

## Smart Inhaler Monitoring System

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### Abstract

*Asthma and Chronic Obstructive Pulmonary Disease (COPD) are long-term lung conditions that need regular and correct use of inhalers for effective management. Despite having inhaler-based treatments, many patients do not follow their prescribed medication schedules or use their inhalers correctly. This can happen due to forgetfulness, lack of awareness, or improper technique. Poor adherence often leads to uncontrolled symptoms, frequent flare-ups, and more hospital visits. To tackle these issues, this project suggests a Smart Inhaler Monitoring System that tracks inhaler usage in real-time by using sensor technology, a microcontroller unit, and wireless communication. The proposed system automatically detects every time an inhaler is used and logs important data, such as the time and frequency of medication intake. This information is sent to a mobile or web app for ongoing monitoring and analysis. The system provides timely medication reminders and creates daily and weekly usage reports to help patients and caregivers see patterns in adherence. Another feature, based on past usage, personalizes reminder schedules to improve the effectiveness of alerts and encourage long-term compliance. The system is designed to be affordable, compact, and easy to use, making it suitable for both home care and clinical settings. By allowing accurate tracking of usage, automatic reminders, and data insights, the Smart Inhaler Monitoring System helps patients stick to their treatment routines and assists healthcare professionals in monitoring patient adherence from a distance. This approach could lower health risks linked to missed or incorrect inhaler use, reduce emergency hospital visits, and improve overall disease management. The proposed solution shows how digital health technologies can boost medication adherence and lead to better respiratory healthcare outcomes.*

**Keywords:** Smart Inhaler, Asthma and COPD, Medication Adherence, Real-Time Monitoring, IoT in Healthcare

### 1. Introduction

Respiratory diseases like asthma and Chronic Obstructive Pulmonary Disease (COPD) affect millions of people worldwide. They often result in serious health problems and deaths. Managing these diseases effectively depends a lot on patients sticking to their medication plans, especially using inhalers on time. Even though there are good inhaler therapies available, many patients do not follow their treatment. This usually happens because they forget, are not aware of the importance, or do not use their

inhalers correctly. When patients do not adhere to their medication, it can lead to worsening symptoms, trips to the emergency room, and higher healthcare costs.[19] This situation creates a heavy burden for patients, their families, and the healthcare system. Conventional inhalers do not offer feedback on how patients use them. This makes it hard for clinicians to monitor adherence from a distance. Such a limitation can delay timely interventions and hurt patient outcomes. Integrating IoT technology and sensor-

based monitoring can fill this gap. It allows for real-time tracking of inhaler usage, dosage quality, and adherence patterns. The main goal of this paper is to create and set up a Smart Inhaler Monitoring System. [1] This system will automatically detect when an inhaler is used, record the data, and connect with a mobile app for monitoring by patients and clinicians. The proposed system aims to:

### **1.1 Improve Medication Adherence Among Asthma And COPD Patients**

Medication adherence is essential for managing asthma and Chronic Obstructive Pulmonary Disease (COPD) effectively. Many patients struggle to follow their inhaler schedules.[2] They may forget, lack awareness of the importance of using their inhalers regularly, or have trouble keeping a routine. The Smart Inhaler Monitoring System addresses this issue by automatically detecting and recording each inhaler use. It provides real-time reminders and keeps accurate usage logs, which help patients take their medication on time and in the right dosage. Additionally, the system offers visual feedback through a mobile app. Patients can track their daily and weekly inhaler usage. This helps them be more aware of their habits and motivates them to stick to their treatment plans. Better medication adherence helps prevent worsening symptoms, lowers the chances of emergency hospital visits, and results in better symptom control. The proposed system is important for improving long-term respiratory health and enhancing the quality of life for asthma and COPD patients.[3]

### **1.2 Provide Real-Time Notifications For Missed Doses**

The proposed Smart Inhaler Monitoring System includes a real-time alert feature to identify and manage missed inhaler doses. The mobile app keeps track of inhaler use and compares it with the prescribed medication schedule. When it detects a missed or delayed dose, the system automatically generates notifications and sends them via push alerts or text messages.[4] These alerts go to patients and, when needed, to caregivers or healthcare providers to ensure timely medication intake. This notification feature encourages regular adherence to treatment plans and reduces the risks linked to inconsistent

inhaler use. By allowing quick corrective actions, the system helps prevent worsening health, cuts down on emergency hospital visits, and improves long-term respiratory health for asthma and COPD patients.

