Developing Indoor Air Quality Monitoring System Using Internet of Things and Wireless Sensor Network

Banu Santoso[1)*], Marti Widya Sari[2)]

[1)]FakultasIlmu Komputer, UniversitasAMIKOM Yogykarta, Jl. Ring Road Utara, Condongcatur, Sleman, Yogyakarta; Telp. (0274) 884201

[2)]Faculty of Science and Technology, Universitas PGRI Yogyakarta, Jl. PGRI I No. 117 Sonosewu, Yogyakarta; Telp. (0274) 376808

*Corresponding author: banu@amikom.ac.id

Abstract

Since Indoor air quality heavily affects human health, the problem of indoor air quality needs serious attention, especially when the air quality is unfriendly and containing smoke. Therefore, it requires monitoring system to determine the smoke level in a room. This study aims to develop an indoor air monitoring system based on IoT and WSN to ease the users for monitoring the air quality in the surrounding environment. The research methods employed through library research, surveys and field observations, development system and testing system. The application development stage includes analysis, system design, implementation, and testing. The air quality level monitoring application was built with the webbased programming language, MySQL database, and Arduino. The level of air pollution was measured by an MQ-2 sensor that serves to detect smoke levels and a web-based application to display information. The indoor air quality monitoring system is able to display the data result through website which can be accessed via the internet. Therefore, users can access the data from the smoke-level measurement of monitored surrounding environment. The testing of the system shows that this application is feasible and applicable to be used as a device to monitor indoor air quality levels.

Keywords:indoor air quality, monitoring system, sensors, wireless sensor network

1. INTRODUCTION

Indoor air quality greatly affects human health, since human spend more time living indoors than outdoors. Indoor air quality is influenced by human activities such as smoking and burning garbage in a room. Indoor air quality is an issue that requires attention due to its effect on human health (Alves et al., 2020; Aung et al., 2019). Indoor air pollution (indoor air pollution), especially in the house is very dangerous for human health, because in general people spend more time doing activities in the house so that the house becomes very important as a microenvironment related to the risk of air pollution (Becker et al., 2000). The impact of air pollutants in the home space on health can occur both directly and indirectly. Direct health problems can occur after exposure, including eye irritation, nasal and throat irritation, as well as headaches, nausea and muscle fatigue, including asthma, hypersensitivity pneumonia, flu and other viral diseases. Whereas indirect health impacts can occur several years later after exposure, including lung, heart disease and cancer, which are difficult to treat and have fatal consequences (Sedyaningsih, 2011).

Pollutant materials in houses, workplaces, or public buildings have different levels compared to the outdoor one. The increasing levels of indoor pollutant materials are not only from outdoor pollutants, but also sourced from indoor pollutants, such as cigarette smoke, kitchen smoke or the use of anti-mosquito burns (Kemp & Kemp, 2019). The continuing science and technology development encourages people to create something useful for others and individual which intend to provide convenience and protection from dangers such as cigarette smoke and fire that threaten human life at any time (Guo et al., 2020). In the development of technology, numerous facilities are automatically designed to assist human activities in regulating the safety and comfort of the indoor environment which requires a higher level of security (Gabriel et al., 2019), especially in a room that must avoid flames, smoke, and poisoned gases such as monoxide gas. This is intended to avoid room fires and poisoned gases that harm human breathing in the room (Becker et al., 2000).

Air pollution is produced directly by humans from the smoke content in the form of CO (Carbon Monoxide) gas found in everyday cigarettes burns, men and women who become active smokers are contributors of the gas (Guo et al., 2020). Accordingly, other humans as passive smokers can be affected as well as the natural surroundings. It is not only CO gas that is produced, but also there are still many other contents produced by the cigarette burn (Huang et al., 2020). Another issue that could be harmful to human being is the smoke from the kitchen which also potentially endangers human health such as coughing and sore eyes. Hence, this

situation must be anticipated to avoid excessive pollution in the room (Heo et al., 2019).

In developed countries the estimated annual mortality due to air pollution in home spaces is 67% in rural areas and 23% in urban areas, whereas in developing countries the mortality rate is related to air pollution in urban area housing spaces by 9% and in rural areas by 1%, of total deaths. Pneumonia is the leading cause of death in children under 5 years with a number of deaths of more than 2 million people each year (Sedyaningsih, 2011). The objective of this research is to develop an indoor air monitoring system based on IoT and WSN to ease the users for monitoring the air quality in the surrounding environment.

