THE PROGRESS: A Journal of Multidisciplinary Studies
Vol.7, No.1 (March, 2026), Pp.106-115
ISSN (Online): 2958-292X, ISSN (Print): 2958-2911
DOI: https://doi.org/10.71016/tp/ype5pk84

Original Article https://hnpublisher.com

Smart Inhaler System for Improved Aerosol Drug Delivery

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ABSTRACT

Aim of the Study: The principle target of the work is to provide assistance to asthmatic patients by means of digital health care. For many patients, managing their asthma can be difficult since some symptoms are hard to control, and the asthma attacks may appear unpredictably. The wave of digital health care is continuously growing and prospering to transform patient healthcare. Asthma is the chronic disease which requires attention of patients, engineers and health care providers. About 50% asthmatic inhaler users are using their inhalers incorrectly, which starts to show negative result of medication because the delivery of medication in patient lungs. The life of asthmatic patients is dependent and is centralized on inhalers.

Methodology: The idea of this system is to ensure the reach of dosage effectively to the lungs to aid the patient and help to lead the easier life. This system specifically focuses on flow rate how much of the dose has been inhaled by the patient whether the patient got the dose accurately and effectively or not. It also keeps the track of doses taken, indicates for the next dose, specifies how much of dose has been inhaled by the patient, provides the record of the patient for time being, helps doctor to monitor the patient’s health by the record it provides, makes it easier managing prolong diseases relatively cured by inhalers.

Findings: The system simplifies chronic disease management for inhaler treated patient problems. It gives precise flow rate data, usage logs, and health records, preventing incorrect inhaler use and gives better outcomes (based on preliminary tests showing effective dose delivery tracking).

Conclusion: This digital solution changes asthma care by allowing precise, monitored inhaler use and easier use by subject, making the way for better healthcare innovations. The data shared by this system is envisioned through module on Arduino IoT Cloud desktop and Arduino Cloud mobile software.

Keywords: Asthma Management, Smart Health Care, Inhaler Usage and IoT-enabled Health.

Article History

Received:
December 27, 2025

Revised:
February 26, 2026

Accepted:
March 2, 2026

Online:
March 6, 2026

1. INTRODUCTION

Asthma is a chronic respiratory condition that causes bronchial tubes, which are lung airways, to become inflamed. The inflammation results in airways turning out to be small, making it impossible to breathe (Listyoko et al., 2024). The asthma attack is the sudden onset of symptoms of asthma which occurs as lining of the airways swells and muscles contract around them, mucus begins to flood airways, restricting airflow more. An asthma attack that involves emergency medical attention in the form of inhalers or even hospitalization may be fatal(Eikholt et al., 2023). van Boven (2023) The desire to live an active life is restricted by untreated asthma; many asthmatic people still may not have as much control of their asthma as they should have, as it states that asthma is blamed for about 400,000 deaths a year worldwide. Moreover, about 50% of asthmatics use their inhaler incorrectly, which has a negative impact on the medicine's outcome (Ologundudu et al., 2025). In an asthmatic life, the asthma inhaler is central and has tremendous potential for advancement towards a new asthma control tool and could potentially enhance the overall awareness of the patient (Aung et al., 2025). The main purpose of the project is to find ways to integrate electronics into the inhaler in order to address the requirements and enhance the user experience (Hardas et al., 2025). By using lights and sensors we came across a digitalized asthma/COPD Smart Inhaler, providing aid to patients and standard way to treat the disease. A Smart Inhaler attached module register and communicates data to the app. In essence, the app analyses the information and provides users and caregivers with data and numbers to give them insights into the conditions of asthma (Viswalingam & Kumar, 2025; Tippannavar et al., 2023).

