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THE IMPORTANCE OF MONITORING ATMOSPHERIC AIR COMPONENTS FOR HUMAN LIFE.

ATMOSFERA HAVOSI TARKIBIDAGI KOMPONENTLARNI NAZORAT QILISHNING INSON HAYOTI UCHUN AHAMIYATI

ЗНАЧЕНИЕ КОНТРОЛЯ КОМПОНЕНТОВ АТМОСФЕРНОГО ВОЗДУХА ДЛЯ ЖИЗНИ ЧЕЛОВЕКА

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Annotatsiya. Ushbu maqolada atmosfera havosining tarkibini nazorat qilishning dolzarbligi, zamonaviy monitoring usullari hamda Arduino platformasiga asoslangan avtomatlashtirilgan tizimlardan foydalanish imkoniyatlari tahlil qilingan. Tadqiqot davomida atmosfera havosining asosiy ko‘rsatkichlari — PM2.5 va PM10 zarrachalari, karbonat angidrid (CO_2), harorat va nisbiy namlik parametrlarini nazorat qilish masalalari ko‘rib chiqildi. Atmosfera monitoringida qo‘llaniladigan sensorlarning ishlash tamoyillari va ularning texnik xususiyatlari o‘rganildi. Shuningdek, Arduino platformasining arzonligi, ixchamligi, moslashuvchanligi hamda real vaqt rejimida ma’lumotlarni yig‘ish va uzatish imkoniyatlari tahlil qilindi. Tadqiqot natijalari atmosfera havosini monitoring qilishda zamonaviy mikroprotsessorli tizimlar samarali va istiqbolli yechim ekanligini ko‘rsatdi. Ushbu yondashuv ekologik monitoringni takomillashtirish, atrof-muhit holatini baholash va inson salomatligini himoya qilishda muhim ahamiyatga ega.

Kalit so‘zlar: atmosfera monitoringi, havo sifati, Arduino, sensorlar, PM2.5, PM10, ekologik nazorat.

Аннотация.В данной статье рассматриваются вопросы контроля состава атмосферного воздуха, современные методы мониторинга и возможности применения автоматизированных систем на базе платформы Arduino. В ходе исследования были проанализированы основные показатели качества атмосферного воздуха, такие как концентрации частиц PM2.5 и PM10, содержание углекислого газа (CO_2), температура и относительная влажность. Также изучены принципы работы сенсоров, применяемых для мониторинга окружающей среды, и их технические характеристики. Особое внимание уделено преимуществам платформы Arduino, включая её низкую стоимость, компактность, гибкость и возможность сбора и передачи данных в режиме реального времени. Полученные результаты показывают, что использование микроконтроллерных систем является эффективным и перспективным решением для мониторинга атмосферного воздуха. Данный подход способствует совершенствованию экологического контроля и повышению уровня защиты здоровья населения.

Ключевые слова: мониторинг атмосферы, качество воздуха, Arduino, сенсоры, PM2.5, PM10, экологический контроль.

Abstract. This article examines the importance of monitoring the composition of atmospheric air, modern monitoring methods, and the possibilities of using automated systems based on the Arduino platform. The study analyzes key air quality parameters such as PM2.5 and PM10 particulate matter, carbon dioxide (CO_2) concentration, temperature, and relative humidity. The operating principles and technical characteristics of sensors used for environmental monitoring are also investigated. Special attention is given to the advantages of the Arduino platform, including its low cost, compact size, flexibility, and ability to collect and transmit data in real time. The results of the study demonstrate that microcontroller-based systems provide an effective and promising solution for atmospheric air monitoring. This approach contributes to improving environmental monitoring systems and protecting public health.

Keywords: atmospheric monitoring, air quality, Arduino, sensors, PM2.5, PM10, environmental monitoring.

