, stakeholders lack the means to access or interpret gas level data, leading to inefficient energy harvesting and undetected safety hazards such as gas leaks or excessive buildup. Moreover, the unpredictable nature of methane generation, influenced by temperature, pH, and substrate composition, adds another layer of complexity to system management.

Furthermore, interpreting methane generation patterns is a challenge due to its dependency on dynamic parameters such as temperature and pH levels within the digester. In response to these issues, this research introduces a web and mobile-based application that leverages a pre-trained machine learning (ML) model to predict methane levels. Users can input real-time environmental parameters (temperature and pH), which are fetched from cloud storage, and the ML model processes this data to deliver predicted methane output. This system eliminates the need for direct IoT integration while still providing accurate and timely insights.

The system is structured to support:

- Methane Prediction Module: Provides real-time suggestions based on ML analysis of temperature and pH input.
- Cloud Integration: Supports seamless data retrieval from Firebase for accurate predictions.
- Alert Mechanism: Notifies users when predicted temperature levels exceed safe or optimal limits.
- Data Visualization: Interactive dashboards and charts help users monitor trends and interpret outputs easily Real-time caregiver connectivity

Built using standard web technologies (HTML, CSS, JavaScript) and Firebase as the backend, the system is modular, scalable, and user-friendly. Its primary goal is to provide an intelligent, low-cost, and efficient monitoring solution for biodigester stakeholders—helping improve safety, optimize methane production, and raise awareness about clean energy generation.

Section 2 outlines the objectives of the system like prediction, alerts, and visualization. Section 3 explains the system overview and how the modules work together. Section 4 presents the block diagram, offering a structural representation of the prediction and monitoring process. Section 5 reviews relevant literature, highlighting existing works that leverage machine learning for biogas prediction and monitoring. Section 6 explains the methodology, detailing the system's design, module implementation, integration, and evaluation process. Section7 includes screenshots showcasing the application interface and its various functionalities. Section 8 delivers the conclusion, emphasizing the effectiveness of ML and AI in optimizing biodigester operations. Section9 lists the references used to support the research and system development.

2. OBJECTIVES:

- To design a user-friendly web and mobile application for methane level monitoring
- To retrieve real-time temperature and pH values from cloud storage.
- To alert users when temperature predictions exceed safe thresholds..
- To predict methane gas levels using a pre-trained machine learning model.
- To provide graphical visualization of methane levels for better insight and tracking.
- To display historical data for last seven days.

3. SYSTEM OVERVIEW

The Methane Monitoring System is a cloud-integrated, data-driven application designed to assist in biogas management by predicting methane levels in biodigesters using machine learning. The system operates through a modular architecture built for both web and mobile platforms. It retrieves real-time sensor parameters like temperature and pH from cloud storage, runs them through a pre-trained ML model, and presents predictions along with visual analytics for all parameters and alert mechanisms. The goal is to empower users with better control and awareness over gas emissions, particularly in agriculture and waste management environments, without relying on physical IoT setups.

1. Methane prediction Module

This core module utilizes a machine learning model to estimate methane gas levels based on current and historical input values.
ML Model Integration: A pre-trained model predicts methane levels using provided temperature and pH data.
Real-Time Execution: As soon as input parameters are retrieved or entered, you can manually put the parameters values and get predictions instantly.
Accuracy-Oriented Output: Predictions are refined using historical trends, reducing anomalies and enabling better decision-making.
This module allows stakeholders to monitor potential gas build-ups and take preventive action early.

2. Parameter Viewer Module

This module handles the display of input values needed for predictions and overall transparency and also offers historical insights.
Live Data Access: Temperature and pH values are fetched directly from a connected cloud storage system.
Value History Logs: Recent values are listed in a timeline for comparison and review.
Manual Input Option: Users may manually input values when live data is unavailable, ensuring uninterrupted prediction access.

This component helps users validate predictions against actual environmental conditions.

3. Alert Notification Module

One of the most vital components, this module focused on safety, this module informs users when predicted temperature levels cross a set threshold.

Threshold Trigger: If the temperature prediction exceeds a pre-defined safety limit, the system activates warnings.
In-App Notifications Only: Users can receive instant alert messages directly through the application
Itself.
Simple Alert Status: No timestamps or alert logs—just straightforward warning messages indicating methane level exceeds.

