Journal of
Industrial Safety Engineering
ISSN: 2395-6674
Volume 13, Issue 2, 2026
May–August
DOI (Journal): 10.37591/JoISE
https://journals.stmjournals.com/joise
Research JoISE

Smart Drainage Cleaning System: A Technological Intervention for Occupational Health and Urban Sanitation

Sreeraj R.[1,*], Jasna Basheer[1], G. Harinarayanan[2], Megha C.[2], Amal Siva[2], Sibi S.[2], Varsha R.[2,1]

Abstract

Manual drainage maintenance in urban environments remains a hazardous task, exposing sanitation workers to toxic gases, infections, and life-threatening accidents. This paper presents the development of an automated 12V Smart Drainage Cleaning System designed to eliminate manual scavenging and enhance cleaning efficiency. The robotic model operates on a 12V DC power supply, integrating an ultrasonic sensor for real time obstacle detection and automated navigation within narrow drainage pathways. The core cleaning mechanism consists of a high torque motor-driven chain and sprocket system. This mechanism rotates a series of lifter plates that effectively filter solid debris such as plastic bottles and polythene while allowing liquid waste to flow through. The collected waste is elevated and deposited into an onboard storage tank. To prevent mechanical overload and ensure timely disposal, a load cell is incorporated to continuously monitor the weight of the accumulated waste, signaling the operator or halting the system when maximum capacity is reached. Controlled by a dedicated motor driver, the robot offers a portable and cost effective solution for proactive sewage management. Experimental results indicate that the system significantly reduces human contact with hazardous materials and provides a more consistent cleaning frequency compared to traditional manual methods. This research demonstrates a sustainable, sensor driven approach to urban sanitation that prioritizes worker safety and environmental hygiene.

Keywords: Drainage cleaning robot, ultrasonic sensor, load cell, ESP32 microcontroller, automated drainage system

INTRODUCTION

Urban drainage systems constitute a critical component of modern urban infrastructure, facilitating the efficient removal of wastewater, stormwater, and surface runoff from residential, industrial, and commercial areas. Proper drainage management is essential for maintaining environmental hygiene, preventing waterlogging, protecting public infrastructure, and minimizing the spread of waterborne diseases. In rapidly urbanizing regions, however, the efficiency of drainage networks is increasingly challenged by improper waste disposal practices and the accumulation of solid waste materials [1].

Drainage channels frequently become obstructed due to the accumulation of debris such as plastic waste, leaves, food residues, sludge, and other non-biodegradable materials. These obstructions restrict the natural flow of wastewater, leading to stagnant water, foul odors, mosquito breeding, and increased risk of urban flooding during heavy rainfall. Such conditions not only degrade environmental quality but also pose serious threats to public health and safety. Effective and regular maintenance of drainage systems is therefore essential to ensure uninterrupted flow and to maintain urban sanitation standards [2].

***Author for Correspondence**
Sreeraj R.
E-mail: sreeraj.rdev@gmail.com

[1]Assistant Professor, Electrical and Electronics Engineering, College of Engineering Perumon, Kerala, India
[2]StudentElectrical and Electronics Engineering, College of Engineering Perumon, Kerala, India

Received Date: June 13, 2026
Accepted Date: July 03, 2026
Published Date: July 06, 2026

Citation: Sreeraj R., Jasna Basheer, G. Harinarayanan, Megha C., Amal Siva, Sibi S., Varsha R. Smart Drainage Cleaning System: A Technological Intervention for Occupational Health and Urban Sanitation. Journal of Industrial Safety Engineering. 2026; 13(2): 16–27p.

Despite the availability of modern technologies, drainage cleaning operations in many developing regions continue to rely heavily on manual labor. Sanitation workers are often required to physically enter drainage systems to remove accumulated waste and blockages. This practice exposes them to hazardous working conditions including toxic gases, harmful pathogens, contaminated water, and unstable environments. Prolonged exposure to such conditions can lead to serious health complications, including respiratory illnesses, skin infections, and in extreme cases, fatal accidents. These occupational hazards highlight the urgent need for safer and more technologically advanced solutions for drainage maintenance [3].

Recent advancements in automation, embedded systems, and sensor technologies provide promising opportunities to address these challenges. Automated drainage cleaning systems can significantly reduce human involvement by utilizing intelligent control mechanisms, sensors, and mechanical cleaning units to detect and remove waste materials from drainage channels. Such systems not only improve operational efficiency but also enhance worker safety by minimizing direct human contact with hazardous environments [4].