Table 1: *Shows Difference In a Normal Lung and an Asthma patient Lung.*

Normal Lung	Asthmatic Lung
Muscle Relaxed	Muscle Tightens
Normal Lining	Swollen Lining
Normal Amount of Mucus	Excess Mucus

1.1 Problems Statement

Asthma or chronic obstructive pulmonary diseases (COPD) are lasting respiratory conditions that need reliability to inhaler based medication for good management. However, a good number of patients fail to achieve proper disease control due to incorrect inhaler technique, poor adherence to prescribed dosage schedules, and lack of continuous monitoring. Studies indicate that more than 50% of patients use inhalers incorrectly, resulting in insufficient drug delivery to the lungs and increased risk of asthma exacerbations, hospitalizations, and mortality.

Conventional inhalers do not provide any mechanism to monitor inhalation flow, confirm dose intake, record usage history, or remind patients of scheduled doses. As a result, patients often forget doses, take multiple doses unintentionally, or inhale medication at an improper flow rate. This lack of feedback and record-keeping also creates challenges for healthcare professionals, as accurate information regarding patient adherence and inhalation effectiveness is unavailable during treatment planning.

Furthermore, existing inhaler systems do not integrate environmental monitoring or real- time data sharing, limiting the ability to assess external factors such as temperature and humidity that may influence asthma symptoms. There is a clear need for a smart, assistive inhaler system that can ensure correct dose delivery, monitor inhalation pressure, provide timely alerts, and transmit usage data to healthcare providers through cloud-based platforms. Therefore, the problem addressed in this project is the absence of an intelligent, user-assisted inhaler system that can improve medication adherence, support correct inhalation technique, enable remote monitoring, and enhance the overall management of asthma and COPD patients.

2. LITERATURE REVIEW

Asthma affects around 26+ million individuals in the United States of America, with 6 million of them being below 18. Although the World Health Organization (WHO) believes that the rate has climbed by more than 60% during the 1980s (Pradeesh et al., 2022). The mortality rate from asthma has become double during that period; this is not a new problem. Drummond et al., (2025) Since ancient Greece, specialists and medical authorities have been alert about asthma, and what they know about not just treatments but also the condition itself has evolved tremendously as medical field and technology has advanced (Poplicean et al., 2024).

The phrase chronic obstructive pulmonary disease (COPD) cite to two different chronic lung diseases. The leading cause is smoking(Zabczyk & Blakey, 2021). COPD can manifest as chronic bronchitis, emphysema, or a combination of the two. These conditions obstruct airway function and make breathing difficult. COVID-19 symptoms may be more severe in those with COPD. COPD is a term that refers to two diseases: emphysema and chronic bronchitis. COPD patients may have one or both of these problems, and the severity of each differs from one individual to the next. Emphysema is a lung disease that causes damage to the air sacs. As a result, the lungs lose their flexibility and are unable to adequately exchange oxygen and carbon dioxide. COPD symptoms may include asthma symptoms, and a history of asthma might raise the chance of developing COPD (Chan et al., 2021). Asthma is caused by inflammation of the airways, which causes spasms and chemical overreactions. COPD is a chronic condition characterized by permanent lung deterioration, increased breathing difficulties, and airway blockage. A person with severe COPD may find it difficult to cook or climb stairs. Medication and more oxygen may be required. Treatment include treating symptoms in order to enhance quality of life, lower the risk of consequences, and limit the advancement of the underlying health concerns. A doctor may advice you to use an inhaler that contains a multiple types of medications to help with breathing (Atanasov et al., 2021).

Inhaler usage as per prescription is ideally accepted situation but more than 50% of people are still not aware of how to use it efficiently and sometimes it creates critical situations due to the incorrect usage of inhaler (O'Byrne et al., 2019). Most of the times maximum doses do not reach the lungs properly because of the less aerosol penetration and in some situations people consume the medication more or less than it was prescribed. Every inhaler medicine has specified doses to be accumulated in a day, people forget the amount of dosage they have taken in a day due to the busy stressful life or age factor as well (Chamaon et al., 2025). Taking multiple doses could lead to severity or taking less then prescribed could also lead to worsening of condition. Mortality rate also increases due to the failure of control over dosage of drug (Ologundudu et al., 2025). Health care providers also face difficulties while treating the patient due to the incomplete information of doses, where they don't have accurate history of how the patient had taken the prescription, even if the consumer had taken exact doses according to prescription, whether he accumulated the acquired dose accurately or not (Drummond et al., 2025).

