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# Blockchain Based Iot System to Monitor Indor Environment*

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## Abstract

The article presents the design and implementation of a test stand aimed at monitoring and assessing the quality of the working environment in laboratory rooms. The proposed system integrates multiple Raspberry Pi microcomputers and environmental sensors to measure quantities such as temperature, humidity, pressure, light intensity, air quality and noise levels. These sensors continuously collect data on indoor environmental conditions, which is critical to ensuring compliance with health and safety standards, especially in hazardous materials laboratories. The system's distinguishing feature is the use of blockchain technology for secure, decentralized data exchange, ensuring immutability and transparency of data collected from sensors. Integration not only increases the reliability of data, but also enables effective audits to which the organization would be subject. Real-time monitoring capabilities enable proactive management of laboratory conditions, optimizing both worker safety and equipment performance. Potential applications include IoT-based environmental monitoring in laboratories, compliance with regulatory standards, and the development of decentralized data management for occupational health.

**Keywords:** IoT, Blockchain, Sensor-based environmental control systems, Indoor environmental quality (IEQ) in workspaces.

## Introduction

In laboratory environments, maintaining appropriate environmental conditions is critical to both human health and the reliability of the equipment used. Laboratories often face unique challenges due to the use of chemicals, biological agents, and sensitive instruments that require precise control of temperature, humidity, air quality, and noise levels. Failure to maintain these conditions can lead not only to a decrease in productivity and deterioration in the quality of tests, but also to health risks for personnel who may be exposed to harmful substances or unsafe working conditions. The need for reliable, continuous environmental monitoring is leading to the adoption of IoT solutions that offer the ability to monitor key parameters in real time using a network of connected sensors. IoT systems enable continuous data collection on factors such as temperature, humidity, air pollution, and noise levels, allowing for proactive adjustments to ensure a safe and compliant working environment. The problem has been noticed before and there is work aimed at developing Iot systems for controlling indoor environmental conditions [1], [2] . However, traditional systems for storing and managing environmental data often fail to provide the transparency and security necessary for regulatory compliance, data integrity, and long-term accountability. The data collected and stored in classic systems are susceptible to manipulation by authorities that want to maintain certification or prevent the creation of potential evidence that could be the basis for later claims by employees due to negligence in the field of occupational health and safety that could be committed by the employer. Data manipulation cannot occur when blockchain technology is used to store it. Decentralizing data storage and making it tamper-proof increases the reliability of monitoring systems and provides a reliable framework for both occupational health compliance and scientific research. Similar conclusions were reached by researchers

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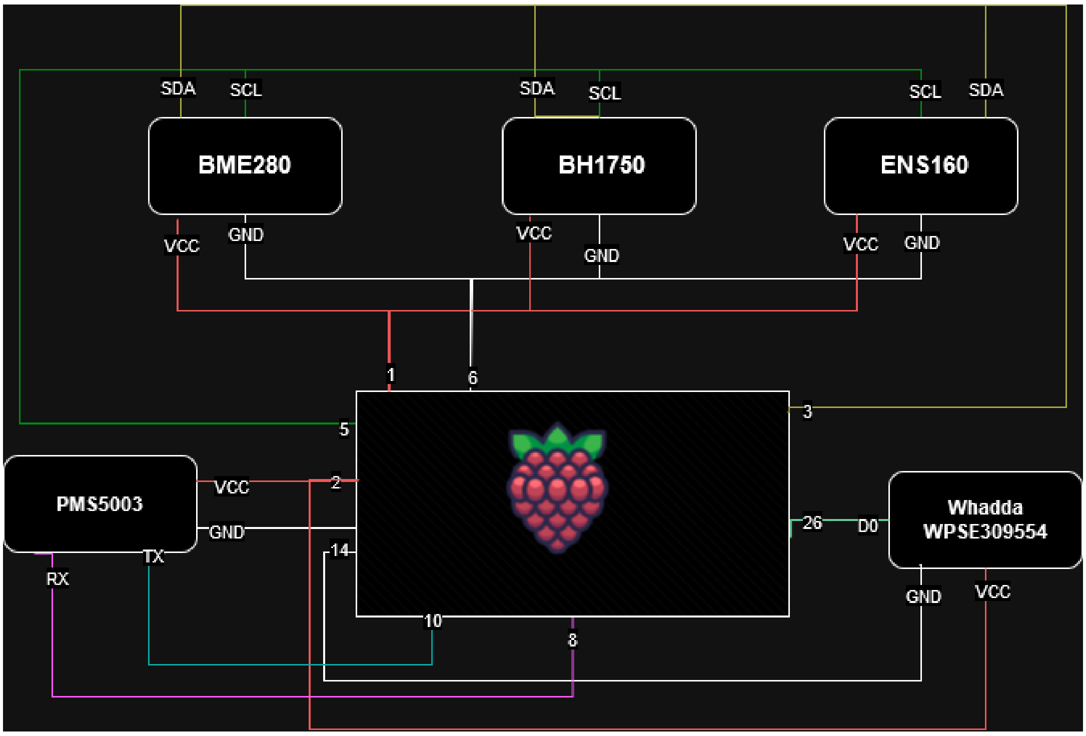
developing a system for monitoring construction sites [3] and dealing with the optimization of heat energy consumption in buildings [4]. This paper presents a research station designed to integrate IoT-based environmental monitoring with blockchain technology. The proposed system, consisting of Raspberry Pi microcomputers, environmental sensors and a blockchain platform, enables secure monitoring of laboratory conditions in real time and ensures the consistency and immutability of the stored data. The main goal of this research is to develop a system that not only ensures compliance with Polish regulations [5] and European Union on occupational safety in laboratories and the European Union [6], but also shows the advantages of using blockchain for transparent and tamper-proof data exchange. This approach aims to contribute to more efficient work environment management while enhancing blockchain's role in monitoring critical workspaces.