In this context, the Smart Drainage Cleaning System is proposed as an automated solution aimed at improving the efficiency and safety of drainage maintenance operations. The system integrates sensing mechanisms, microcontroller-based control units, and a mechanical plate rotation mechanism designed to collect and remove solid waste from drainage channels. The collected waste is transferred into a storage container, ensuring continuous water flow and preventing blockage formation within the drainage network [5].

Furthermore, the implementation of automated sanitation systems aligns with the broader vision of smart cities, where intelligent technologies are utilized to optimize urban infrastructure management and promote sustainable development. By reducing manual intervention, improving reliability, and providing a cost-effective cleaning mechanism, the proposed Smart Drainage Cleaning System offers a practical technological solution to one of the most persistent challenges in urban sanitation [6].

The development of such systems represents an important step toward modernizing drainage maintenance practices while simultaneously addressing occupational safety concerns and improving overall urban environmental conditions.

SYSTEM OVERVIEW

The proposed Smart Drainage Cleaning System is designed to automate the removal of solid waste materials from drainage channels in order to prevent blockages and ensure uninterrupted wastewater flow. The system integrates sensing elements, a control unit, and a mechanical waste-removal mechanism to perform drainage cleaning with minimal human intervention. The overall architecture is designed to improve sanitation efficiency while enhancing the safety of maintenance workers [7].

The system consists of several major subsystems including a waste detection unit, control and processing unit, mechanical cleaning mechanism, and waste collection unit. These components operate in coordination to detect the presence of accumulated waste in the drainage channel, activate the cleaning mechanism, and transfer the removed waste into a storage container [8].

The waste detection unit employs sensors placed along the drainage path to monitor the accumulation of floating or obstructing waste materials. When the waste level exceeds a predefined threshold, the sensors transmit signals to the control unit indicating the presence of a blockage or excessive debris within the drainage channel. This sensing mechanism ensures that the cleaning process is activated only when necessary, thereby improving system efficiency and reducing unnecessary power consumption [9].

The control unit, typically implemented using a microcontroller-based embedded system, acts as the central processing element of the system. It receives input signals from the sensors and processes the data to determine the appropriate response. Upon detecting waste accumulation, the controller activates the motor driver circuit that powers the mechanical cleaning mechanism. The control unit also ensures proper timing and coordination of system components, enabling reliable and automated operation [10].

The mechanical cleaning mechanism forms the core functional element of the system. It generally consists of a rotating plate or conveyor-type structure driven by an electric motor. When activated, the rotating mechanism collects solid waste materials from the drainage water and lifts them upward. The design of the mechanism ensures that water continues to flow through the drainage channel while the solid waste is separated and transported away from the flow path.

The collected debris is then transferred to a waste collection unit, typically a container positioned at the outlet of the mechanical system. This container temporarily stores the removed waste until it can be disposed of properly. By continuously removing accumulated waste materials, the system helps maintain free flow of wastewater and prevents the formation of drainage blockages.

The proposed system operates automatically with minimal human supervision, making it suitable for deployment in urban drainage systems, industrial wastewater channels, and municipal sanitation networks. By integrating automation with mechanical waste removal, the Smart Drainage Cleaning System improves operational efficiency, reduces maintenance effort, and minimizes the health risks associated with manual drainage cleaning.

HARDWARE ARCHITECTURE

The hardware architecture of the proposed Sewage Cleaning Robot consists of multiple interconnected subsystems responsible for sensing, control, actuation, and waste removal. The system integrates sensors, a microcontroller-based control unit, motor drivers, and mechanical components to perform automated sewage cleaning operations Figure 1. The architecture is designed to ensure efficient detection of waste accumulation, controlled movement of the robot, and effective removal of debris from sewage channels. Each hardware component performs a specific function within the system and works in coordination to achieve automated cleaning with minimal human intervention.