2. RELATED WORKS

Air quality monitoring is very important to detect pollutants that can damage the environment and endanger the health of living creatures. Therefore, monitoring pollutant gas data is very much needed, to prevent increasingly widespread air pollution (Schieweck et al., 2018). To measure smoke levels, data and information are needed both from measurements in the field and the results of analysis in the laboratory. One of the control and monitoring systems currently being developed is a Wireless Sensor Network (WSN) based system (Kristianto et al., 2019). WSN consists of individual nodes that capable to interact with their environment by sensing, controlling and communicating their physical parameters (Pule et al., 2018).

WSN has many applications, ranging from industrial monitoring projects, medical telemetry and environmental monitoring. This WSN-based application has different operational requirements, which is why many technicians adopt different WSN architectures, which are tailored to their needs. For military surveillance, for example, the main requirements required are high bandwidth, high security and wide network coverage. For industrial monitoring applications require requirements related to security, reliability and access in real time (Kemp & Kemp, 2019; Kristianto et al., 2019; Pule et al., 2018). In addition to using WSN, the system was also developed based on internet of things (IoT) technology. In IoT technology, data transfer can be done in two-way direction through the internet network (Santoso & Sari, 2019; Sari et al., 2017). IoT can integrate physical devices with computer systems smoothly from anywhere. The sensor is placed somewhere for monitoring purposes and the next process is carried out after analyzing the data. At present, a number of devices are equipped with sensors and processing devices, to help monitor and control various devices (Khare et al., 2020; Saleh & Hamad, 2017).

Research conducted by Lesmana and Rahayu (Lesmana & Rahayu, 2016) designed a room air quality monitoring instrument built using the MQ7 sensor as a measurement of carbon monoxide (CO), GP2Y1010AUOF sensor as a measurement of dust or particulate matter (PM10) and MQ131 sensor as a measurement of O3 gas. Graphical and numerical data displays were shown on a computer screen using LabVIEW software. To facilitate users, the data from the measurement of the room air quality index were presented using the air quality index standard regulated by the government - the Air Pollution Standard Index (PSI in Indonesian ISPU). Research about created a simulation of a room pollution detection system using smoke sensors with SMS (Short Message Service) notifications and Arduino-based alarms (Tri et al., 2016), and design of indoor air quality monitoring systems with TCP/IP communication based on ATMEGA16 microcontroller (Kim et al., 2012). This air quality monitoring system was able to identify the room temperature and dangerous air levels (such as carbon monoxide levels) in the room; subsequently provide indications and information to users.

Research conducted by Peng and Wang (Peng & Wang, 2019) to determine the level of smoke from forest fires, following this, they created an algorithm that combines manual features and deep learning features. There were several monitoring stations to check air quality levels in urban environments. Generally, these monitoring stations only carry out data acquisition of measured values from the sensor and store it in a database (Yu et al., 2017). The processing of measured results and statistical analysis were mainly carried out in different places where data were retrieved from various communication systems (Abraham & Li, 2014; Kušljevic et al., 2014). Measured data acquisition was usually carried out on-line while statistical processing and analysis was done off-line.

The effect of dust in the Sahara Desert was also investigated by Ku and Bourgouin (Ku & Bourgouin, 2018), using the Atmospheric Transfer Modeling system and the International Monitoring System. Research related to Air pollution was carried out in the city of Vila Real, Portugal, where the assessment of urban pollution and its effect on historical urban buildings was considered the main objective. The research was also supported by an environmental impact assessment study on historical buildings in the city (Silva et al., 2020).

3. METHODS

This research employed library research, surveys and field observations, system development and testing system. The application development stage included analysis, system design, implementation, and testing.

3.1. System Component

Arduino UNO is a microcontroller board that uses ATmega328. Arduino has 14 digital input / output pins of which 6 can be used as PWM outputs, 6 analog inputs, a 16 MHz crystal, USB connection, power jack, ICSP header, and reset button. The UNO is the most used and documented board of the whole Arduino family. Arduino technical specification shown in Table 1.