Introduction. Atmospheric air is one of the fundamental resources for human life, and monitoring its composition and quality is extremely important for ensuring environmental sustainability, protecting public health, and supporting economic development. When the components of air remain in their natural balance, favorable

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conditions are created for humans and other living organisms. However, in recent years the rapid growth of industrial enterprises, the increase in emissions from transportation, energy production processes, and the extensive use of chemical substances in agriculture have significantly disrupted the natural balance of the atmosphere. As a result, air pollution has become a serious environmental problem that poses a direct threat to human health and well-being.

According to the World Health Organization (WHO), more than seven million people worldwide die every year from diseases related to air pollution. In addition, statistics from the European Union indicate that more than 400,000 premature deaths occur annually due to poor air quality. This issue is also highly relevant in Uzbekistan, where atmospheric pollution is observed in large industrial regions and urban areas. For example, in Tashkent city the concentration of PM2.5 particles sometimes exceeds the permissible limits by 6–8 times, which has a negative impact on the health of the population.

Figure 1. Atmospheric air pollution and its effects on the environment.

The atmosphere is composed of several major gases that naturally exist in relatively stable proportions. The dominant components include nitrogen (N_2), oxygen (O_2), argon (Ar), carbon dioxide (CO_2), and water vapor. Under natural conditions, the balance of these components ensures the stability of ecological systems and supports the life of living organisms. However, human activities have significantly altered this balance. Industrial emissions, vehicle exhaust gases, energy production processes, and intensive agricultural practices have led to a considerable increase in the concentration of harmful pollutants such as carbon monoxide (CO), nitrogen oxides (NOx), sulfur dioxide (SO_2), methane (CH_4), and fine particulate matter including PM2.5 and PM10.

Among these pollutants, fine particulate matter is considered particularly dangerous due to its ability to penetrate deeply into the human respiratory system. Scientific studies have shown that prolonged exposure to PM2.5 and PM10 particles can contribute to serious health problems, including respiratory diseases, cardiovascular disorders, and other chronic conditions. Therefore, the monitoring and management of air quality have become global priorities in environmental protection and public health policies.

In many developed countries, atmospheric monitoring systems have been widely implemented using automated stations and advanced sensor technologies. For example, the AirNow system in the United States and the Copernicus Atmosphere Monitoring Service in Europe provide real-time information about air quality conditions to the public. These monitoring platforms not only provide environmental data but also enable authorities and citizens to take preventive measures when pollution levels rise above safe limits.

In Uzbekistan, several initiatives aimed at monitoring atmospheric air quality have also been introduced. Monitoring stations have been established in major industrial cities such as Tashkent, Almalyk, and Angren. Despite these efforts, the spatial coverage of monitoring systems remains limited, and there is still a need to expand the infrastructure in order to achieve more comprehensive environmental control.

Scientific literature emphasizes that the development of automated air quality monitoring systems is important not only from an environmental perspective but also from an economic standpoint. The financial burden associated with treating diseases caused by air pollution places significant pressure on national healthcare systems and government budgets. Consequently, improving air monitoring technologies, integrating innovative solutions, and adapting international best practices to local conditions have become essential tasks for modern environmental management.

From this perspective, investigating the importance of monitoring atmospheric air components for human life is highly relevant. This study analyzes the environmental challenges associated with air pollution, existing monitoring technologies, international

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experiences, and innovative approaches aimed at improving atmospheric observation systems. The results of this research highlight the environmental, social, and economic significance of effective atmospheric monitoring.

Main Section

1. Scientific and Methodological Basis for Monitoring Atmospheric Air Components

Atmospheric air is one of the most critical factors for human life, and continuous monitoring of its composition and quality is essential not only for addressing environmental challenges but also for safeguarding public health. In the modern era, industrialization, the increase in the number of vehicles, energy production processes, and various manufacturing activities have led to the release of a wide range of harmful substances into the atmosphere. Among these pollutants, carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NOx), sulfur dioxide (SO_2), methane (CH_4), as well as fine particulate matter — PM2.5 and PM10 — stand out as particularly hazardous components.