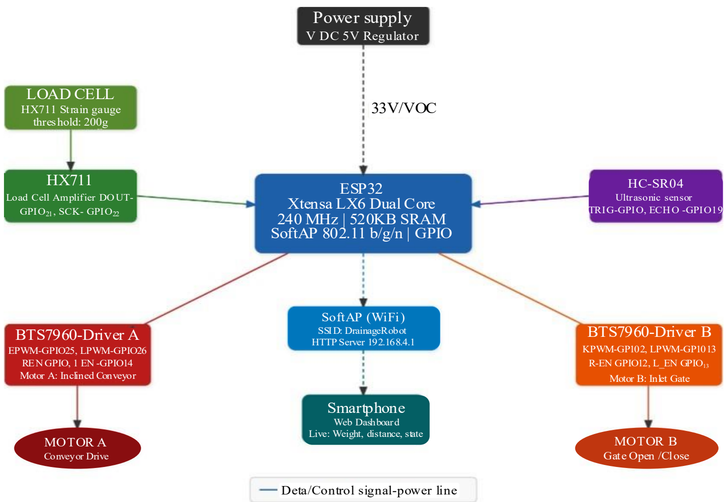

Figure 1. Hardware architecture Of ESP32-based drainage cleaner robot.

Microcontroller Unit

The microcontroller unit acts as the central processing component of the sewage cleaning robot. It is responsible for receiving input signals from various sensors, processing the data, and generating appropriate control signals to operate the motors and other actuators. The microcontroller continuously monitors the sensor data to detect obstacles, waste accumulation, or environmental changes inside the sewage channel. Based on the processed data, the controller activates the cleaning mechanism and controls the movement of the robot. The use of a microcontroller enables real-time decision-making, efficient system control, and low power consumption.

Motor Driver Module

The motor driver module is used to interface the microcontroller with the DC motors used for locomotion and cleaning operations. Since the microcontroller cannot directly supply the required current to drive motors, the motor driver acts as an intermediary power amplifier. The motor driver receives control signals from the microcontroller and regulates the direction and speed of the motors accordingly. This allows the robot to move forward, backward, or stop depending on the operational requirements. Additionally, the motor driver controls the rotation of the mechanical cleaning mechanism responsible for lifting and removing waste materials from the sewage flow.

DC Motors and Locomotion System

DC motors are used to provide mobility to the sewage cleaning robot. These motors drive the wheels or track mechanism that allows the robot to navigate through the drainage channel. The locomotion system is designed to provide stable movement in wet and uneven sewage environments. The motors enable the robot to travel along the sewage path while performing cleaning operations simultaneously. The controlled motion ensures that the robot can access different sections of the drainage system efficiently.

Waste Detection Sensors

Sensors play an important role in detecting the presence of debris, blockages, or obstacles within the sewage system. These sensors continuously monitor the surrounding environment and send signals to the microcontroller when waste accumulation is detected. The sensor data allows the robot to initiate the cleaning process only when necessary. This intelligent sensing mechanism improves operational efficiency and prevents unnecessary energy consumption. Depending on the system design, ultrasonic sensors or proximity sensors can be used to detect obstacles and measure the distance between the robot and accumulated waste.

Mechanical Cleaning Mechanism

The mechanical cleaning mechanism is the core component responsible for removing solid waste from the sewage channel. It typically consists of a rotating plate, conveyor mechanism, or lifting arm driven by a motor. When activated, the mechanism collects floating debris such as plastics, leaves, and other solid waste materials from the sewage water. The waste is then lifted and transferred into a collection container attached to the robot. This process ensures that the sewage flow remains unobstructed and reduces the chances of drainage blockage.

Power Supply Unit

The power supply unit provides the required electrical energy for operating all the hardware components of the robot. A rechargeable battery is typically used to supply power to the microcontroller, sensors, motor drivers, and DC motors. The power management system ensures stable voltage levels for different components and enables the robot to operate for extended periods. Efficient power distribution is essential for maintaining reliable operation of the sewage cleaning robot in field environments.

Waste Collection Unit

The waste collection unit is designed to temporarily store the debris removed from the sewage channel. The collected waste is deposited into a container attached to the robot after being lifted by the cleaning mechanism. This container can later be emptied manually after the cleaning operation is completed. The inclusion of a waste collection unit prevents debris from re-entering the drainage flow and ensures effective waste management.

SOFTWARE ALGORITHM DESIGN AND IMPLEMENTATION

Software Architecture of the Drainage Cleaning Robot

The drainage cleaning robot requires a reliable software control system to monitor the conditions inside the drainage channel and to control the cleaning mechanism when necessary. The embedded software for this system is developed using an ESP32 microcontroller programmed in the Arduino development environment. The program collects data from different sensors and processes this information to automate the cleaning operation. In this system, the control algorithm reads environmental data from the sensors, processes the signals to obtain useful physical values such as distance and weight, and then makes decisions based on predefined conditions. Depending on these conditions, the microcontroller controls the relay module that drives the cleaning motor. The software runs continuously in a loop so that the robot can constantly monitor the drainage environment. The ultrasonic sensor is used to detect obstacles or waste accumulation in the drainage channel, while the load cell measures the amount of waste collected by the robot. Using these measurements, the system decides whether the cleaning motor should be turned on or kept off. Similar robotic cleaning systems commonly use microcontroller-based control architectures where sensors continuously send data to the controller, which processes the information and generates the required control signals for the actuators. In this system, the software follows four main stages during operation: sensor initialization, distance measurement using ultrasonic sensing, weight measurement using the load cell, and finally decision-making for motor control. This sequence is repeated continuously to ensure real-time monitoring and efficient cleaning of the drainage system.