3. RESEARCH METHODOLOGY

This system begins with a power source consisting of six lithium-ion batteries connected to buck converters that distribute voltages to the entire system for operation. The voltage is allocated in three ways: 8V to the Arduino Mega, 8V to the Arduino Uno, and 5V to the ESP32 model. The differential pressure sensor, RTC real-time control module, LCD liquid crystal display 20x4 and relay are all pinned to Arduino to perform their tasks as programmed, and they forward the data to the Arduino, which then transfers the data to the LCD for display and to the ESP32, which then forwards the data through the cloud to the application/software, for visualizing. We can also visualize the data through serial monitor, after selecting the com-port as we are using two Arduinos. We have also placed LED and buzzer as an indicator to indicate the turning on of motor, to show its on task. When the system is turned on, we get the time and date first appearing on the LCD along with appearing the status of motor. RTC is a four-pin module in which two are signal one for ground and one for supply, 2 signal pins are input and output, the input signal takes the command by program for ones and give the output simultaneously as we entered the time as input, it's like setting up time as per your zone. RTC module displays on going date and time. Pressure sensor connected to the system is differential pressure sensor as it calculates both input and output pressure it has two openings from one side the drug introduced will move and from other opening consumer consumes the drug, exactly what happens here when the consumer consumes the drug he/she sucks the vapors thrown out of the pipe he or she inhales and exhales doing that , so it calculates the pressure of inhalation done and gives the data through which a doctor can also track the working of lungs of the patient. Led and buzzers are also connected to Arduino at mega when they sense the signal to the motor as relay conveys for working and indicates the turning on of motor for dose selection and moving it to flow sensor. The relay here, which is connected to the Arduino Mega, operates on binary commands of 0 and 1. On zero, it generates the signal to turn on the motor, and on 1, it generates the signal to turn off the motor. The relay gets the signal to turn the motor on and off through time set given in the program to the system for turning on or turning off. We also select the set of time to accumulate the dose as we acquire. Motor is also connected to relay, works when the relay generates the signal 0, and starts to suck the liquid from the container towards the flow sensor from where the drug and liquids gets stored in container for the accumulation of dose on time after alarms goes off to show now the drug can be consumed. Now for transferring the data wirelessly to any desktop or laptop we acquire different modules like Bluetooth technology and other wireless modules but we have used an IOT module ESP32 to transmit the data to online website that shows the prototype of our software/application, for now we have used Arduino IOT cloud to transmit our data on mobile or desktop through internet, both Arduinos are connected to ESP32 for forwarding the data to the Arduino IOT cloud or Arduino IOT software. DHT31 a temperature and humidity sensor is directly attached to ESP32 module to forward the eco- friendly data directly to the desktop/software.