This ensures timely intervention and reduces environmental and health risks.

4. Dashboard Interface Module

This module acts as the central hub for monitoring and interacting with the system:

Unified Access View: Presents real-time methane predictions, parameter values, and alert summaries in one place.
Recent Activity Tracker: Shows the last 7 days of prediction outcomes and alert events for trend awareness.
Multi-User Support: Allows multiple users to log in with unique credentials to view data and access system features securely.
Alert Summary Section: Highlights only triggered alerts without timestamps to reduce clutter and prioritize quick action.

This module ensures an organized and responsive experience for users managing parameters and methane levels across multiple sessions.

4. BLOCK DIAGRAM OF PROCESS:

The block diagram of the process is shown in **Figure 1**,

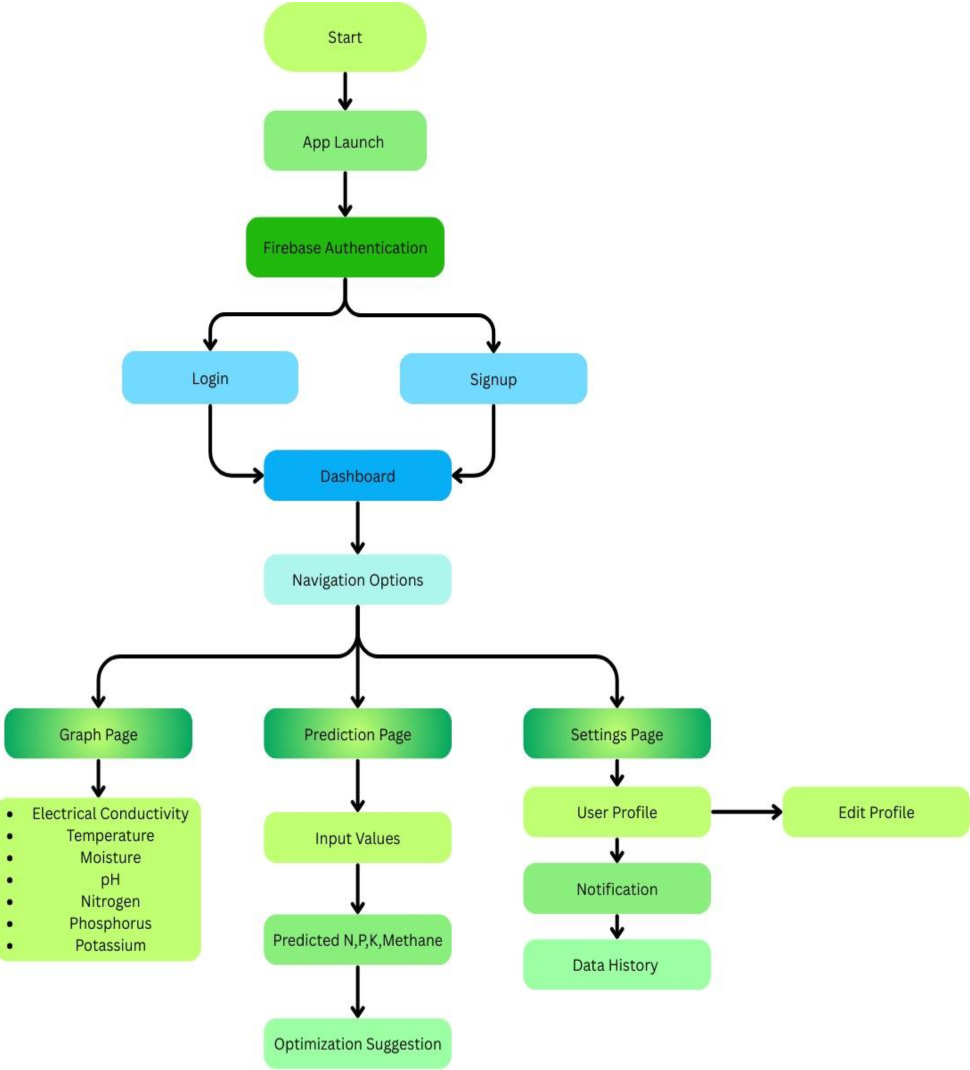


Figure 1: Process diagram

5. LITERATURE SURVEY:

The ten existing approaches for biogas prediction and monitoring are summarized with their benefits and drawbacks, tailored to suit the features of the biogas prediction and monitoring app. Singh, K. et al. [1] developed a random forest and decision tree-based machine learning model for biogas production prediction. This method showed high accuracy with various environmental factors, making it suitable for the app's prediction feature, but struggles with noisy data, which would require robust data preprocessing in the app. Kumar, S. et al. [2] introduced an AI-based optimization system for biogas plants, which monitors parameters such as pH and temperature. This feature aligns well with the app's real-time monitoring capability but is limited by its reliance on constant data input, which could pose challenges for app users in rural or remote areas. Patel, M. et al. [3] proposed an IoT-based real-time biogas monitoring system. The app could integrate this model to provide continuous feedback, but the high implementation cost of IoT devices may make it difficult for small-scale biogas users to implement without additional infrastructure. Gupta, A. et al. [4] applied a data-driven machine learning model for biogas yield prediction, demonstrating good accuracy. This is ideal for the app's prediction feature; however, it may not be generalizable to all types of organic waste, which would need customization in the app based on user data. Sharma, R. et al. [5] utilized support vector machines (SVM) for optimizing biogas production. While this method would be effective in providing precise predictions, its computational intensity might be a challenge for the app to handle on lower-end devices or during real-time processing. Mehta, R. et al. [6] employed deep learning techniques like neural networks for predicting biogas production. These models perform well with large datasets, which suits the app's need for predictive analytics but would require considerable computational power and training data, potentially affecting app performance in low-resource settings. Reddy, K. et al. [7] developed a hybrid machine learning approach combining genetic algorithms and neural networks for enhanced biogas plant efficiency. This technique aligns with the app's goal of optimizing biogas production but could be difficult to implement on a large scale, as it may require a more advanced