Sensor and Control Module Initialization

The first stage of the program involves the initialization of the sensors and control modules used in the drainage cleaning robot. During system startup, the microcontroller configures all the input and output pins that are connected to the ultrasonic sensor, load cell amplifier, and relay module. Proper initialization is important to ensure that each hardware component communicates correctly with the microcontroller and operates as expected.

The ultrasonic sensor used in the system requires two dedicated pins for its operation: the Trigger (TRIG) pin and the Echo (ECHO) pin. The trigger pin is responsible for generating ultrasonic pulses that are transmitted into the environment, while the echo pin receives the reflected sound waves from nearby objects or obstacles.

In addition to the ultrasonic sensing system, the robot also incorporates a load cell to measure the weight of collected waste. The load cell is interfaced with the microcontroller through the HX711 amplifier module, which plays a crucial role in signal conditioning. Since the load cell produces very small analog signals from the strain gauge, the HX711 amplifier converts these signals into digital values that can be easily processed by the microcontroller.

During the initialization stage, the HX711 module is calibrated using a calibration factor obtained through experimental measurements. This calibration ensures that the digital output values correspond accurately to the actual weight applied to the load cell. The relationship used for calibration can be expressed as follows:

$$W = R / C \tag{1}$$

Where

- W = measured weight
- R = raw digital output from HX711
- C = calibration factor

The calibration factor ensures that the measured values correspond accurately to real physical weight. Additionally, the relay module is configured as a negative-trigger switching device, meaning that the relay is activated when the control signal is LOW and deactivated when the signal is HIGH.

At the end of the initialization stage, the system resets the load cell reading to zero using a tare operation to ensure that the system starts from an unloaded condition.

Ultrasonic Distance Measurement Algorithm

The ultrasonic sensor is used in the proposed system to detect the presence of waste or obstacles within the drainage channel. This sensor operates based on the principle of sound wave reflection. In this method, the sensor transmits ultrasonic sound waves toward the surrounding environment and measures the time taken for the reflected waves to return after striking an object. By analyzing the time delay between transmission and reception of the sound waves, the system can determine the distance between the sensor and the detected object.

In the implemented algorithm, the ultrasonic sensing process begins by generating a short ultrasonic pulse through the trigger pin of the sensor. This trigger signal is produced by sending a pulse of approximately 10 microseconds to the ultrasonic transmitter. Once the pulse is emitted, the sensor waits for the reflected echo signal to return through the echo pin. The microcontroller measures the time duration of this echo signal, which corresponds to the time taken by the sound wave to travel to the object and return to the sensor. The measured time is directly proportional to the distance between the sensor and the detected obstacle.

The distance between the sensor and the object is calculated using the following equation:

$$D = (V_s \times t) / 2 \tag{2}$$

where D represents the distance to the object in centimeters, t represents the time duration of the echo pulse in microseconds, and Vs represents the speed of sound in air.

The speed of sound in air is approximately given by $V_s = 0.0343$ cm/μs (3)

By substituting this value into the distance equation, the final equation used in the program becomes

$$D = (0.0343 \times t) / 2 \tag{4}$$

The division by two in the equation accounts for the round-trip travel of the sound wave, as the measured time includes the duration required for the sound to travel from the sensor to the object and then return back to the sensor.

This distance measurement process is performed continuously by the microcontroller to monitor the presence of accumulated waste inside the drainage system. When the calculated distance falls below a predefined threshold value, which is set to 15 cm in this system, it indicates that an object or waste material is present close to the robot. This information is then used by the control algorithm to activate the cleaning mechanism when necessary.