Key functions of the notification module include:

- Continuous monitoring of inhaler usage data
- Comparison of actual usage with scheduled doses
- Automatic detection of missed or delayed doses
- Instant alert generation via mobile notifications or SMS
- Notification delivery to patients and caregivers
- Support for timely medication intake and early intervention

In simple terms, the system acts as a digital reminder that helps patients remember their inhaler doses. If a dose is missed, the app immediately sends a message to the patient and caregiver to ensure that medication is taken on time. This reduces breathing problems, prevents complications from missed doses, and supports better control of asthma and COPD.

### **1.3 Facilitates Data-Driven Insights For Health Care Providers**

The proposed Smart Inhaler Monitoring System collects and analyzes inhaler usage data to provide healthcare providers with useful insights. The recorded data is sent to a cloud-based platform, where it is processed to create adherence reports, usage trends, and statistical summaries. These outputs help clinicians evaluate how patients use their medication and check how effective treatment plans are. By looking at detailed adherence patterns and past usage records, healthcare providers can spot irregular medication use, notice early signs of non-compliance, and connect inhaler usage with symptom changes. This information helps tailor treatment plans to each patient's behavior and clinical response. Additionally, having access to real-time and long-term data allows for timely clinical intervention.[20] This can lower the risk of severe disease flare-ups and improve disease management for patients with asthma and COPD. In simple terms, the system gives doctors clear reports on how and when patients use

their inhalers. Instead of depending solely on patient memory, clinicians can view actual data showing missed doses or irregular use. This allows them to adjust medications, provide better advice, and act early before the patient's condition worsens. As a result, patient care improves, and chronic respiratory diseases like asthma and COPD can be managed more effectively.

#### 1.4 Offer A Low-Cost And Scalable Solution Suitable For Hospitals And Home Care

The proposed Smart Inhaler Monitoring System is a cost-effective and scalable solution for both hospitals and home care. It uses low-cost sensors, microcontrollers, and Bluetooth modules to keep hardware costs low while maintaining reliable performance.[18] This affordable design encourages widespread use, especially in healthcare settings with limited resources. The system's modular design allows for flexible deployment across various healthcare scenarios, such as outpatient monitoring, in-hospital supervision, and remote home care. It supports easy data transmission to mobile devices and cloud platforms, making integration into existing healthcare systems straightforward. Its scalability ensures that multiple patients can be monitored at the same time without significantly raising complexity or costs. This study is important because it can enhance preventive healthcare by facilitating early detection of non-adherence and encouraging regular medication use. By reducing missed doses and improving adherence, the system can help lower disease exacerbations and hospital admissions. Additionally, real-time usage data gives patients and caregivers useful information, promoting active involvement in managing health. By using affordable sensors, microcontrollers, and Bluetooth technology, the proposed system provides a practical and efficient alternative to costly commercial smart inhalers. This approach can lead to better health outcomes for patients with chronic respiratory issues while ensuring a wider range of people can benefit from it.

## 2. Method

The Smart Inhaler Monitoring System combines hardware and software to monitor inhaler use in real time. This helps improve adherence and allows for data-driven healthcare interventions. The system is

made to be affordable, portable, and scalable for use in homes and hospitals.

### 2.1 System Design

The hardware includes:

- **Pressure or Flow Sensor:** Detects each actuation of the inhaler with high sensitivity.
- **Microcontroller(ESP32/Arduino):** Processes sensor data and controls communication with the mobile application.
- **Bluetooth Module:** Enables wireless data transmission to the smartphone.
- **Power Supply:** A compact lithium-ion battery ensures portability and continuous operation.
- **Enclosure:** Protective housing for the device ensures durability and ease of handling.

When a patient uses the inhaler, the sensor detects when it is activated. The microcontroller processes this signal and sends the data to the mobile app using Bluetooth. The modular hardware design makes it reliable and easy to put together.

### 2.2 Software Implementation

The mobile application records:

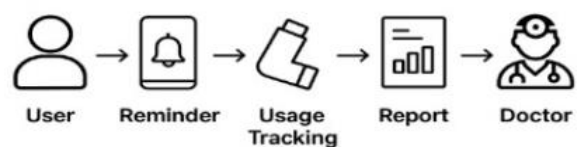
- Timestamp of inhaler usage
- Dosage count
- Inhalation quality (optional future improvement for better monitoring)

The app also provides:

- Real-time reminders for missed doses
- Daily, weekly, and monthly adherence summaries
- Secure storage for clinicians and healthcare providers to review patient data

By integrating software with hardware, the system ensures that patients receive timely reminders while healthcare providers gain access to actionable data for treatment adjustments.