Several factors influence air quality, including industrial emissions, vehicular exhaust, combustion processes, and natural sources. To highlight the components that most significantly impact human health, Table 1 presents their main sources and associated health risks.

Table 1. Major air pollutants, their sources, and health impacts

Component	Main Sources	Impact on Human Health
CO_2	Vehicles, Industry	Can affect respiratory efficiency and contribute to long-term climate change
CO	Transport emissions	Reduces oxygen transport in the blood, leading to cardiovascular issues
PM2.5, PM10	Dust, combustion products	Can penetrate deep into the lungs, causing respiratory diseases, asthma, and cardiovascular disorders

SO_2	Energy production, industrial plants	Irritates respiratory tract, contributes to acid rain
NO_2	Transport, industrial emissions	Causes allergies, bronchitis, and contributes to greenhouse effects

Accurate measurement and continuous monitoring of these air pollutants serve as a crucial component in the formulation of evidence-based environmental policies and in promoting a healthy lifestyle among the population. Traditional methods, such as laboratory analyses and stationary monitoring stations, have been widely used. However, these approaches are often time-consuming, expensive, and limited in their capacity to cover multiple areas simultaneously.

Consequently, in recent years, significant attention has been directed toward automated air quality monitoring systems. Using automatic sensors, atmospheric gases and particulate matter can be measured online, with results transmitted in real-time to computer databases. The advantages of these systems include continuous operation, extensive spatial coverage, and a reduction of human-induced errors.

Advancements in modern science and technology have further enhanced the efficiency of this process. Specifically, microprocessor- and microcontroller-based systems, particularly solutions built on the Arduino platform, have begun to play a significant role in environmental monitoring. Arduino-based devices are relatively inexpensive, user-friendly, and offer flexible programming capabilities, making them widely applicable in scientific research, educational settings, and practical fieldwork.

As a contemporary approach to air quality monitoring, the use of Arduino-based automated systems is increasingly becoming a priority. Unlike traditional stationary stations, these systems are compact, portable, cost-effective, and provide the general public with accessible information about environmental conditions.

2. Methods of Air Quality Monitoring and Advantages of the Arduino Platform

Air quality is an integral part of human life and activity, and monitoring its condition has been a critical issue since ancient times. Adequate oxygen levels in the air support vital biological processes, whereas the accumulation of harmful gases and particulate matter

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has severe negative impacts on human health, ecological systems, and overall societal development. Consequently, the regular monitoring of atmospheric air has become one of the most important global tasks today.

Figure 2. Air Quality Monitoring Station

Traditional Methods of Air Quality Monitoring.Early approaches to air monitoring involved collecting samples in specialized containers and conducting chemical analyses in laboratory conditions. These methods are highly accurate and allow precise measurement of various gases, dust, and other harmful substances in the atmosphere. For instance, titrimetric and gravimetric techniques can determine the concentrations of SO_2, NO_2, and other components in the air.

However, laboratory-based methods have several limitations: they are time-consuming, require substantial financial resources, and do not provide real-time monitoring. Additionally, the properties of collected samples may change before they reach the laboratory, affecting the accuracy of the results.

To overcome these limitations, stationary automatic monitoring stations were later developed. These stations are permanently installed in specific areas and continuously measure key gases and harmful substances in the atmosphere. Compared to laboratory methods, these stations are more efficient and faster, providing a comprehensive assessment of air quality. In many large cities, specialized automated environmental

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monitoring stations detect gases such as CO_2, CO, NO_2, and SO_2, as well as particulate matter like PM2.5 and PM10. Nevertheless, such stations are very expensive, and it is often not feasible to install enough units to cover all urban areas adequately.