user interface for efficient execution. Zhang, L. et al. [8] designed a real-time monitoring system using machine learning for predicting and optimizing biogas production, which fits the app's monitoring capabilities. However, this model's reliance on continuous data input could be challenging in environments where data collection is sparse or inconsistent. Sharma, K. et al. [9] used regression analysis models to predict biogas production, offering a simpler approach that could be incorporated into the app for quick predictions. However, the lack of ability to handle non-linear relationships could limit its predictive capabilities in more complex biogas production systems. Joshi, A. et al. [10] applied reinforcement learning optimization techniques, which would be valuable for the app's long-term efficiency improvements. However, the need for complex tuning would make this approach more suitable for advanced users rather than general biogas plant operators. Demonstrates how AI can enable remote tracking and performance management. Its unique aspect is the seamless integration of real-time data access, allowing users to monitor biodigester performance from any location.

6. METHODOLOGY

The development of the Methane Monitoring and Prediction System followed a modular and user-oriented design strategy. The project prioritized simplicity, accessibility, and cloud-based data responsiveness to suit both rural and research applications. The frontend was built using HTML, CSS, and JavaScript, while Firebase served as the backend to manage sensor data and ML predictions. A pre-trained machine learning model was integrated to generate methane level predictions using temperature and pH inputs. Each module—cloud data access, prediction logic and alerts—was independently tested and then integrated to ensure smooth performance. The methodology comprised the following stages:

1) Requirement Analysis

- Studied challenges in biogas systems and the importance of methane level monitoring.
- Identified core features: cloud-based sensor data access, methane prediction using ML, alert notifications, and a live dashboard.
- Defined non-functional requirements: low latency, high responsiveness and real-time data sync.

2) Design and Prototyping

- Wireframes were created for the web and mobile interfaces using HTML and CSS..
- UI was designed to display predicted methane levels, real-time parameters, and graphical alerts.
- Firebase database and ML model flow were structured in parallel for smooth integration and live updates.

3) Module Implementation

Each feature was developed as an independent module:

- **Cloud data module**: Retrieved temperature and pH data from a Firebase-based cloud source.
- **Prediction module**: Used a trained ML model to estimate methane levels from sensor inputs.
- **Alert module**: Triggered notifications when temperature crossed the defined threshold levels.
- **Dashboard Module:** Displayed real-time parameters values, methane predictions, and dynamic visual graphs**.**

4) Integration and Backend Connectivity

- Firebase Realtime Database enabled seamless sync between data, prediction results, and frontend display..
- Frontend components were linked with Firebase to ensure live updates and consistent data flow.
- Modules were structured for scalability and ease of future upgrades without code conflicts.