## Proposed solution

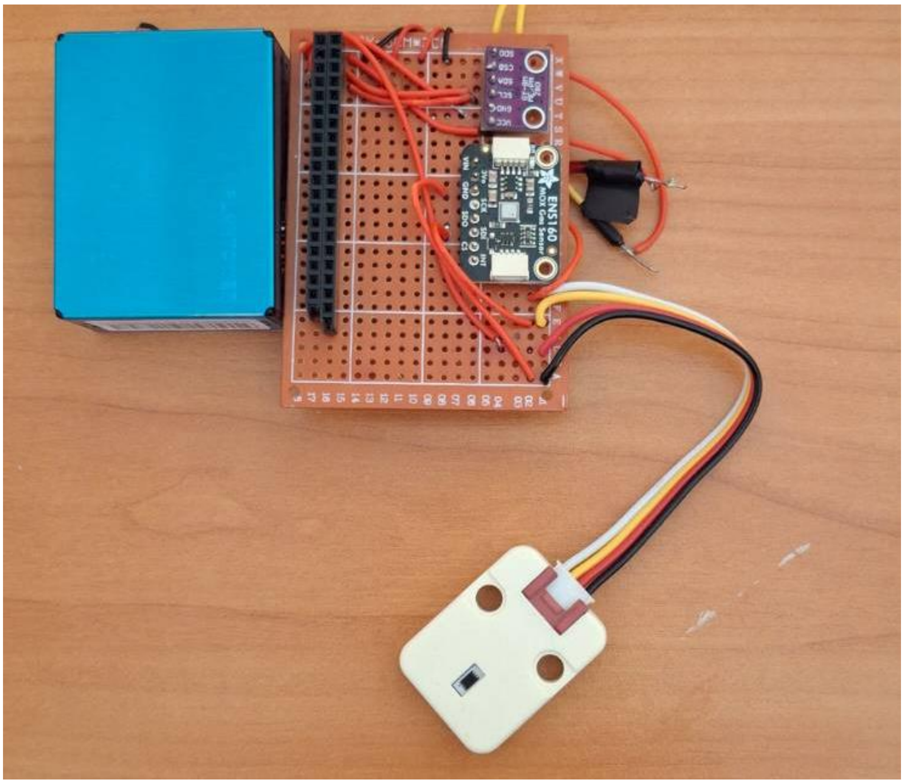
With new demands from organizations, there is a growing need to implement a distributed and secure way to manage the data collected by IoT devices. In the context of IoT, blockchain technology offers unique solutions that can significantly increase data integrity and the security of information exchange between devices. Traditional, centralized data storage systems are more susceptible to single points of failure and cyberattacks, which is especially important in laboratory environments where the accuracy of environmental data directly affects the quality of work and security. The use of blockchain makes it possible to store data in a permanent and immutable manner, which ensures its integrity and credibility, also in the eyes of accreditation institutions. As part of the proposed test system, all measurement data is collected by the Raspberry Pi Zero 2. They are stored permanently and securely. As a distributed Distributed database, the BigchainDB software was used in the research [7], which is part of the blockchain infrastructure, enables decentralized data management, eliminating the need for central servers and increasing the system's resilience to failures. The Raspberry Pi 5, thanks to its increased computing power and new PCIe support feature, plays an important role in the system architecture, especially as a blockchain network node. This is possible thanks to the new PCI Express interface, which allows you to connect external memory, which was previously impossible in this class of computers. This allows the device not only to have increased storage capacity, but also to process data more efficiently. This technical improvement strengthens the Raspberry Pi 5 in analyzing and storing data and coordinating its synchronization, ensuring the compatibility and availability of data on different nodes. This allows the blockchain infrastructure to work more efficiently and reliably in a decentralized environment, where the consistency and availability of data across locations are crucial to the integrity of the entire system. Blockchain technology also increases the security and transparency of information exchange between IoT devices, which minimizes the risk of unauthorized access or data manipulation. With the database distributed, every modification is recorded and verified, making the system more resilient to abuse and fully auditable. The small size and low power consumption of the Raspberry Pi Zero 2W units make them perfect for monitoring different locations, without taking up a lot of space and excessive power consumption, which is especially beneficial in conditions of limited access to energy sources. As part of the test station, the Raspberry Pi Zero 2W units are equipped with advanced environmental sensors that provide precise data on the quality of the working environment. The BME280 sensor measures basic atmospheric parameters such as temperature, humidity and pressure. The BH1750 sensor monitors light intensity, which allows you to assess the lighting conditions and their compliance with normative requirements [5]. Air quality is monitored by ENS160 sensors, which measure the concentration of gaseous pollutants, ensuring proper air quality in the laboratory, and by specialized air quality sensors, which measure the content of particulate matter, which is important for the health of employees and meeting hygiene requirements [6]. In addition, the system is equipped with a noise sensor that allows you to monitor the level of sound intensity, which affects the comfort and safety of work. A diagram of the design and arrangement of the sensors is shown in Drawing 1. The number of sensors in a single laboratory should be adapted to the shape and size of the room. Tests have shown that optimal results are achieved with sensor placements every 5-8 meters, with the minimum number of sensors per room not less than three, ensuring reliable and consistent environmental data.