Table 1.   Arduino technical spesification

Item	Specification
Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
LED_BUILTIN	13
Length	68.6 mm
Width	53.4 mm
Weight	25 g

ESP8266 is an integrated chip component designed for the needs of today's connected world. This chip offers a complete and integrated Wi-Fi networking solution, which can be used as an application provider or to separate all Wi-Fi networking functions from other application processors. ESP8266 has on-board processing and storage capabilities that allow the chip to be integrated with sensors or with certain device applications via input output pins with only short programming. ESP8266 was developed by a developer from China named "Espressif". The ESP8266 series products are currently still in the development stage (current R&D: esp8266-32). ESP8266 itself is equipped with GPIO (General Purpose Input / Output). With this GPIO we can perform input or output functions like a microcontroller. For example, the ESP8266-01 series has 2 GPIOs, while the ESP8266-12E series has an analog read pin and several digital pins.

MQ2 smoke sensor is a sensor that is usually used to determine air quality or to determine the content that occurs in the air. The MQ2 sensor is made from gas-sensitive material, SnO2. If the sensor detects the presence of gas in the air with a certain level of concentration, the sensor will assume there is smoke in the air. When the sensor detects the presence of these gases, the sensor's electrical resis-

tance will decrease. By utilizing the working principle of this MQ 2 sensor, the smoke content can be measured.

3.2. System Design

The flowchart of the smoke level monitoring system design is presented in the following Figure 1, which illustrates the process of the system started by switching on the device so that the sensor works, as a result the sensor will transfer data to Arduino Uno and subsequently received by the ESP8266 WiFi module and send to the smoke level monitoring website.
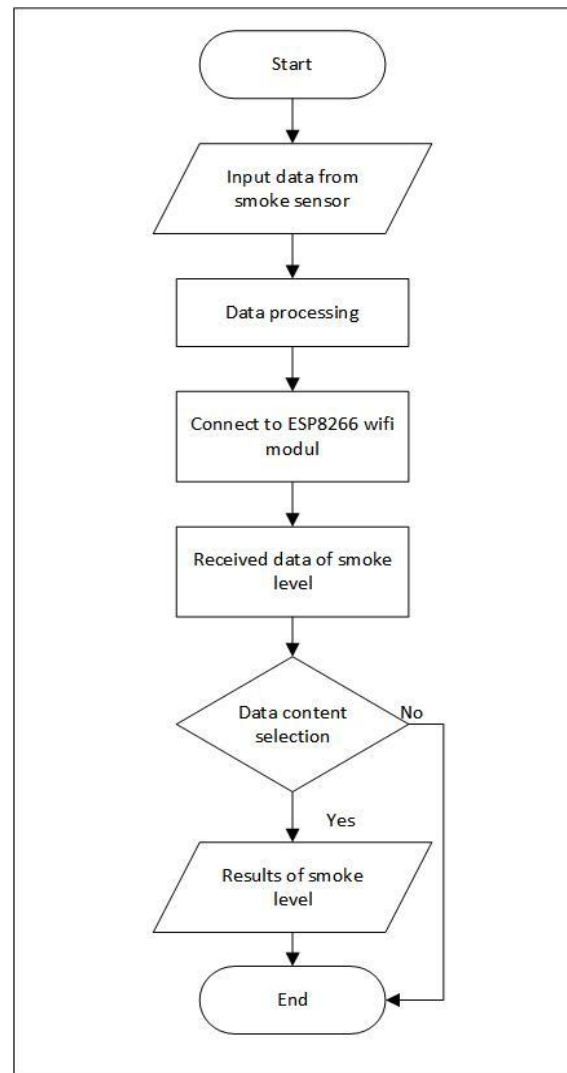

Figure 1. Flowchart of system

The Block diagram illustrates the workflow of the system, starting from the smoke detection by the smoke sensorMQ-2. MQ-2 sensor serves to determine the presence of carbon monoxide gas where this sensor is used to monitor smoke levels.
Accordingly, the data is sent to Arduino and the wifi module ESP 8266, the data will eventually be sent to the database server via the internet. The monitoring system can access the data of the smoke content on

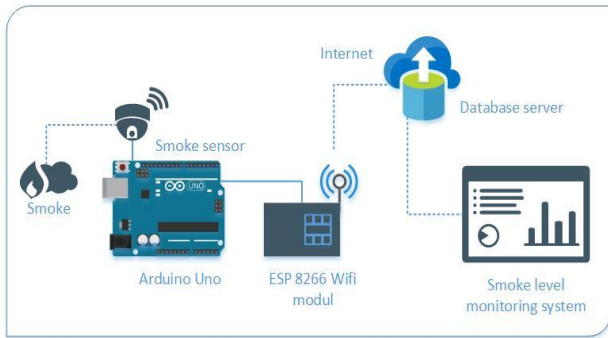the database server via the internet, as shown in Figure 2.