3.1 Research Design

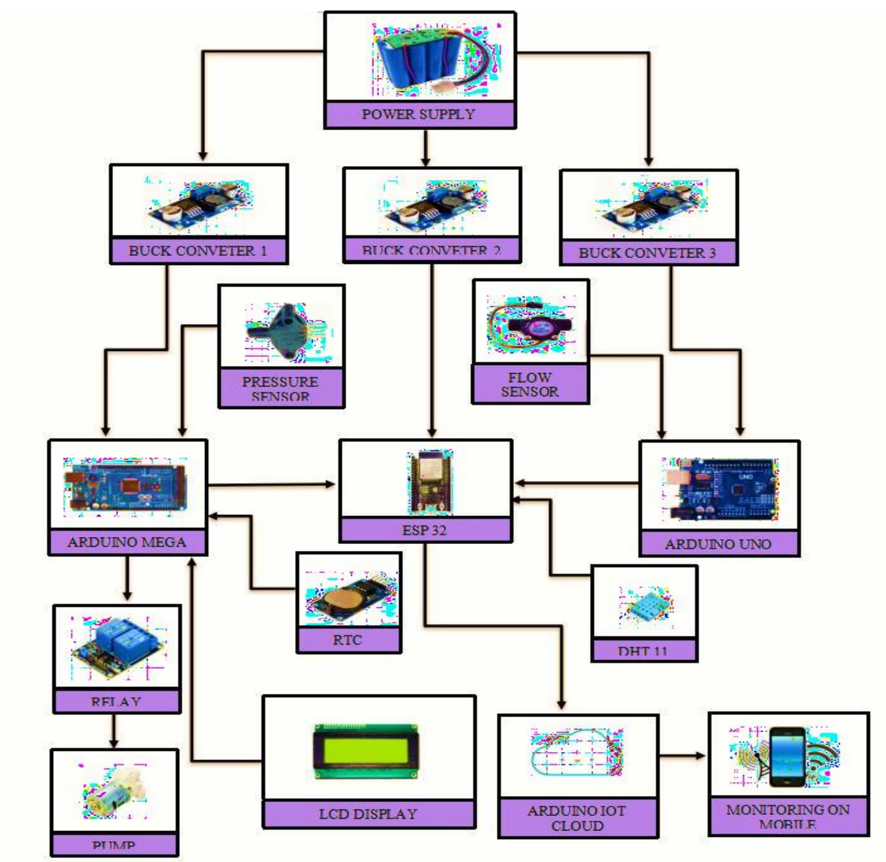

Figure 1: *Graphical Illustration of Model Design.*

3.2 Algorithm

Algorithms are used to make systems more accurate and efficient; here it is implicated to reach the goal of providing inhalation of dosages on time. The algorithm of smart inhaler is divided in chunks, at first the Arduino simply complies with the program that is installed in it. It gathers the data conveyed from all the sensors and display them on LCD and serial monitor. Arduino reads the time algorithms provided to it and controls the relay giving it signal of either turning the motor on or off, it complies with it and allows the selection of dosage for intake as per time introduced. The last part of the algorithm is about sending the data to Arduino cloud to display it on desktops/mobiles through IoT module as shown in Figure 2.