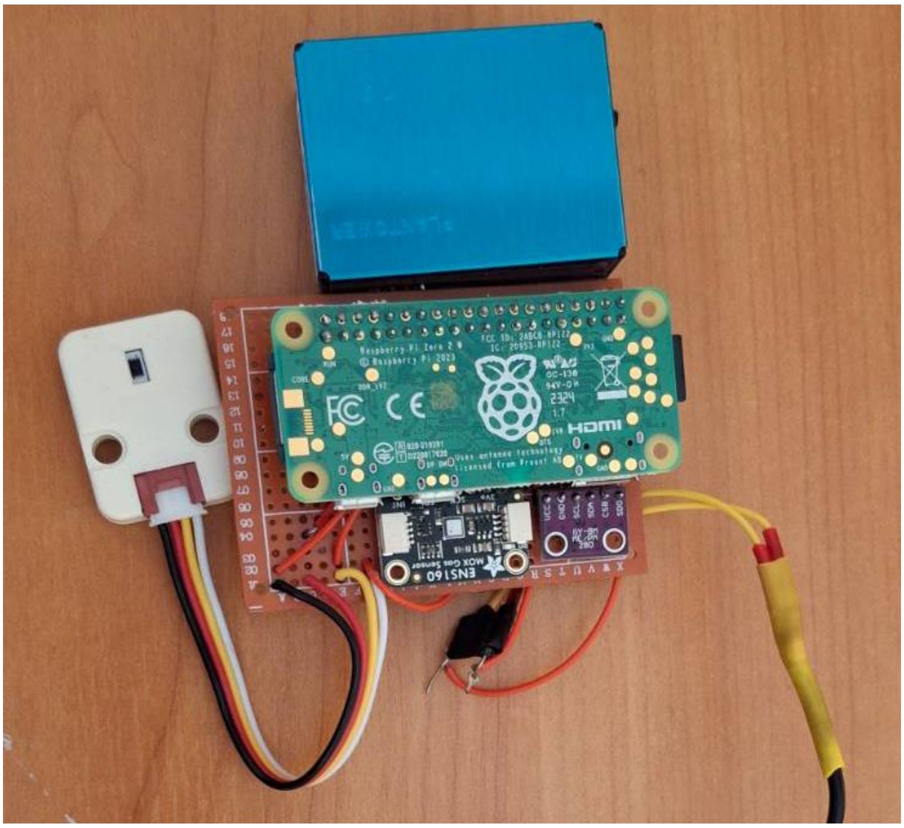

**Drawing 1 Diagram of the sensor based on Rasberry pi zero 2W [own study]**

## Developed solutions and tests

To ensure the reliability and accuracy of the measurements, the test station underwent a number of rigorous tests, which were an indispensable stage of preparation for its use in laboratory conditions. At the beginning, each of the sensors used underwent a calibration process to compare their results with the values obtained with the use of reference measuring devices. This allowed them to determine the precision of each device and identify possible deviations that could affect the quality and reliability of the results. In particular, the calibration of the sound sensor needed to be adjusted due to the hardware limitations of the Raspberry Pi, which does not have an analogue output. For this reason, the sensor has been configured to trigger a high signal on the digital output when the noise threshold value is exceeded, enabling precise signalling of alarm conditions. Then, research was carried out to monitor the results of measurements under various environmental conditions. These tests determined the impact of factors such as humidity, temperature and light intensity on the accuracy of individual sensors.