Figure 2. System block diagram

System testing is done by running the device and applications. In this study, the transparent box is used as a prototype of room installed smoke sensors.
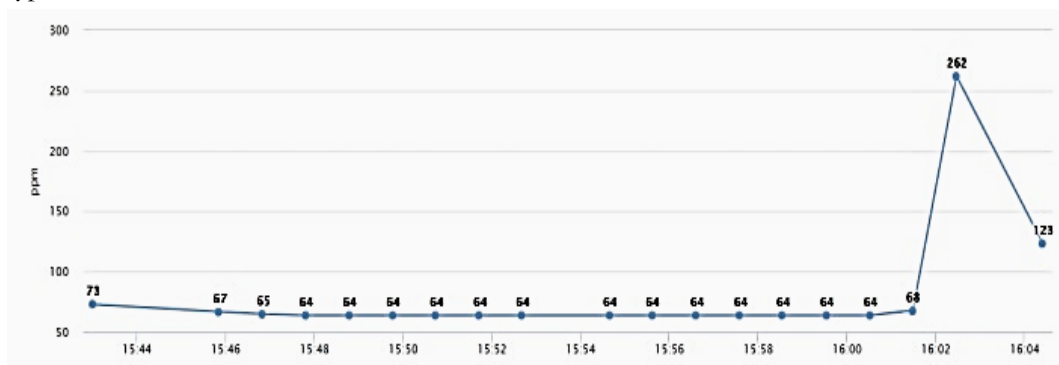
Furthermore, it can be seen the smoke level that is displayed through a web-based system monitoring application.

4. RESULTS AND DISCUSSION

System test results in the form of graph and table. The data on the graph shows the value of smoke level and time. The test results are presented in Figure 3 and Table 2. Smoke level sensor values are displayed in the form of a numerical line graph in ppm (parts per million). Figure 3 shows the highest point of smoke content which is 262 ppm at 16:02:28, while the smoke level is almost stable at 15:54:39 until 16:00:31, with a value of 64 ppm.

Figure 3. System results graphic

Table2. System testing results

No	Time	Smoke level (ppm)
1	16:04:25	123
2	16:02:28	262
3	16:01:29	68
4	16:00:31	64
5	15:59:32	64
6	15:58:33	64
7	15:57:35	64
8	15:56:36	64
9	15:55:37	64
10	15:54:39	64

Table 2 shows the results of the system testing which was carried out between 15:54 and 16:04.

The tests were conducted by 30 respondents to determine the overall system prototype performance, by assessing a number of parameters, namely: system performance, the use of prototype, and accuracy of the displayed data, as served in Figure 4, Figure 5 and Figure 6.

Figure 4 explains the System Performance that generally can be categorized as 'Very good' and is shown through the user test results of 70%. Figure 5

explains the Use of Prototypes, categorized as 'Easy' which is shown through the user test results of 57% and for the Accuracy Data in Figure 6 of 63% which is 'Very accurate' result.
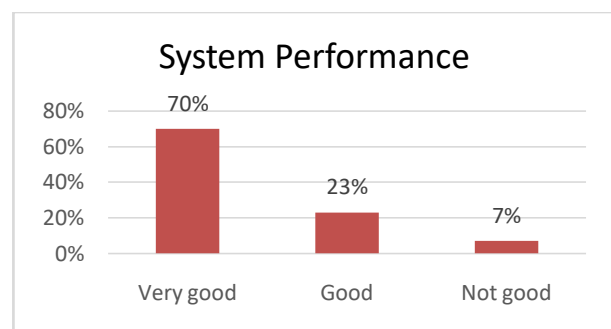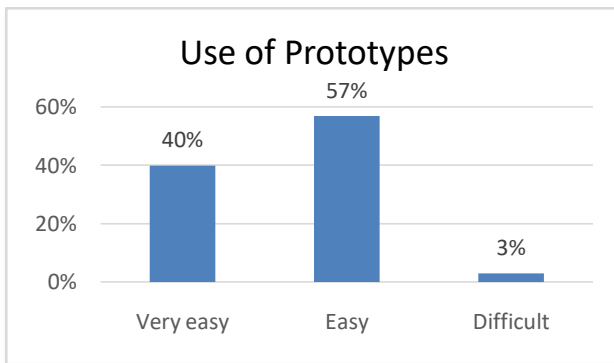