Load Cell Weight Measurement Algorithm

In addition to detecting the presence of waste in the drainage channel, the proposed system also measures the weight of the collected debris using a load cell. The load cell is connected to the HX711 amplifier module, which converts the very small analog signals generated by the strain gauges into digital signals that can be processed by the microcontroller. The HX711 module reads the sensor output and transmits the data to the ESP32 microcontroller through two communication pins: Data Output (DOUT) and Clock (CLK). This interface allows the microcontroller to obtain accurate weight measurements from the load cell.

To improve measurement stability and reduce the influence of noise, the algorithm calculates the average of multiple readings obtained from the load cell. In the implemented system, the weight is computed as the average of ten consecutive measurements. Averaging multiple readings helps to minimize fluctuations in sensor output and provides a more reliable estimate of the actual weight.

The average measurement is calculated using the following equation:

$$W_{avg} = (1/n)\, \Sigma\, W_i \tag{5}$$

where Wi represents the individual weight measurement and n represents the number of samples used for averaging. In the current implementation, the value of n is chosen as

$$n = 10 \tag{6}$$

The weight obtained from the load cell is initially measured in kilograms. For easier interpretation and monitoring, this value is converted into grams using the following relationship:

$$W_g = 1000 \times W_{kg} \tag{7}$$

where Wg denotes the weight in grams and Wkg represents the weight measured in kilograms. This measurement allows the system to continuously monitor the amount of waste being collected by the robot and ensures that the cleaning mechanism operates only when necessary.

Decision-Making and Motor Control Algorithm

After obtaining both the distance measurement from the ultrasonic sensor and the weight measurement from the load cell, the system performs logical decision-making to determine whether the cleaning motor should be activated. The main objective of this control algorithm is to prevent unnecessary motor operation while ensuring efficient cleaning performance. By analyzing the sensor readings, the controller can identify the presence of waste or debris in front of the robot and activate the cleaning mechanism only when required.

The control logic implemented in the system is based on a threshold comparison of the measured distance. If the detected distance between the robot and the obstacle is less than a predefined threshold value, the system interprets this condition as the presence of debris or waste in front of the robot. The decision rule governing the motor operation can therefore be expressed as:

Motor =
(ON, $D < D_{threshold}$
OFF, $D \geq D_{threshold}$) (8)

where Dthreshold represents the predefined threshold distance used for detecting waste accumulation. In this implementation, the threshold distance is set to

$$D_{threshold} = 15 \text{ cm} \tag{9}$$

When the condition $D < 15$ cm is satisfied, the relay module activates the motor responsible for driving the drainage cleaning mechanism. Since the relay module used in this system is a negative-trigger relay, the control signals operate differently compared to standard relay modules. Specifically, the relay is activated when a LOW signal is applied and deactivated when a HIGH signal is applied.

Therefore, when waste is detected within the threshold distance, the microcontroller sends a LOW signal to both relay channels, which activates the cleaning motor. Conversely, when no waste or obstacle is detected, the relay remains in the HIGH state, ensuring that the motor remains turned off. This control strategy ensures that the motor operates only when necessary, thereby improving energy efficiency and reducing mechanical wear on the cleaning mechanism.

Continuous Monitoring Loop

The final stage of the software algorithm is the continuous monitoring loop. The program repeatedly performs the following operations: Trigger ultrasonic sensor Measure echo duration Compute object distance Read load cell measurements Calculate average weight Compare measurements with threshold conditions Control the relay module The process repeats indefinitely with a delay of 500 milliseconds between successive iterations. This delay ensures stable sensor readings and prevents rapid switching of the relay.

Flowchart of the Control Algorithm

The operational logic of the drainage cleaning robot is represented using a control flowchart that describes the sequential execution of the program. The flowchart provides a clear visualization of how the microcontroller processes sensor inputs and controls the cleaning mechanism. Flowchart-based representations are widely used in robotic control systems to illustrate the decision-making process and system behavior during real-time operation Figure 2.