Modern Approaches and Compact Monitoring Systems

With the advancement of technology, new forms of air quality monitoring have emerged—mobile and compact systems. These devices are cost-effective, portable, and accessible to the general public. For example, mobile systems built on small sensors are used in schools, universities, and research centers for educational and experimental purposes. Moreover, community-based initiatives allow ordinary citizens to measure air quality directly.

Table 2 presents modern devices and methods used for air quality monitoring.

Sensor Name	Measured Parameter	Measurement Range	Advantages	Application Area
DHT22	Temperature and Humidity	-40 to +80°C, 0–100% RH	Low cost, reliable performance	General environmental monitoring
MQ-135	CO_2, NH_3, Benzene	10–1000 ppm	Capable of detecting multiple gas components	Industrial and residential areas
PMS5003	PM2.5, PM10	0–500 µg/m³	High measurement accuracy	Urban air quality monitoring
CCS811	CO_2 and VOC	400–8192 ppm	Compact size and easy integration	Indoor air quality monitoring

Arduino-based monitoring systems represent one of the most compact and efficient solutions for environmental monitoring applications.

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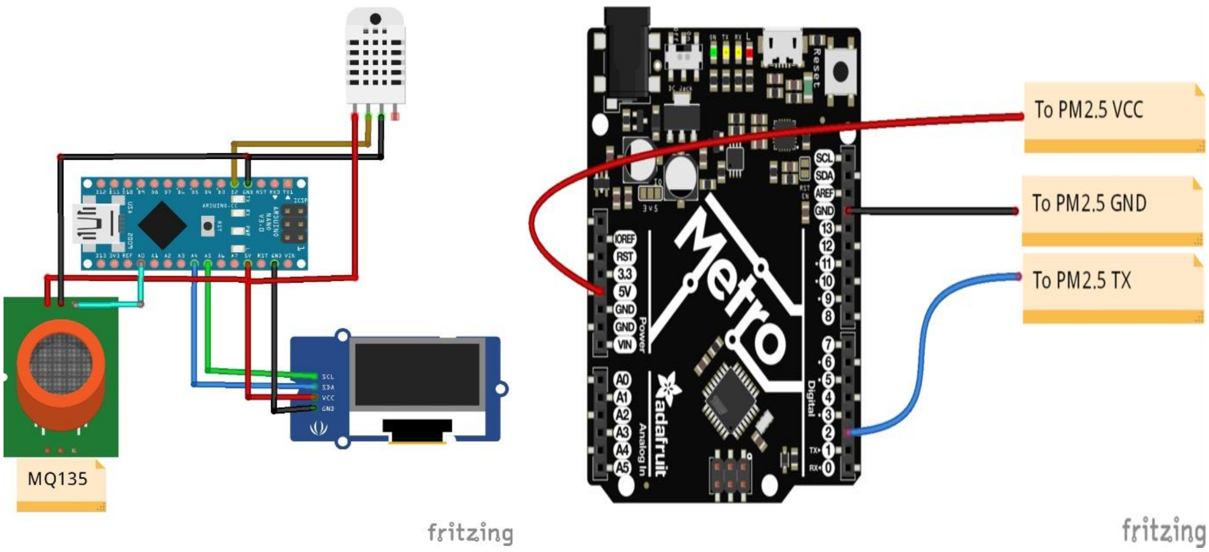

Figure 3. Arduino-based atmospheric monitoring system

Advantages of the Arduino Platform.Arduino is an open-source microcontroller platform that stands out among similar systems due to its simple interface, wide range of applications, and relatively low cost. Because of its compatibility with numerous sensors, ease of programming, and compact design, Arduino has become an effective tool for atmospheric monitoring systems.

The main advantages of the Arduino platform include the following:

Cost efficiency.Traditional stationary air-quality monitoring stations are expensive, whereas air-monitoring devices built on the Arduino platform can be assembled at a significantly lower cost. This affordability makes it possible to deploy such systems on a much wider scale.