5) Testing and Evaluation

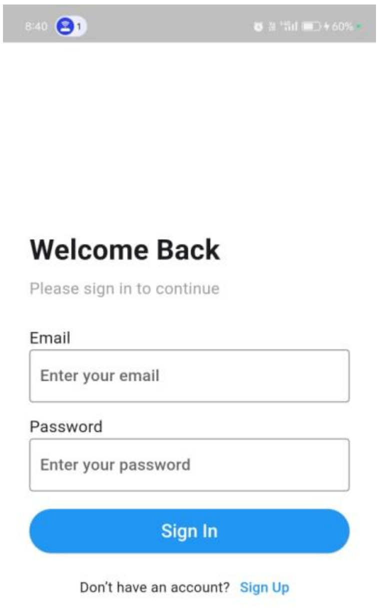
- System accuracy was tested by retrieving cloud-based sensor data and validating methane predictions.
- UI performance, including dashboard load time, graph rendering, and alert notifications, was thoroughly evaluated.
- Tester feedback led to visual refinements and improved interaction flow across devices.

7. SCREENSHOTS:

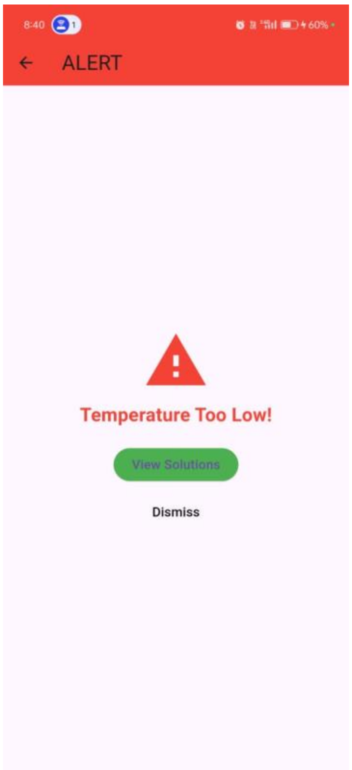
The various screenshots of the working model is shown in **Figure 2**,


BCM
Bio-Composter Monitor
Monitor and optimize your biogas process easily.
Get Started

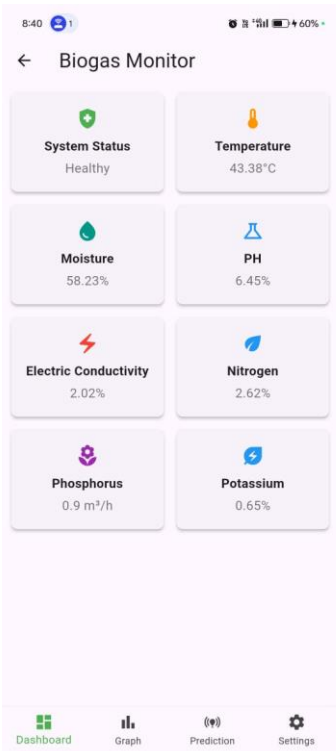
(a)


Welcome Back
Please sign in to continue
Email
Enter your email
Password
Enter your password
Sign In
Don't have an account? Sign Up

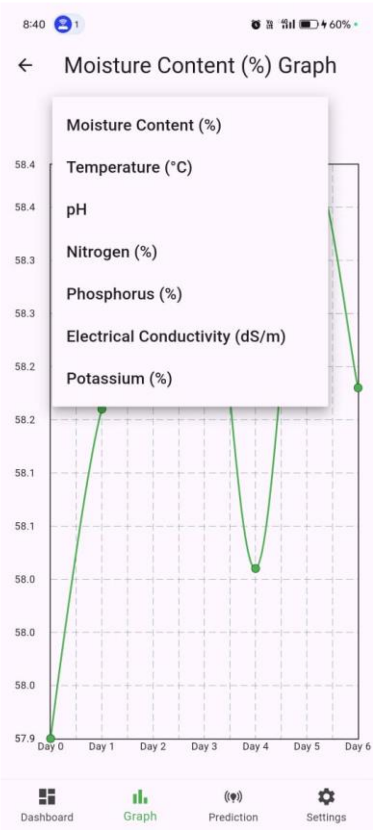
(b)