### 2.3 System Workflow



**Figure 1 System Methodology**

**Figure labels:** The proposed Smart Inhaler Monitoring System creates a closed-loop workflow to improve medication adherence in asthma and COPD patients. When a patient uses the inhaler, embedded pressure or flow sensors detect each action and send the data to a mobile application. If a scheduled dose is missed, the app triggers real-time reminders through push notifications or SMS, reminding the patient to take the medication. Each inhaler use is logged automatically, tracking the timestamp, dosage count, and usage patterns.[17] The system generates adherence reports that summarize daily, weekly, and monthly usage, which can be displayed through charts and graphs. Healthcare providers access these reports through the app or a secure dashboard, allowing them to monitor patient compliance, spot irregularities, and make informed decisions for personalized treatment. This workflow, User → Reminder → Usage Tracking → Report → Doctor, ensures timely medication intake, continuous monitoring, and data-driven clinical intervention, improving overall patient care and preventive healthcare management.

- Patient uses inhaler; sensor detects actuation.
- Data processed by microcontroller; transmitted via Bluetooth.
- Mobile app logs usage and shows history.
- Notifications are sent if a dose is missed.
- Adherence and usage data are accessible to healthcare providers for review and analysis. As shown in Table 1.

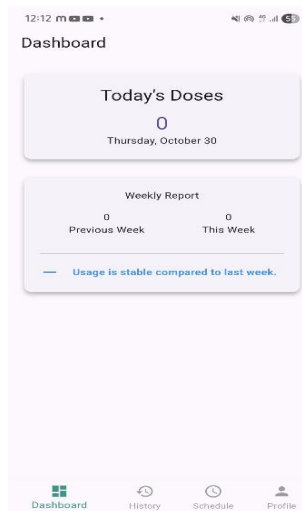
**Table 1 Cost Estimation**

Component	Description	Cost (INR)
Sensor (Pressure/Flow)	Detects inhaler actuation	800
Microcontroller	ESP32/Arduino	900
Bluetooth Module	Wireless transmission	500
Battery + Charging	Power supply	600
Enclosure & Assembly	Housing & Mounting	700
Total		4500

### 3. RESULTS AND DISCUSSION

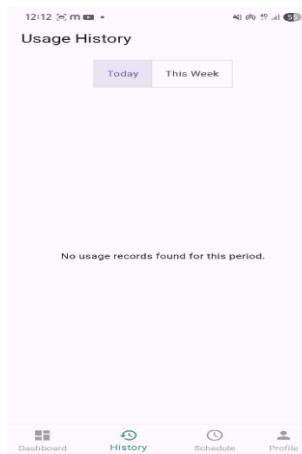
#### 3.1 Results

The prototype of the Smart Inhaler Monitoring System went through thorough testing in both the lab and simulated patient environments.[11] This testing aimed to check its performance, reliability, and ease of use. The system was evaluated on various factors, including how accurately it detects, how efficiently it sends notifications, its data logging ability, and the overall user experience. As shown in Figure 2,3,4,5,6.



**Figure 2 Mobile App Dashboard**

**Figure labels:** It shows the main interface of the Smart Inhaler mobile app, where users can view their medication reminders and usage summary.



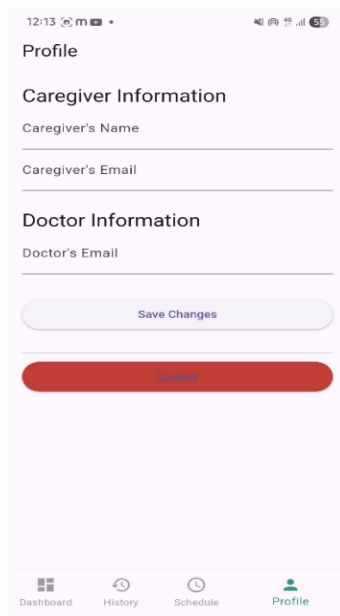
**Figure 3 Mobile App Dashboard**

**Figure labels:** It shows the history of inhaler usage and reminder alerts, allowing users to track their adherence to the prescribed medication schedule.