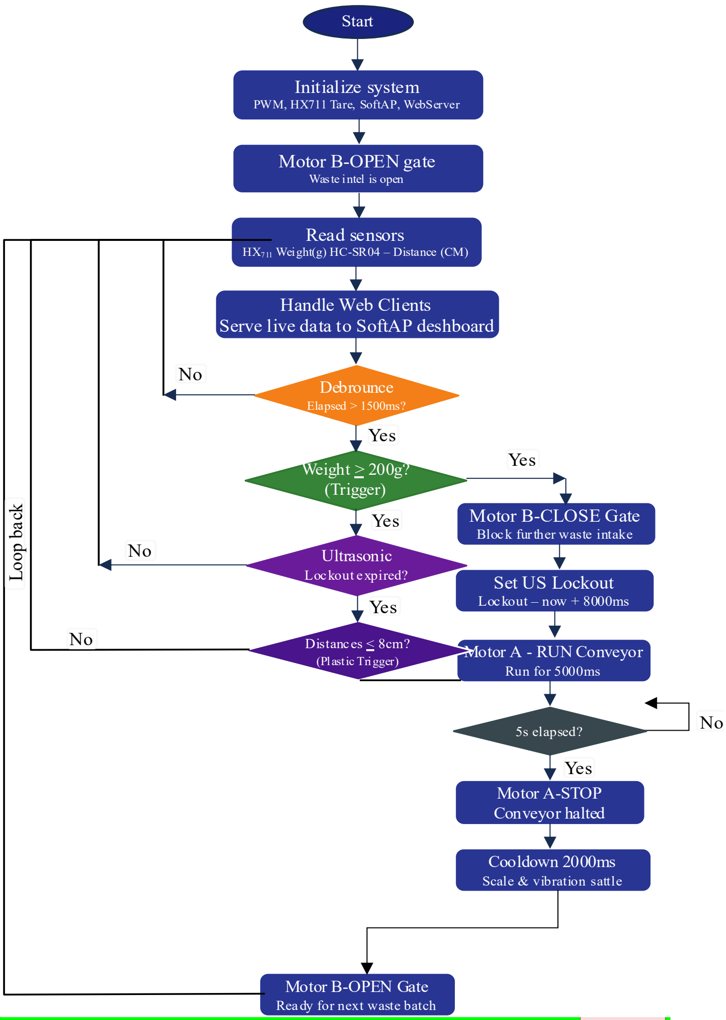

Figure 2. Operational flowchart of drainage cleaner robot control algorithm.

The software execution begins with system initialization, where all sensors and output devices are configured. After initialization, the microcontroller continuously monitors the drainage environment by collecting data from the ultrasonic sensor and the load cell. The ultrasonic sensor periodically transmits an ultrasonic pulse and measures the echo signal duration to determine the distance between the robot and any obstruction inside the drainage channel. The load cell simultaneously measures the weight of collected debris through the HX711 amplifier.

The obtained sensor readings are then processed by the controller. If the measured distance is less than the predefined threshold distance, the controller interprets this as the presence of waste or blockage in the drainage channel. Consequently, the relay module activates the cleaning motor to remove the debris. If no obstruction is detected, the relay remains inactive and the motor stays turned off.

The process repeats continuously in a loop to ensure real-time monitoring of drainage conditions.

Software Implementation Outcome

The implemented software algorithm enables the drainage cleaning robot to autonomously detect and respond to waste accumulation within the drainage system. By integrating ultrasonic sensing with load cell measurements, the system is capable of identifying the presence of debris and activating the cleaning mechanism accordingly.

The ultrasonic sensor provides reliable distance measurements that allow the robot to detect obstacles or waste deposits in front of the cleaning mechanism. Meanwhile, the load cell system offers additional monitoring capability by measuring the weight of collected waste, which can be further utilized to improve system efficiency and prevent unnecessary motor operation.

The use of threshold-based decision logic ensures that the cleaning motor operates only when required. This significantly reduces power consumption and increases the lifespan of mechanical components such as motors and gears.

Furthermore, the modular structure of the software allows easy expansion of the control algorithm. Additional sensors such as gas detectors, cameras, or water level sensors can be incorporated into the system to enhance the intelligence and safety of the drainage cleaning robot.

SYSTEM WORKFLOW

The proposed drainage gutter cleaning machine is a self-contained automated system designed to remove solid waste from drainage channels efficiently. The system is installed across the drainage channel and operates continuously to capture debris while allowing water to flow freely through the drainage path. The major components of the system include a modular grill, metallic plate mechanism, load sensor, ultrasonic sensor, ESP32 microcontroller, motor drive system, chain and belt transmission mechanism, and a buck converter for voltage regulation.

The modular grill is positioned at an elevated location across the drainage channel. Its primary function is to allow wastewater to pass through while trapping large solid particles such as plastic waste, leaves, and other debris. As solid particles accumulate on the grill, they gradually move toward the lower section of the system where the cleaning mechanism is installed.