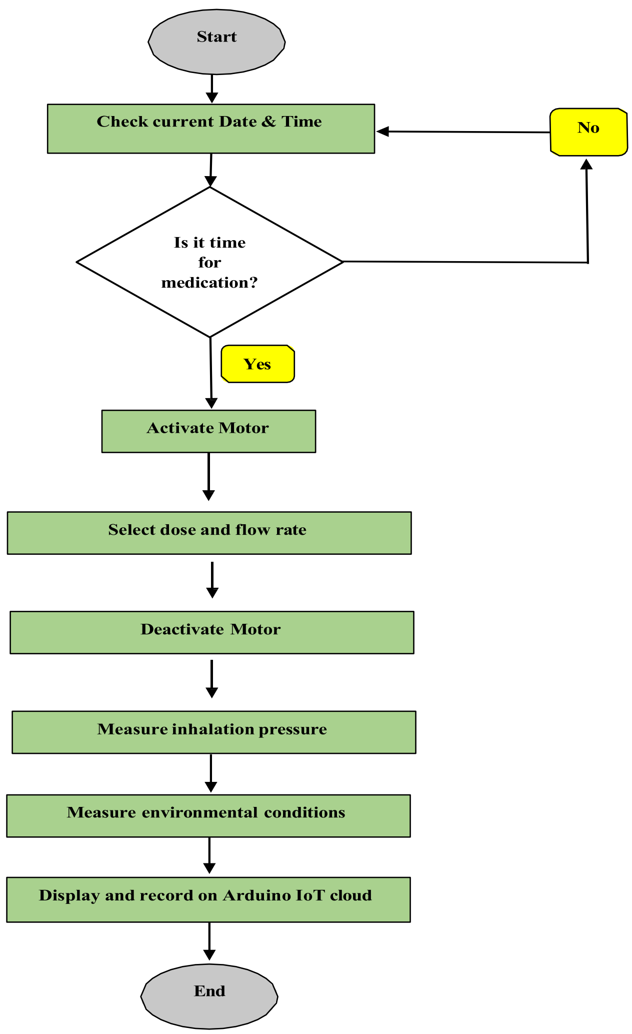

Figure 2: *Illustrative flow of algorithm of smart inhaler.*

4. RESULTS

This system begins with a power source consisting of six lithium-ion batteries connected to buck converters that distribute voltages to the entire system for operation. The voltage is allocated in three ways: 8V to the Arduino Mega, 8V to the Arduino Uno, and 5V to the ESP32 model. The differential pressure sensor, RTC real-time control module, LCD liquid crystal display 20x4 and relay are all pinned to Arduino to perform their tasks as programmed, and they forward the data to the Arduino, which then transfers the data to the LCD for display and to the ESP32, which then forwards the data through the cloud to the application/software, for visualizing. The data can be visualized through serial monitor, after selecting the com port two Arduino are used. The LED and buzzer as an indicator to indicate for motor functioning. When the system is turned on, get the time and date first appearing on the LCD along with appearing the status of motor. RTC is a four-pin module in which two are signal one for ground and one for supply, 2 signal pins are input and output, the input signal takes the command by program for ones and give the output simultaneously as the time is entered as input, it’s like setting up time as per zone. RTC module displays on going date and time. Pressure sensor connected to the system is differential pressure sensor as it calculates both input and output pressure it has two openings from one side the drug introduced will move and from other opening consumer consumes the drug, exactly what happens here when a subject consumes the drug they inhale the vapors thrown out of the pipe, so it calculates the pressure of inhalation done and gives the data through which a doctor can also track the working of lungs of the patient. Led and buzzers are also connected to Arduino at mega when they sense the signal to the motor as relay conveys for working and indicates the turning on of motor for dose selection and moving it to flow sensor. The relay here, which is connected to the Arduino Mega, operates on binary commands of 0 and 1. On zero, it generates the signal to turn on the motor, and on 1, it generates the signal to turn off the motor. The relay gets the signal to turn the motor on and off through time set given in the program to the system for turning on or turning off. We also select the set of time to accumulate the dose as we acquire. Motor is also connected to relay, works when the relay generates the signal 0, and starts to suck the liquid from the container towards the flow sensor from where the drug and liquids gets stored in container for the accumulation of dose on time after alarms goes off to show now the drug can be consumed. The designed Smart Inhaler module executed the results and are given below taken while testing on asthmatic patients as per their dosage and asthma conditions prescribed by concern doctor. Results are present in Figure 3.