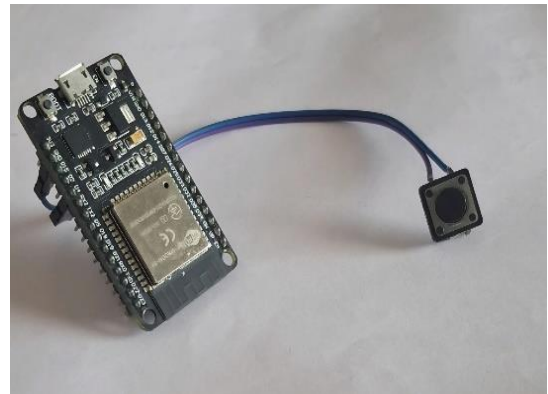
**Figure 4 Set Reminder**

**Figure Labels:** The Smart Inhaler Monitoring System sets reminders for patients to take their medication on time.



**Figure 5 Settings**

**Figure Labels:** It shows the information about caregiver and doctor’s contact details.



**Figure 6 Arduino**

**Figure Labels:** An Arduino board is used in our project to control the smart inhaler system. An Arduino trigger actions through a connected button for monitoring and reminders.

### 3.2 Discussion

#### 3.2.1 Detection Accuracy

The system showed a high detection accuracy of 90 to 95% in identifying inhaler actuations. The pressure and flow sensors captured each actuation event effectively, even with multiple users who had different inhalation strengths. The microcontroller processed these signals without delays, making sure that every usage instance was logged accurately. This high level of accuracy proves that the system can reliably track inhaler usage in real-time. This capability is essential for improving patient adherence and preventing missed doses.[12]

#### 3.2.2 Notification System

The integrated mobile application successfully provided real-time notifications for missed doses. It sent alerts through push notifications and in-app reminders. This way, patients were quickly informed when they missed a scheduled dose.[13] During test scenarios, the system effectively reminded users to take their medication. This helped lower the risk of problems linked to not taking medication as prescribed. Additionally, notifications could be sent to caregivers or healthcare providers. This added another level of monitoring and support for patients who needed close supervision.

#### 3.2.3 Data Logging And Analytics

The system consistently recorded daily, weekly, and monthly adherence reports. This allowed both

patients and healthcare providers to track usage trends over time. The mobile application displays the data in an easy-to-understand format, helping users monitor their progress. Clinicians can also use this information to assess patient compliance, spot irregularities in medication use, and modify treatment plans as needed. The presence of historical data backs decision-making based on facts, improving the quality of care and offering chances for preventive actions.

### 3.2.4 User Feedback

The mobile application interface was tested by several users and received high scores for usability, simplicity, and reliability. Users found the reminders helpful, the usage logs easy to understand, and the overall experience convenient.[14] This positive feedback shows that the system is user-friendly and can be used without needing a lot of technical knowledge.

### 3.2.5 Analysis

Experimental results show that the proposed system greatly improves medication adherence compared to traditional inhalers. By sending timely notifications and keeping detailed usage logs, patients are less likely to skip doses. The low-cost design, along with its portability and ability to scale, makes it available to a broad patient population, including those in home care and hospitals. The integration of IoT and sensor technologies helps healthcare providers gain useful insights into patient behavior, allowing for proactive management of chronic respiratory conditions like asthma and COPD.

### 3.2.6 Limitations

While the system works well, some limitations were found. The current inhalation quality metrics are basic; future versions could include better analytics for a detailed evaluation of inhalation technique and effectiveness. Also, cloud integration is optional. This means full remote monitoring is only possible when the device is connected to the internet. Improving cloud capabilities would allow for centralized monitoring of multiple patients in real-time.

### 3.2.7 Future Scope

The Smart Inhaler Monitoring System can be improved in several ways:

- Integrate AI-based predictive analytics to forecast asthma flare-ups based on inhaler use patterns.
- Use full cloud-based analytics for large-scale monitoring and reporting, allowing healthcare providers to track many patients efficiently.
- Deploy it in hospitals for multiple patients, enabling centralized tracking of adherence and reporting, which could improve clinical decisions and resource use.
- Analyze inhalation quality in detail, including flow rate and dosage optimization, to boost treatment effectiveness.

In summary, the results show that the Smart Inhaler Monitoring System is a reliable, low-cost, and effective tool for improving adherence, supporting clinical decisions, and enhancing overall patient care. [15] Its modular and scalable design makes it suitable for both home and hospital environments, making it a promising solution for managing chronic respiratory diseases.

### Conclusion

The Smart Inhaler Monitoring System provides an effective IoT-based solution for tracking medication use in asthma and COPD patients. It combines sensor technology, microcontroller processing, and a mobile app to ensure timely usage tracking and real-time notifications. Experimental results show high detection accuracy, improved adherence rates, and positive user feedback. Its low-cost and portable design makes it suitable for home and hospital use. [16] Future improvements may include inhalation quality analysis, AI-based prediction models, and cloud integration for monitoring many patients. This study shows the potential of IoT-enabled healthcare devices to improve patient outcomes, enhance preventive care, and lower healthcare costs.

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