ALERT
Temperature Too Low!
View Solutions
Dismiss

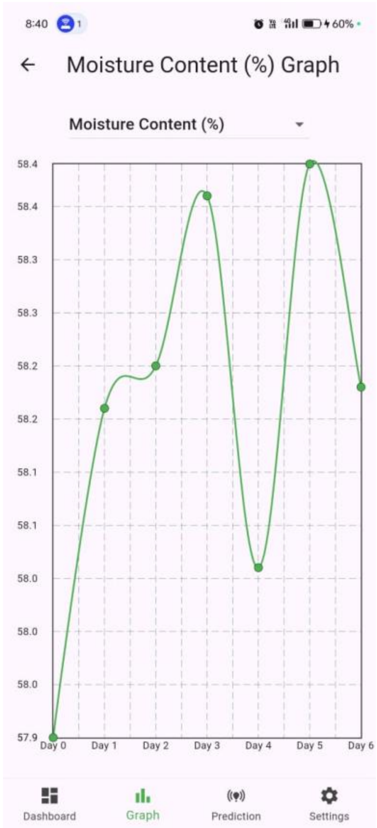
(c)


Biogas Monitor
System Status
Healthy
Temperature
43.38°C
Moisture
58.23%
PH
6.45%
Electric Conductivity
2.02%
Nitrogen
2.62%
Phosphorus
0.9 m³/h
Potassium
0.65%
Dashboard
Graph
Prediction
Settings

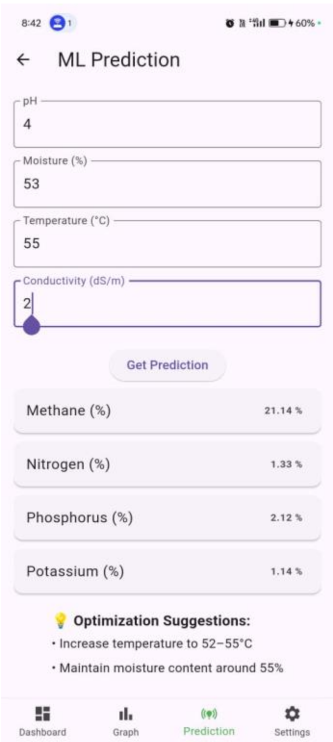
(d)


8:40
Moisture Content (%) Graph
Moisture Content (%)
Temperature (°C)
pH
Nitrogen (%)
Phosphorus (%)
Electrical Conductivity (dS/m)
Potassium (%)
58.4
58.4
58.3
58.3
58.2
58.2
58.1
58.1
58.0
58.0
58.0
57.9
Day 0
Day 1
Day 2
Day 3
Day 4
Day 5
Day 6
Dashboard
Graph
Prediction
Settings

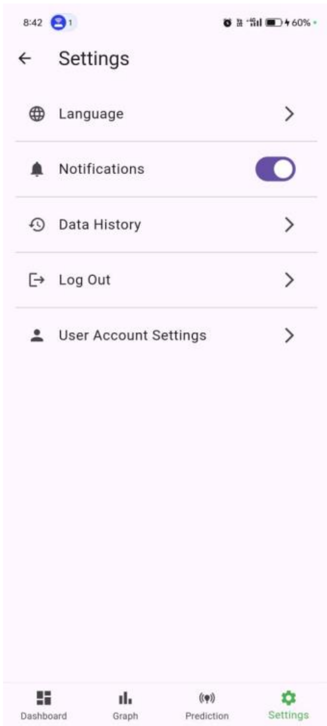
(e)


8:40
Moisture Content (%) Graph
Moisture Content (%)
58.4
58.4
58.3
58.3
58.2
58.2
58.1
58.1
58.0
58.0
58.0
57.9
Day 0
Day 1
Day 2
Day 3
Day 4
Day 5
Day 6
Dashboard
Graph
Prediction
Settings