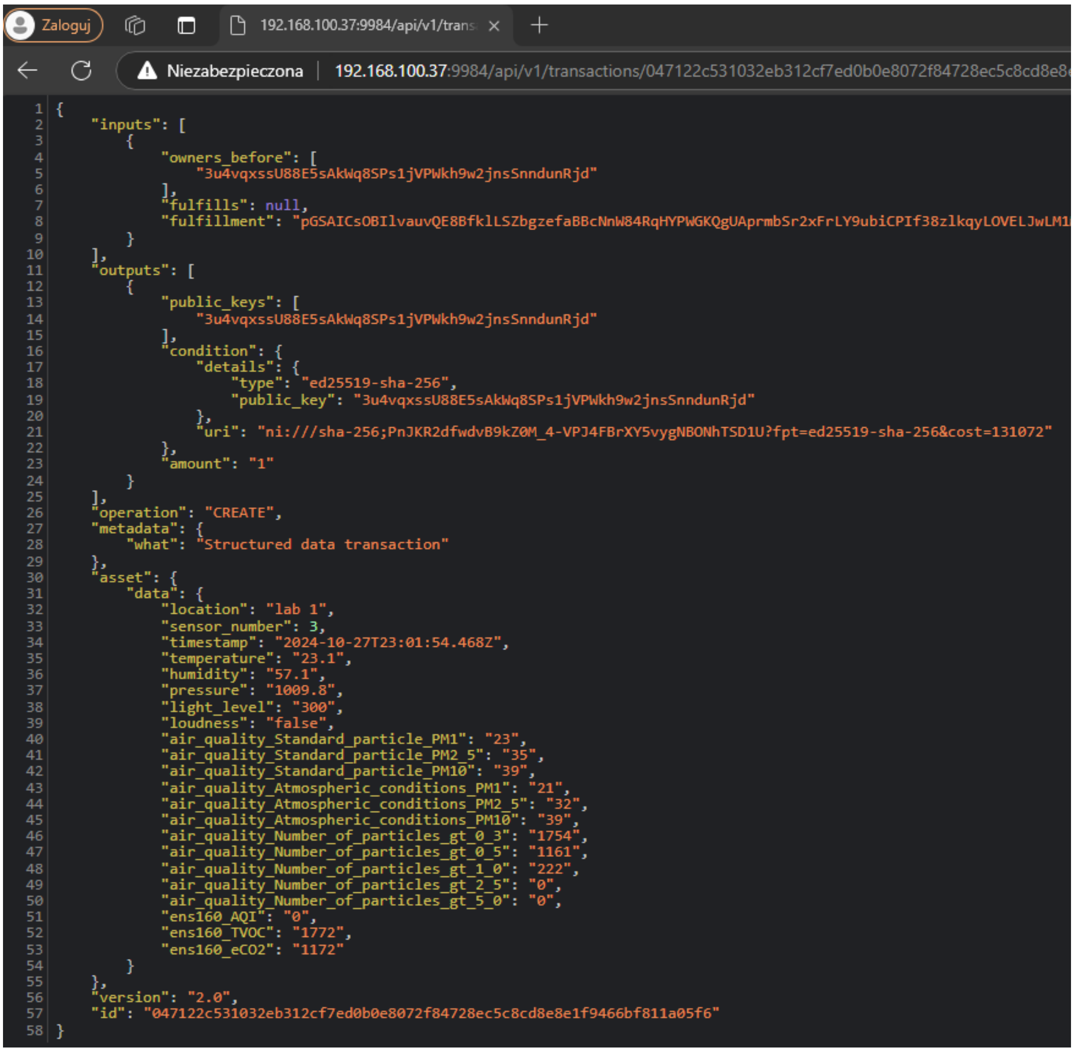



**Drawing 2 Author's overlay for measuring environmental conditions [own study]**




**Drawing 3 Raspberry Pi with a mounted overlay [own study]**

The analysis of the collected results was carried out in accordance with the guidelines contained in the literature [5] and [6], which confirmed that the data generated by the system are sufficiently accurate to meet the requirements for environmental monitoring in laboratories, especially in the context of ensuring high standards of occupational safety. Finally, the finished set of sensors integrated in the form of a dedicated overlay for the Raspberry Pi was tested in simulated operating conditions. This study, illustrated in Drawings 2 and 3, is characterized by a modular design, enabling its adaptation to various spatial conditions and measurement requirements. The measurements made by the research station are directly transmitted to the decentralized BigchainDB database, which allows data to be stored and secured using blockchain technology. BigchainDB offers a unique approach to measurement data management, combining high performance with security and resilience to modifications, which is a key element in ensuring the integrity of results. Storing data in BigchainDB eliminates the need for traditional, centralized servers, which are more susceptible to failures and attacks, and improves the flow of information between individual system components, such as the Raspberry Pi 5 and Raspberry Pi Zero 2W. BigchainDB Driver software [8] was used to enter data into the BigchainDB database, which turned out to be a convenient and efficient tool for real-time data transfer from various sensors. The software, used in the proprietary monitoring system, has been optimized for IoT networks, integrating data from sensors such as BME280, BH1750, ENS160 and noise sensors, which are able to monitor a variety of environmental parameters in laboratories, from temperature and humidity to air quality and sound levels. The introduction of such tools contributes to the improvement of data analysis and management through access to a detailed and consistent database, enabling quick insight into the conditions in a given room. Drawing 4 shows sample data recorded by one of the sensors, located in a laboratory room, recorded using blockchain technology. The use of blockchain in the data storage process allows for precise tracking and verification of historical data, as well as its subsequent analysis in the context of environmental changes over time. The integration of BigchainDB technology with IoT devices, such as Raspberry Pi, contributes to the creation of a permanent, immutable database that not only protects information from loss, but also enables