To automate the cleaning process, the system uses two types of sensors: a load sensor and an ultrasonic distance sensor. The load sensor measures the weight of the accumulated waste on the grill, while the ultrasonic sensor measures the distance between the waste surface and the sensor to detect excessive accumulation. The ultrasonic sensor used in the system is capable of measuring distances up to approximately 4.5 meters, while the load sensor can detect waste loads up to 30 kg.

The sensor data is continuously monitored by an ESP32 microcontroller, which acts as the main control unit of the system. When the sensed waste accumulation exceeds the predefined threshold values, the microcontroller activates the cleaning mechanism. The system uses a 24-V DC motor connected to a chain and belt drive mechanism, which rotates the metallic plate located at the bottom of the system. This rotating plate helps remove the accumulated debris from the grill and transfers it into a storage tank.

The collected waste is deposited into a storage tank positioned below the cleaning mechanism. The bottom portion of the tank contains small drainage holes that allow excess water present in the debris to drain out. This process reduces the moisture content of the collected waste and facilitates easier disposal or recycling. Additionally, disinfectant spray mechanisms are incorporated inside the storage tank to disinfect the collected waste and reduce odor or microbial contamination.

During prolonged operation, there is a possibility that debris accumulation may block the holes of the modular grill. To prevent this, a metallic brush is attached below the rotating metallic plate. As the plate moves, the brush continuously cleans the surface of the grill, preventing clogging and maintaining uninterrupted water flow.

A buck converter is used in the system to regulate and supply the required voltage levels to the microcontroller and sensors from the main power source. This ensures stable operation of all electronic components.

Overall, the automated drainage gutter cleaning system provides an efficient and reliable solution for removing solid waste from drainage channels, thereby reducing manual labor and improving drainage system efficiency Figure 3.

Step-by-Step Workflow of the System

1. The drainage gutter cleaning machine is installed across the drainage channel.
2. The elevated modular grill allows water to flow through while trapping solid waste particles.
3. Debris gradually accumulates on the grill surface during operation.
4. The load sensor measures the weight of accumulated waste.
5. The ultrasonic sensor measures the distance between the sensor and the waste surface.
6. Sensor data is continuously transmitted to the ESP32 microcontroller.
7. When the detected weight exceeds 30 kg or the distance threshold indicates overflow, the cleaning process is activated.
8. The microcontroller drives a 24-V motor connected to a chain and belt transmission system.
9. The rotating metallic plate moves the accumulated debris from the grill into the storage tank.
10. Water present in the debris drains through holes provided at the bottom of the storage tank.
11. Disinfectant spray is applied inside the storage tank to disinfect the collected waste.

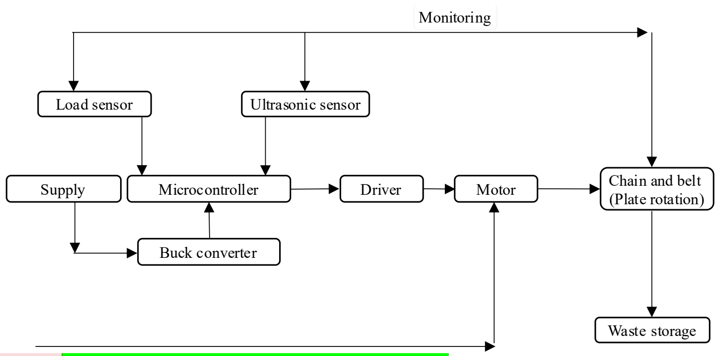

Figure 3. Block diagram of sewage cleaning robot.

Commented [s3]: <Author> Please check: Figure 3 text has been typed by us

12. A metallic brush attached below the plate cleans the grill surface during rotation to prevent clogging.
13. The system then returns to the monitoring state for further debris detection.

RESULTS AND DISCUSSION

The project successfully implemented an automated cleaning cycle driven by real-time sensor data, utilizing ultrasonic sensors to monitor waste height and load cells paired with an HX711 amplifier to measure debris weight. This system operates on a threshold-based activation model, where the motor triggers automatically once waste accumulation reaches preset limits—specifically when the debris height is within 15 cm of the sensor or the weight hits a maximum threshold.

For the removal process, a 12V motor powers a chain and sprocket mechanism that rotates a lifter plate to capture and deposit large debris into a dedicated storage tank. Throughout this process, the system maintains continuous monitoring by providing real-time debugging output via a serial monitor, displaying precise distance and weight readings in both kilograms and grams.

