RESEARCH PAPER

Smart Drainage Suction System

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Abstract-Traditional medical suction systems require manual disposal of collected biological fluids such as blood, saliva, and mucus, which increases the risk of accidental spills and exposure of healthcare workers to infectious materials. To address these challenges, this work proposes a portable automated suction drainage system aimed at improving safety and hygiene in clinical environments. The system integrates sensor-based monitoring and automated control to minimize human intervention in handling contaminated fluids. Its compact and lightweight design enhances portability, making it suitable for bedside care, emergency units, ambulances, and small healthcare settings. By reducing direct contact with medical waste, the proposed system contributes to better infection control and improved operational efficiency in fluid management.

Keywords- Medical suction system, Automated drainage, Infection control, sensor-based monitoring, Portable.

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I. INTRODUCTION

Suction is a vital medical procedure used in healthcare to remove unwanted bodily fluids such as mucus, saliva, blood, and other secretions from the patient's body. It is based on the principle of negative pressure and is critical for maintaining a clear airway, improving visibility during medical procedures, and preventing complications such as aspiration and infection [25]. When a patient is unconscious, intubated, or unable to clear secretions independently, suction is particularly important.

Suction is widely used across hospitals, including operation theatres, intensive care units, emergency departments, neonatal care units, dental clinics, and general wards. Clinical reports indicate that approximately 80–90% of hospitals rely on suction machines for routine and critical medical procedures [8]. Suctioning is performed multiple times a day in high-dependency areas, increasing the need for safe and reliable suction equipment.

An ordinary suction machine, also known as a medical aspirator, consists of a vacuum pump, pressure regulator, tubing, a bacterial filter, and a reusable collection canister [14]. The machine generates negative pressure to aspirate bodily fluids, which are collected in the canister. Once filled, the waste fluid must be manually drained and the canister cleaned for reuse.

Despite their effectiveness, conventional suction machines have notable limitations. Manual handling of waste fluids exposes healthcare workers to infectious materials, increasing contamination and spillage risks. It is essential to thoroughly sterilize reusable canisters in order to prevent cross-contamination [23]. These limitations highlight the need for safer and more hygienic suction systems in modern clinical environments.

II. RELATED WORKS

Modern medical waste management (MWM) has become a critical priority in healthcare, as improper handling and classification of infectious waste pose severe health risks to both personnel and patients [14]. Traditional suction units, which are essential for clearing surgical fields, often suffer from mechanical failures such as blood clotting and flow interruptions caused by traditional piston-pump valves [15]. Research indicates that these challenges can be addressed by transitioning to valve-less peristaltic pumps, which ensure a continuous flow and eliminate obstacles in the liquid path that typically lead to blockages [19]. Furthermore, the automation of these processes is gaining traction; for instance, the SACHETS system utilizes deep learning to identify and clear blood accumulations autonomously, reducing the cognitive load on surgeons and improving surgical safety [3].

The risks associated with manual drainage are particularly acute in resource-limited settings or during public health crises, where improvised equipment is often necessary to manage life-threatening conditions like neonatal pneumothorax [20]. High-powered, mobile suction systems like the Stryker Neptune™ have demonstrated superior performance over traditional wall suction, especially when repurposed to create negative pressure isolation environments—such as the VANISH system—to protect healthcare workers from aerosolized pathogens [7]. Despite these technical capabilities, current design standards for portable aspirators often fail to reflect clinical realities, frequently proving under-powered for viscous materials like vomit or thick blood [20].

Effective management must also address the environmental impact of the waste generated. The COVID-19 pandemic significantly increased the volume of hazardous medical waste, emphasizing the need for sustainable practices like steam sterilization and efficient segregation to move away from expensive and environmentally taxing incineration [13]. Comprehensive institutional strategies that prioritize on-site segregation and staff training are identified as the most vital factors for achieving a sustainable "green" healthcare environment [15]. Ultimately, the shift toward closed-loop, automated systems is essential to minimize human contact with bio-hazards and ensure that medical waste is treated and disposed of in an environmentally responsible manner [18].

Modern medical waste management significantly benefits from the integration of automated systems designed to minimize human contact with infectious bio-fluids and enhance clinical efficiency. Current research highlights various advancements, such as suction systems featuring dedicated cleaning stations that automatically drain and provide visible cleanliness indicators [25], and automatic drainage disposal apparatuses that utilize antiseptic feeding mechanisms to eliminate manual handling [1]. Systems emphasize operator safety through the use of sealed discharge passageways and reusable components to reduce hazardous exposure [23, 16], while autonomous tools are increasingly developed to isolate healthcare personnel from infectious microorganisms [17]. Technical innovations include main control systems that monitor pipe pressure to regulate negative pressure pumps and relief valves for efficient sputum drainage [2], and specialized devices that incorporate suction and intake tubes to improve suction uniformity and reduce labour intensity [27]. Other developments focus on real-time monitoring of drainage volume through negative-pressure devices [28] and the use of flexible liners within sealed chambers to manage waste-treating materials [6]. While some units utilize automatic valves to regulate fluid flow during collection [9], the collective shift in the literature is toward comprehensive, automated mechanisms that prioritize infection control, surgical safety, and the streamlining of hazardous waste disposal.