its auditability and full transparency. Thanks to the use of a public database of identification numbers, arranged chronologically, each user with access to the network has the ability to easily verify the working conditions in which the data was stored. This database structure not only increases transparency, but also makes it easier to audit processes in the laboratory. In the context of visualizing data collected in the BigchainDB database, it is possible to integrate with Grafana, a popular open-source tool for data visualization. The plugins available for Grafana allow it to be effectively connected to distributed databases, which makes it easier to process and display information collected in real time. The use of Grafana allows for simple interpretation of environmental data through graphs, alerts and control panels that clearly present laboratory conditions, while enabling easy monitoring of the history of environmental parameters and quick response to changes. This integration introduces additional analytical capabilities, supporting a better understanding of dynamic changes and increasing transparency in the monitoring process.




**Drawing 4 Representation of those stored in the database [own study]**

## Conclusion

In conclusion, the use of distributed ledger technology (DLT) in laboratories brings a number of significant benefits that can significantly improve the quality and safety of work in this environment. First of all, DLT increases the transparency of operations by allowing each transaction to be verified, which builds trust in the data management system. Every piece of information collected is permanent, which means that it can be audited at any time and therefore fosters transparency and accountability. The high level of security that DLT offers is crucial in the context of data protection against manipulation and forgery. This type of safety is particularly important in laboratories, where occupational safety regulations are becoming more and more stringent. The implementation of DLT has the potential not only to increase the security and reliability of stored data, but also to become a key tool in confirming compliance with standards in the future. As regulatory regulations become stricter, DLT may prove essential for the effective monitoring and management of working conditions. This makes it possible to raise safety standards in laboratories and facilitate the accreditation process. However, in order for this solution to be widely used, regulatory organizations must meet the new technologies and pre-accept them. Only then will it be possible to successfully implement DLT in laboratories, which will further improve safety and quality of work.

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