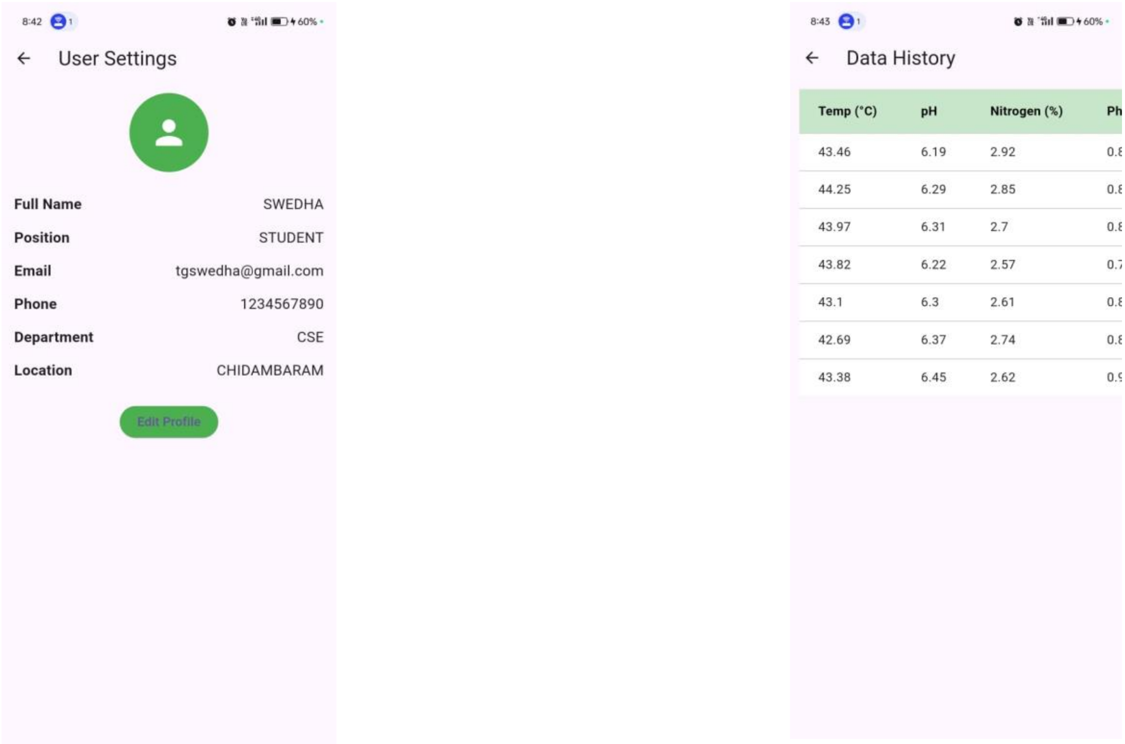
(f)


8:42
ML Prediction
pH
4
Moisture (%)
53
Temperature (°C)
55
Conductivity (dS/m)
2
Get Prediction
Methane (%) 21.14 %
Nitrogen (%) 1.33 %
Phosphorus (%) 2.12 %
Potassium (%) 1.14 %
Optimization Suggestions:
• Increase temperature to 52–55°C
• Maintain moisture content around 55%
Dashboard
Graph
Prediction
Settings

(g)


8:42
Settings
Language
Notifications
Data History
Log Out
User Account Settings
Dashboard
Graph
Prediction
Settings

(h)



(i) (j)

Figure 2: Screenshots of (a) Welcome screen (b) Login screen (c) Alert screen (d) Dashboard screen (e) and (f) Graphical visualization of all parameters (g) Prediction screen (h) Settings (i) User settings (j) data history

8. CONCLUSION

The integration of machine learning (ML) and artificial intelligence (AI) in biodigester systems has significantly improved the efficiency and safety of biogas production. The reviewed studies show that ML models, particularly hybrid and deep learning approaches, provide accurate methane predictions and enhance biogas upgrading. These technologies enable real-time monitoring, offering users remote access to system performance, and ensuring early detection of faults, which minimizes operational risks. AI-driven solutions have also helped optimize energy production by improving methane concentration andupgrading biogas quality, contributing to more sustainable energy systems. The scalability of these models allows them to be applied to both small and large biodigester systems, making them versatile for diverse operational needs. Overall, the application of ML and AI in biodigesters represents a major advancement in optimizing renewable energy production, ensuring efficiency, and promoting a greener, more sustainable future..

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