Figure 3: *Time and date on the LCD along with the status of motor*

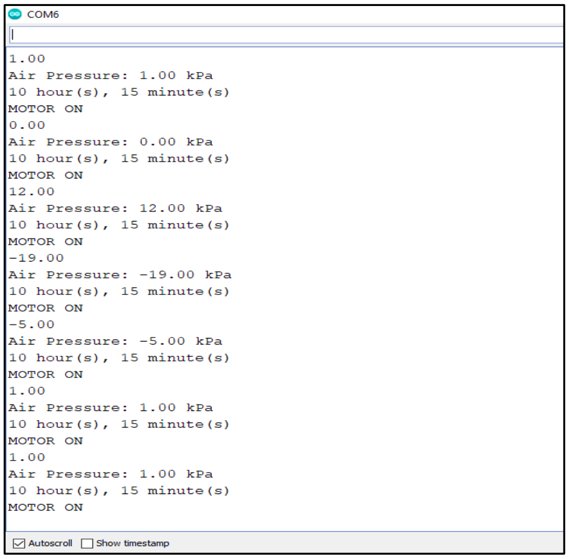

Figure 4: *results on Arduino Serial Monitor as the Motor ON/OFF*

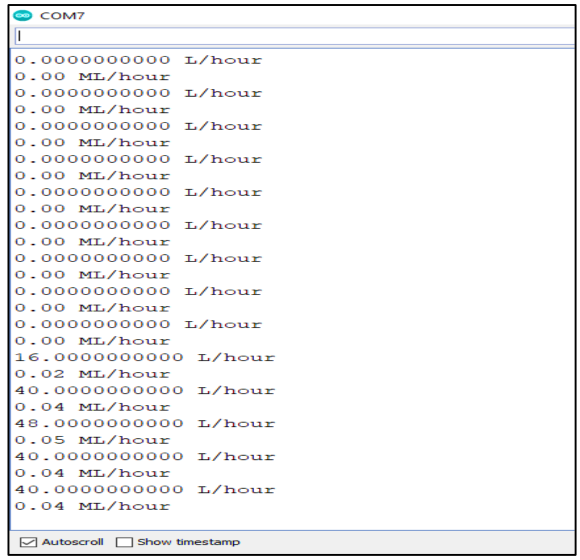

Figure 5: *Results on Arduino Serial Monitor as the Motor ON/OFF*

Now for transferring the data wirelessly to any desktop or laptop we acquire different modules like Bluetooth technology and other wireless modules but we have used an IOT module ESP32 to transmit the data to online website that shows the prototype of our software/application, for now we have used Arduino IOT cloud to transmit our data on mobile or desktop through internet, both Arduinos are connected to ESP32 for forwarding the data to the Arduino IOT cloud or Arduino IOT software. DHT31 a temperature and humidity sensor is directly attached to ESP32 module to forward the eco-friendly data directly to the desktop/software. Results are present in Figures below.