III. MATERIALS AND METHODS

The Materials and Methods section describe the components used and the procedure followed for the development of the Automated Suction Machine. The project is implemented using a combination of electronic, mechanical, and biomedical components to achieve controlled suction and automatic waste drainage. The selected materials ensure safe operation, automation, and reliability of the system. The methodology explains the integration of sensors, control units, actuators, and fluid-handling components to demonstrate the working principle of the automated suction and drainage process.

A. Block Diagram

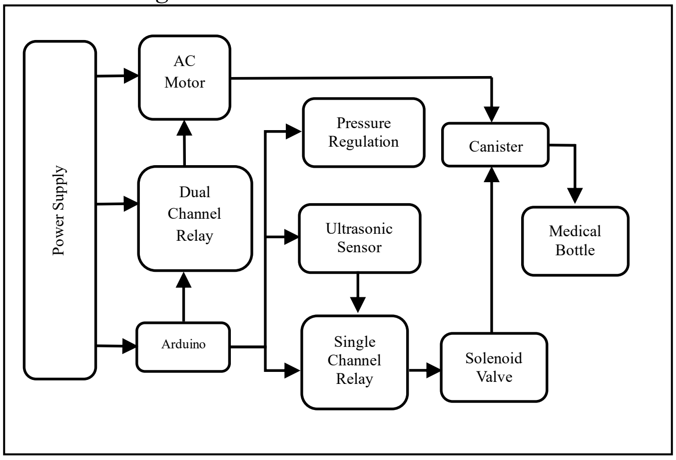

Fig 3A: Block Diagram of Automated Suction Machine

IV. PROPOSED WORKING

The proposed portable automated suction and drainage system operates based on the principles of negative pressure suction, real-time fluid level monitoring, and automated waste disposal control. The system is designed to minimize human intervention while ensuring safe and hygienic handling of biological fluids.

Initially, when the device is powered on, the suction unit generates negative pressure within the suction line and collection canister. This pressure difference enables the aspiration of biological fluids such as mucus, blood, and secretions from the patient into the canister through the suction tubing. The canister is designed to maintain an airtight environment to ensure efficient suction performance.

To continuously monitor the fluid level inside the canister, an ultrasonic sensor is mounted at the top of the container. The sensor emits ultrasonic waves toward the fluid surface and receives the reflected signals. Based on the time taken for the echo to return, the distance between the sensor and the fluid surface is calculated. This distance is inversely proportional to the fluid level and is continuously transmitted to the Arduino microcontroller for processing.

The microcontroller compares the measured fluid level with a predefined threshold value programmed into the system. When the fluid reaches the specified limit, the controller initiates an automated response sequence. First, it deactivates the suction mechanism to prevent overflow and ensure safe operation. Subsequently, it triggers the drainage mechanism by activating the solenoid valve through a relay interface.

Upon activation, the solenoid valve opens and allows the collected fluid to flow from the canister into a sealed medical waste bottle. The drainage process is controlled to ensure complete transfer of the collected fluid while preventing leakage or backflow. Once the fluid level drops below the minimum threshold, the microcontroller deactivates the valve, thereby closing the drainage path and restoring the system to its initial state.

In addition to automated operation, the system incorporates a manual override feature using an external switch. This allows the user to initiate the drainage process at any time, even if the fluid level has not reached the preset threshold, thereby providing operational flexibility.

For additional safety, a ball-based shut-off mechanism is integrated within the canister to prevent fluid from entering the internal components of the suction unit in case of excessive fluid accumulation or sensor failure. This ensures protection of the device and enhances reliability.

Overall, the system operates in a cyclic manner consisting of suction, monitoring, threshold detection, drainage, and reset stages. This integrated approach ensures efficient fluid management, reduces manual handling of contaminated waste, and enhances safety and hygiene in medical environments.

V. RESULT & DISCUSSION

The portable automated suction system that was created worked well for collecting and draining biological fluids. The system made controlled negative pressure for suction and positive pressure for drainage, which made sure that it worked smoothly and without leaks or backflow. By combining the Arduino-based control unit with the ultrasonic sensor, it was possible to accurately monitor the fluid levels inside the canister in real time. The system could automatically switch between suction and drainage modes when the set threshold level was reached, which showed that the automation process was reliable. It was noted that the solenoid valve and relay-controlled mechanisms responded in a consistent and timely manner, which made sure that the fluid was moved correctly. Also, using a sealed disposable waste collection bottle helped keep people from coming into direct contact with contaminated fluids

Fig 5: Automated Drainage Suction Machine

VI. CONCLUSION

The suggested portable automated suction and drainage system is a clean and effective way to handle medical fluids. The system uses automated control and sensor-based monitoring to cut down on the amount of infectious waste that needs to be handled by hand. This lowers the risk of contamination for healthcare workers. The system's small size and portability make it useful in a wide range of healthcare settings, such as hospitals, ambulances, and home care settings. Being able to automatically handle collecting and getting rid of fluids makes clinical practice safer and easier.

VII. FUTURE SCOPE

In future developments, a battery backup system can be integrated to ensure uninterrupted operation during power failures and enhance the reliability of the device in critical medical environments. The incorporation of a peristaltic pumping mechanism may help reduce clogging and improve the smooth flow of biological fluids during suction. Additionally, the implementation of a one-way valve can prevent backflow of collected fluids, thereby improve system safety and maintain hygienic operation

VIII. REFERENCE

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