Figure 4. System performance
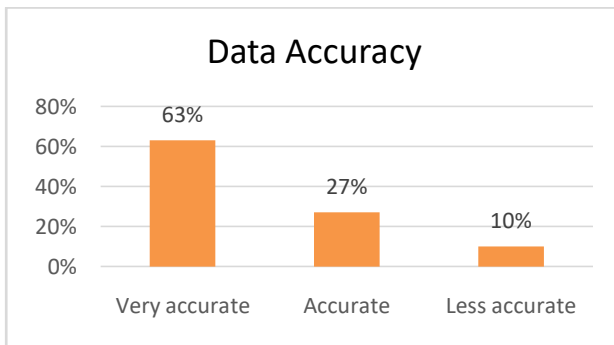
Figure 5. Use of protoypes

Figure 6. Data accuracy

The smoke sensor device series consists of MQ-2 sensors, Arduino UNO Microcontroller and Wifi ESP 8266 Module can be used to detect smoke in a room, and can be used to determine the level of smoke in the surrounding environment. The monitoring system application can provide information on the results of web-based smoke content monitoring. The advantage of a web-based monitoring system application is that it can be accessed from anywhere, thus, the smoke levels in a room can still be monitored.

5. CONCLUSION

To conclude, it is clearly explained that the prototype system is able to detect levels of smoke in a room. In addition, the web-based smoke level monitoring system can be accessed via the internet and it can display smoke levels in a room. However, this current research still has shortcomings – the prototype system is still made on a small scale, and the measurement of smoke content is only for indoors, in addition, this experiment only used one smoke sensor. Therefore, further research prototype system can be made in a wider scope or in outdoor areas, and coupled with other sensors, such as indoor temperature and light sensors.

6. REFERENCES

Abraham, S., & Li, X. 2014. A Cost-E ff ective Wireless Sensor Network System for Indoor Air Quality Monitoring Applications. Procedia - Procedia Computer Science, 34, 165–171. https://doi.org/10.1016/j.procs.2014.07.090

Alves, C. A., Vicente, E. D., Evtyugina, M., Vicente, A. M., Nunes, T., Lucarelli, F., Calzolai, G., Nava, S., Calvo, A. I., Alegre, B., Oduber, F., Castro, A., & Fraile, R. 2020. Indoor and outdoor air quality : A university cafeteria as a case study. Atmospheric Pollution Research, 11(3), 531–544. https://doi.org/10.1016/j.apr.2019.12.002

Aung, W., Noguchi, M., Yi, E. P., Thant, Z., & Uchiyama, S. 2019. Preliminary assessment of outdoor and indoor air quality in Yangon city , Myanmar. Atmospheric Pollution Research, 10(3), 722–730. https://doi.org/10.1016/j.apr.2018.11.011

Becker, T., Muhlberger, S., Braunmuhl, C. B., Ziemann, T., & Muller, G. 2000. Air pollution monitoring using tin-oxide-based microreactor systems. 108–119.

Gabriel, M. F., Felgueiras, F., Mourão, Z., & Fernandes, E. O. 2019. Assessment of the air quality in 20 public indoor swimming pools located in the Northern Region of Portugal. Environment International, 133(November), 105274. https://doi.org/10.1016/j.envint.2019.105274

Guo, J., Zhao, M., Xue, P., Liang, X., Fan, G., Ding, B., Liu, J., & Liu, J. 2020. New indicators for air quality and distribution characteristics of pollutants in China. Building and Environment, 106723. https://doi.org/10.1016/j.buildenv.2020.106723

Heo, S., Nam, K., Loy-benitez, J., Li, Q., Lee, S., & Yoo, C. 2019. Energy & Buildings A deep reinforcement learning-based autonomous ventilation control system for smart indoor air quality management in a subway station. Energy & Buildings, 202, 109440. https://doi.org/10.1016/j.enbuild.2019.109440

Huang, K., Sun, W., Feng, G., Wang, J., & Song, J. 2020. Indoor air quality analysis of 8 mechanically ventilated residential buildings in northeast China based on long-term monitoring. Sustainable Cities and Society, 54(November 2019), 101947. https://doi.org/10.1016/j.scs.2019.101947

Kemp, A. H., & Kemp, S. A. H. 2019. Real Time Wireless Wireless Sensor Network based Indoor Air Quality Monitoring System Monitoring System. IFAC PapersOnLine, 52(24), 324–327. https://doi.org/10.1016/j.ifacol.2019.12.430

Khare, A., Sharma, R., & Ahuja, N. J. 2020. Experimental Investigation of Integrated ID Method to Mitigate Message Loss in IOT Control Devices. 15(1), 32–45.