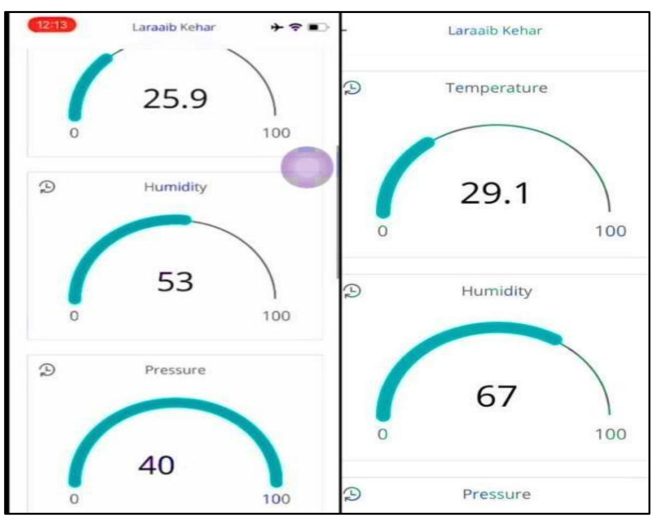

Figure 6: *Results in DHT31 a temperature and humidity sensor*

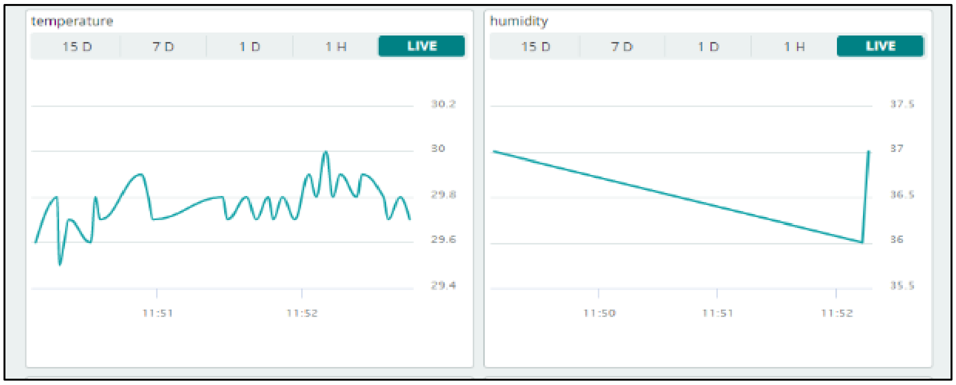

Figure 7: *Temperature and humidity Change*

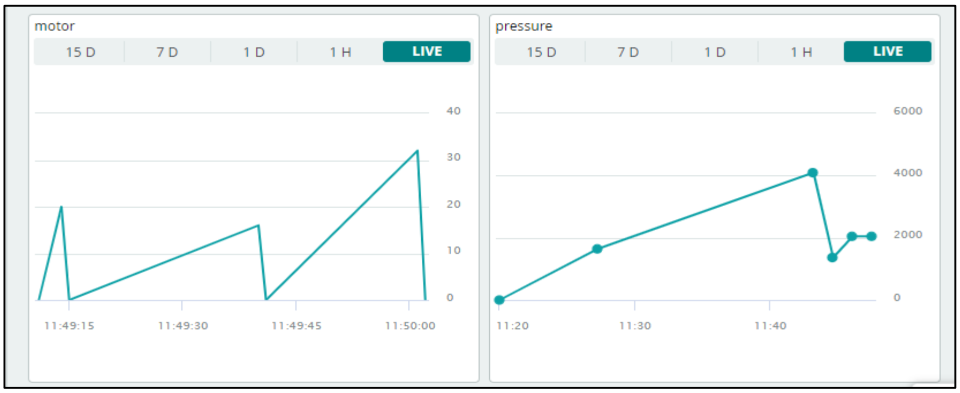

Figure 8: *Results of Change in Motor and Pressure*

5. DISCUSSION AND FINDINGS

The project utilizes AnyDesk for encrypted remote approach to the Arduino-ESP32 system, allowing adjustments made by doctor to dose alarms, timers, or configurations while subject is using inhaler. Unlike already available smart inhalers, this proprietary tool (encryption that is military grade, cross platform) allows users device connections for faster interventions, e.g., prescription changes if a patient needs reduction in dose or misses doses.

This design extends edge processed prototypes (e.g., ESP32 with flow and pressure for 85% inhalation accuracy) by incorporating relay motor for liquid nebulization and dual microcontroller tolerance of fault, unlike cloud reliant C4A systems. It addresses adherence barriers (e.g., technique errors in 30% to 50% of users) with the help of indicators and monitoring, similar to AI-DPI validation for asthma or COPD.

AnyDesk helps in adherence gaps in IoT inhalers (e.g., technique errors in 73% of subjects using inhalers) by allowing remote dose recalibration without patient visits extending RTC/ESP32 logging [previous discussion] to telemedicine. Patient trials results in seamless variations (e.g., reducing accumulation time from 5min to 3min), aligning with C4A self-management systems but including control not seen in app only designs which needs stable internet; lacks native MDM integration. Enhance with platforms like SocketXP for fleet scale monitoring of clinics, adding AI alerts for asthma spikes that are triggered by pollution.

6. CONCLUSION

Smart inhalers can overcome the problems faced by patients and health care professionals. The prototype is created for proper treatment of asthmatic patients, this system is designed to provide solution for asthmatic patients who need aid with medication and monitoring. The quality of life can be enhanced and regulated as it is an assistive device. All the primary features in the system have been successfully planned, created, and tested. Several modules have been used to implement the system. The battery management and voltage regulation are both handled by the power supply which is made by six lithium-ion cells. The suggested architecture collects and aggregates data relevant to the individual, analyses the data, and provides immediate and individualized information using Arduino IOT and cloud services. The device can be connected with any mobile phone through software of Arduino IOT cloud; you need a username and password for the login. The results will appear on Arduino IOT cloud, serial monitor. The time and date are displayed along with the status of motor, whether it is on or off, on the LCD. This system is designed in such a way which will be helpful for healthcare professionals as well to understand the patient's condition more accurately over a period. Smart inhaler reminds the patient about the doses to take in a day and keeps a record of it for further improvement, and also helps in intake of the drug properly with a particular flow rate that is prescribed.

Acknowledgements

None.

Disclosure Statement

No potential conflict of interest was reported by the authors.

Funding Source

The authors received No funding to conduct this study.

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