Real-time measurement.By integrating various gas sensors, Arduino-based systems can detect and measure atmospheric components such as CO_2, CO, NO_2, SO_2, CH_4, O_3, as well as particulate matter including PM2.5 and PM10, in real time.

Flexibility.Multiple sensors can be integrated into a single system, enabling simultaneous monitoring of several environmental parameters such as air temperature, humidity, pressure, and the concentration of harmful substances.

Data transmission capability.Using communication modules such as Wi-Fi, GSM, or LoRa, collected data can be transmitted remotely and stored on servers. This allows the creation of shared monitoring databases that can be accessed from different locations.

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Compact and portable design.Arduino-based monitoring devices can be assembled in a compact form, making them suitable for use in schools, university laboratories, industrial areas, and residential environments.

Open programming environment.The Arduino IDE is freely available and supports programming in a simplified C/C++ language. This makes the platform particularly convenient for students, young researchers, and environmental technology startups.

Practical Applications.Currently, Arduino-based atmospheric monitoring systems are being implemented in many countries around the world. For example:

In the United States, the Air Quality Egg project encourages citizens to monitor air quality using Arduino-based devices and various sensors, with the collected data shared online through a collaborative database.

In several European countries, environmental startups are developing low-cost monitoring devices based on Arduino technology and distributing them to schools and universities. This not only increases young people's awareness of environmental issues but also facilitates scientific observation and data collection.

In Uzbekistan, similar initiatives have begun to emerge in recent years. Students and young researchers are increasingly developing Arduino-based monitoring projects, which are used both for scientific research and for educational purposes.

3. Sensors Used in Atmospheric Monitoring and Their Operating Principles

To accurately assess the state of atmospheric air, continuous monitoring of its physical and chemical composition is required. This process involves measuring parameters such as the concentration of harmful gases, particulate matter, temperature, humidity, and carbon dioxide levels. Modern automated monitoring systems rely on different types of electronic sensors to perform these measurements.

In Arduino-based systems, sensors serve as the primary sources of environmental data. They collect information from the surrounding environment, which is then transmitted to the microcontroller for processing and analysis.

*Gas Sensors in Air Quality Monitoring.*Gas sensors play a crucial role in atmospheric monitoring, as they are used to detect the concentration of harmful gases in the air. The widely used MQ series sensors are based on semiconductor technology. Their operation relies on the change in electrical resistance of the SnO_2 (tin oxide) layer. When the concentration of gases in the air increases, chemical reactions occur on the sensor