Kim, M., Sankararao, B., Kang, O., Kim, J., & Yoo, C. 2012. Monitoring and prediction of indoor air quality (IAQ) in subway or metro systems using season dependent models. Energy & Buildings, 46, 48–55. https://doi.org/10.1016/j.enbuild.2011.10.047

Kristianto, R. P., Santoso, B., & Sari, M. W. 2019. Integration of K-Means Clustering and Naïve Bayes Classification Algorithms for Smart AC Monitoring and Control in WSAN. 2019 4th International Conference on Information Technology, Information Systems and Electrical Engineering (ICITISEE), 495–500.

Ku, J., & Bourgouin, P. 2018. In fl uence of mineral dust on changes of 7 Be concentrations in air as measured by CTBTO global monitoring system. 192(July), 454–466. https://doi.org/10.1016/j.jenvrad.2018.07.015

Kušljevic, M., Vidakovic, M., & Rajs, V. 2014. Smart SCADA system for urban air pollution monitoring. 58, 138–146. https://doi.org/10.1016/j.measurement.2014.08.036

Lesmana, R. N., & Rahayu, Y. 2016. Membangun Sistem Pemantau Kualitas Udara Dalam Ruangan Dengan Mengaplikasikan Sensor CO Berbasis LabVIEW. Jom FTEKNIK, 3, 1–6.

Peng, Y., & Wang, Y. 2019. Real-time forest smoke detection using hand-designed features and deep learning. Computers and Electronics in Agriculture, 167(July), 105029. https://doi.org/10.1016/j.compag.2019.105029

Pule, M., Yahya, A., & Chuma, J. 2018. Wireless sensor networks : A survey on monitoring water quality. Revista Mexicana de Trastornos Alimentarios, 15(6), 562–570. https://doi.org/10.1016/j.jart.2017.07.004

Saleh, M. H., & Hamad, Q. S. H. 2017. WIRELESS HOME AUTOMATION SYSTEM BASED ON MICROCONTROLLER. 12(11), 3034–3043.

Santoso, B., & Sari, M. W. 2019. Design of Student Attendance System Using Internet of Things (IoT) Technology. Journal of Physics, 1254, 1–11. https://doi.org/10.1088/1742-6596/1254/1/012064

Sari, M. W., Ciptadi, P. W., & Hardyanto, R. H. 2017. Study of Smart Campus Development Using Internet of Things Technology. IOP Conference Series: Materials Science and Engineering, 190(1). https://doi.org/10.1088/1757-899X/190/1/012032

Schieweck, A., Uhde, E., Salthammer, T., Salthammer, L. C., & Morawska, L. 2018. Smart homes and the control of indoor air quality. Renewable and Sustainable Energy Reviews, 94(July), 705–718. https://doi.org/10.1016/j.rser.2018.05.057

Sedyaningsih, E. R. 2011. Peraturan Menteri Kesehatan Republik Indonesia Nomor 1077/Menkes/PER/V/2011 Tentang Pedoman Penyehatan Udara Dalam Ruang Rumah.

Silva, L. T., Mendes, B., & Silva, F. 2020. Contribution of an environmental monitoring system to evaluate the potential effect of urban air pollution. Procedia Structural Integrity, 22(2019), 130–136. https://doi.org/10.1016/j.prostr.2020.01.018

Tri, B., Utomo, W., & Saputra, D. S. 2016. Simulasi Sistem Pendeteksi Polusi Ruangan Menggunakan Sensor Asap Dengan Pemberitahuan Melalui SMS (Short Message Service) Dan Alarm Berbasis Arduino. 10(1), 56–68.

Yu, S., Yu, Z., Ma, X., Zhang, G., & Feng, G. 2017. Study on the influence of pollution source location on indoor pollutant distribution under different air supply. Procedia Engineering, 205, 2623–2630. https://doi.org/10.1016/j.proeng.2017.10.204