The physical construction of the system centers on a robust main frame, fabricated from L-angle iron or pipe, which typically stands between 60 and 90 cm in height with a width of 30 to 45 cm. Within this structure, a 25 cm x 20 cm x 15 cm collector bucket made of sheet metal or plastic is positioned to capture debris. This waste is moved by a lifter mechanism consisting of 10 to 15 cm metal strips or rods attached to a bicycle or roller chain measuring between 120 and 180 cm. The entire operation is managed by a centralized control unit featuring an Arduino-compatible microcontroller, which utilizes a BTS7960 motor driver for mechanical actuation and a buck converter for efficient power supply management.

The implementation of this technological intervention yields several critical benefits for urban infrastructure and worker safety. By replacing manual scavenging, the system significantly improves occupational health, drastically reducing workers' exposure to hazardous waste, toxic gases, and infectious diseases. Sanitation efficiency is also enhanced through the use of a modular grill, which ensures continuous water flow while effectively capturing the solid waste—such as plastics and bottles—that typically causes blockages. Furthermore, the system aids in overall urban maintenance; automated, regular cleaning prevents untreated sewage from overflowing into water bodies during monsoon seasons, thereby significantly reducing environmental pollution.

CONCLUSIONS

The proposed automated drainage cleaning system presents an efficient and practical solution for addressing the problem of waste accumulation in drainage channels. The system integrates mechanical cleaning mechanisms with sensor-based monitoring and embedded control to enable automated removal of debris. By utilizing an ESP32 microcontroller along with ultrasonic and load cell sensors, the system continuously monitors the level of waste accumulation and activates the cleaning mechanism only when necessary. This sensor-driven control strategy ensures reliable operation while reducing unnecessary motor activity and energy consumption.

The ultrasonic sensor provides real-time distance measurements to detect the presence of accumulated debris, while the load cell measures the weight of collected waste to monitor system performance. These sensor inputs are processed by the microcontroller through a threshold-based decision algorithm that determines when the cleaning motor should be activated. Once the threshold condition is satisfied, the motor-driven chain and belt mechanism rotates the metallic cleaning plate to remove the accumulated waste and transfer it to the collection unit. This automated approach helps maintain uninterrupted wastewater flow and prevents drainage blockages.

The developed system significantly reduces the need for manual drainage cleaning, which is often hazardous and labor-intensive. By automating the waste removal process, the proposed solution improves sanitation efficiency, minimizes human exposure to contaminated environments, and contributes to safer urban drainage maintenance. Additionally, the modular design of the system allows for further enhancements, such as the integration of additional sensors or remote monitoring capabilities.

Overall, the proposed drainage cleaning robot demonstrates the feasibility of using embedded systems and sensor-based automation for improving drainage maintenance operations. The system offers a cost-effective and scalable solution that can be implemented in urban drainage networks, industrial wastewater channels, and municipal sanitation infrastructures. Future work may focus on integrating advanced sensing technologies, remote monitoring systems, and improved mechanical designs to further enhance the reliability and efficiency of automated drainage cleaning systems.

REFERENCES

1. Stojanovic M, Preisig J. Underwater acoustic communication channels: Propagation models and statistical characterization. IEEE Commun Mag. 2009; Jan: 84–89.
2. van Walree PA. Propagation and scattering effects in underwater acoustic communication channels. IEEE J Ocean Eng. 2013; Oct: 614–631.
3. Priya S. Development of a Semi-Autonomous Robotic System for Sewer Cleaning. J Environ Eng Waste Manag. 2021; Mar: 112–118.
4. Thomas L, Menon V. Occupational Health Risks in Manual Sewer Cleaning and the Role of Technological Interventions. Int J Public Health Saf. 2018; Jul: 45–50.
5. Patel R, Varma G. Automated Drainage Blockage Detection Using Machine Learning. J Smart Environ Syst. 2020; Jan: 34–41.
6. Kumar S, Singh A, Sharma P. IoT-based smart sewer monitoring and blockage detection system. Int J Eng Res Technol. 2021;10(5):215–220.
7. Li Y, Wang H, Zhang X. Design and implementation of an autonomous sewer inspection robot using embedded vision. IEEE Access. 2020;8:154321–154332.
8. Rahman MM, Islam MT, Hossain MA. Wireless sensor networks for underground pipeline and sewer monitoring: A review. Sensors. 2019;19(23):5245.
9. Kim K, Choi H, Lee J. Real-time underwater acoustic communication for autonomous robotic applications. IEEE Access. 2021;9:112456–112468.
10. World Health Organization. Guidelines on sanitation and health. Geneva: World Health Organization; 2018.