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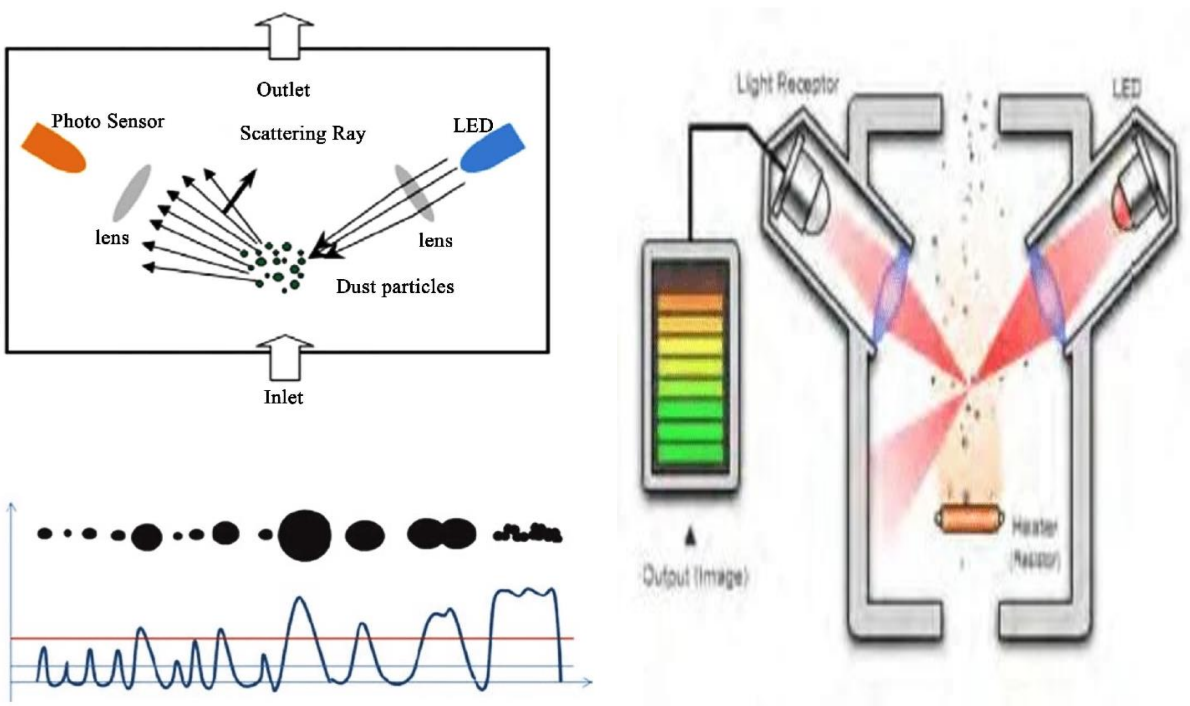
surface, resulting in changes in the electrical signal. This signal is then received by an Arduino microcontroller through analog inputs and converted into digital values.

Although gas sensors are affordable and sensitive to a wide range of gases, precise measurements require prior calibration to ensure accuracy.

*Particulate Matter Sensors.*Determining the level of air pollution also involves monitoring suspended particulate matter, particularly PM2.5 and PM10, which pose significant health risks. Particulate matter sensors generally operate on optical principles. Inside the sensor, a light source and a photodetector are arranged so that particles passing through the air scatter the light. The intensity of the scattered light is proportional to the concentration of particles, allowing accurate measurement of airborne particulate matter..



4. Sensors Integration and Experimental Results

Laser Particle Sensor Operation

The intensity of scattered light in a laser particle sensor is directly proportional to the number of airborne particles. The sensor’s internal processing unit converts this optical signal into quantitative particle concentration values. An Arduino microcontroller receives this information through a digital interface, enabling real-time data processing for further analysis.

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*Temperature and Humidity Monitoring.*Physical parameters such as temperature and humidity play a significant role in air quality assessment, as they directly affect the dispersion of gases and particulate matter. The DHT22 sensor is commonly used for this purpose, measuring humidity via a capacitive element and temperature using an internal thermistor. Data from the sensor are converted into digital signals and transmitted to the Arduino. For applications requiring higher accuracy, integrated sensors capable of measuring atmospheric pressure are also employed, providing a more complete environmental assessment.

*Carbon Dioxide Measurement.*Monitoring CO_2 levels is another essential aspect of air quality assessment. Infrared absorption sensors are typically used to determine CO_2 concentration by measuring the absorption of infrared radiation by CO_2 molecules. These sensors provide stable, long-term measurements, which are crucial for accurate monitoring. The Arduino platform receives the data digitally, integrating it into the system's processing algorithm.

*Data Processing and Analysis.*All sensor data are processed by the Arduino microcontroller. Signals from analog sensors are digitized using analog-to-digital converters, while digital sensors transmit data directly. Software organizes and filters the data, presenting real-time measurements to the user. Information can be displayed locally on a screen or transmitted remotely to servers via wireless communication.

Experimental Results.An Arduino-based automated air monitoring system was developed and tested. The system included gas sensors, particulate matter sensors, temperature and humidity sensors, and a CO_2 sensor. It was capable of collecting, processing, and displaying real-time data.

The experiment was conducted over three days, with multiple measurements recorded each day to calculate average values. Observations included atmospheric temperature, relative humidity, PM2.5 and PM10 concentrations, and CO_2 levels. The results indicated that the ambient temperature ranged between 28–30°C, while relative humidity remained between 40–45%. Under these conditions, particle suspension times in the air increased. PM2.5 levels reached up to 50 µg/m³, and PM10 levels were approximately 70 µg/m³. These fluctuations were associated with increased vehicular traffic and decreased wind speeds.

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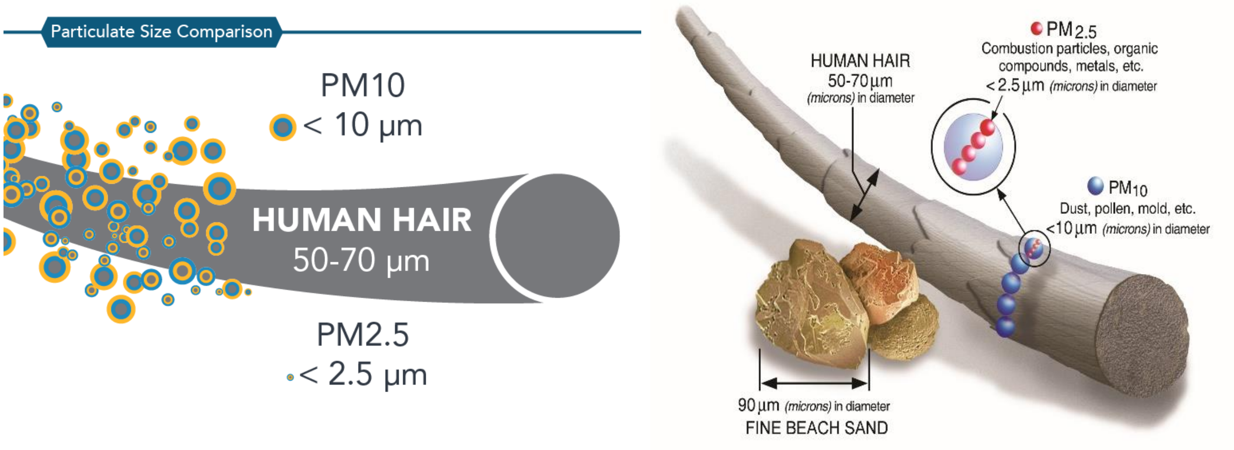

Figure 5. Comparison of PM2.5 and PM10 particle sizes

The concentration of carbon dioxide (CO_2) varied within the range of 480–530 ppm during the monitoring period. The obtained results indicate that in enclosed environments or in areas with high traffic intensity, the CO_2 concentration tends to increase. This observation confirms the influence of anthropogenic factors on atmospheric air quality.

The analysis of the collected data revealed a certain relationship between the concentration of particulate matter and ambient temperature. As the temperature increases, vertical air movement intensifies, which affects the distribution of particles in the atmosphere. Under conditions of higher humidity, fine particles tend to aggregate, increasing their mass and causing them to settle more rapidly in the lower layers of the atmosphere.

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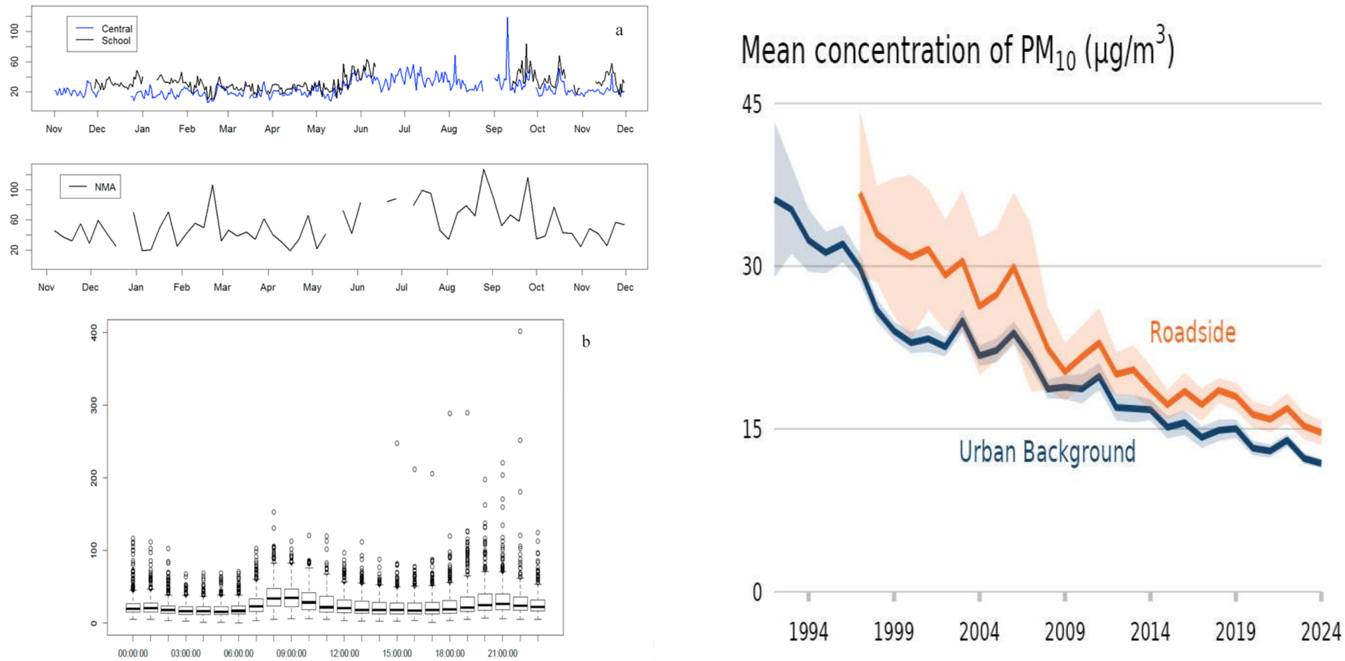
The Arduino-based monitoring system performed measurements consistently throughout the observation period. Data obtained from the sensors were continuously processed and displayed on the screen in real time. No operational interruptions were observed during the experiment, indicating that the developed device demonstrates sufficient reliability for



practical environmental monitoring applications.

Figure 6. Temporal Variation of Atmospheric Parameters

The obtained results indicate that the developed automated monitoring system effectively tracks key atmospheric parameters. Its affordability, modular design, and expandability make it a promising technological solution in the field of environmental monitoring.

Conclusion

This study analyzed the importance of monitoring atmospheric composition, existing monitoring methods, Arduino-based automated systems, and the sensors used in these processes. Experimental results demonstrated that continuous observation of harmful gases and fine particulate matter is crucial for human health, environmental sustainability, and economic considerations.

Although conventional laboratory and stationary monitoring methods provide high accuracy, their coverage is limited and they cannot operate in real time. Therefore,

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compact, affordable, and mobile monitoring systems based on the Arduino platform represent an effective approach to air quality management today. These systems not only collect real-time data but also allow remote data transmission, multi-sensor monitoring, and early detection of environmental hazards.

The collected data revealed that continuous tracking of PM2.5 and PM10 particles, CO_2 concentration, temperature, and humidity is essential for understanding the impact of human activity on air quality. Arduino-based systems, due to their low cost, compactness, and flexibility, can be widely applied in public initiatives, education, and scientific research.

From this perspective, developing efficient and comprehensive atmospheric monitoring systems, integrating innovative technologies, and adapting international experience to local conditions remain vital tasks for humanity. This research confirms that such monitoring is not only critical for controlling the ecological environment but also plays a significant role in protecting human health and ensuring the socio-economic stability of society.

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