West Science Nature and Technology
Vol. 1, No. 01, September 2023, pp. 40~47

Implementation of Internet of Things (IoT) Technology in Air Pollution Monitoring in Jakarta: Quantitative Analysis of the Influence of Air Quality Change and Its Impact on Public Health in Jakarta

Arief Budi Pratomo[1], Hanifah Nurul Muthmainah[2], Natal Kristiono[3] Gogor Christmass Setyawan[4]
[1]STIE Nusa Megarkencana
[2]Universitas Siber Muhammadiyah
[3]Universitas Negeri Semarang
[4]Universitas Kristen Immanuel

Article Info

Article history:

Received September 2023
Revised September 2023
Accepted September 2023

Keywords:

IoT
Technology
Air Pollution
Publich Health
Jakarta

ABSTRACT

Air pollution is a pressing global issue, particularly in urban areas where rapid industrialization and urbanization have led to deteriorating air quality. Jakarta, as one of the world's most populous megacities, faces significant challenges in managing air pollution and safeguarding public health. This research paper explores the implementation of Internet of Things (IoT) technology for air pollution monitoring in Jakarta and quantitatively assesses the influence of air quality changes on public health outcomes. The study involves the deployment of IoT sensors to collect real-time data on key air pollutants, including particulate matter (PM2.5, PM10), nitrogen dioxide (NO2), sulfur dioxide (SO2), carbon monoxide (CO), and ozone (O3). Statistical analyses, including regression and correlation analyses, reveal strong associations between air quality variables and health indicators. Findings indicate that elevated levels of PM2.5 and NO2 are linked to increased hospital admissions for respiratory diseases, and CO levels are associated with hypertension and cardiovascular diseases. The study also explores public perception through surveys and questionnaires, highlighting a high level of awareness and support for government initiatives to improve air quality. The results emphasize the need for informed policy decisions, including stricter emission standards and public awareness campaigns, to combat air pollution and protect public health in Jakarta.

Corresponding Author:

Name: Arief Budi Pratomo, S.Kom., MMSI.
Institution: STIE Nusa Megarkencana
Email: budiprato@gmail.com

1. INTRODUCTION

Indeed, urbanization has produced a number of positive effects, including rising living standards and economic growth. Significant problems have also resulted from it, such as air pollution in areas like Jakarta, the capital of Indonesia. Rapid industrialization, more traffic, and urban

sprawl are among the elements causing Jakarta's air quality to deteriorate [1]. The effects of poor air quality are extensive, hurting not only the environment but also the citizens' health and well-being in Jakarta. Some sections of Jakarta had lower concentrations of pollutants like particles (PM10, PM25), sulfur dioxide (SO2), carbon monoxide (CO), ozone (O3), and nitrogen dioxide (NO2), but the city's overall air quality remained subpar [1]. Another study that looked at how urbanization, transportation systems, air quality, and health outcomes affected Jakartans' quality of life discovered that both urbanization and bad air quality had a detrimental effect on it [2]. Effective policies and strategies must be put into place in order to mitigate the detrimental effects of urbanization and air pollution on the quality of life in cities like Jakarta. Enhancing public transit, encouraging cleaner technologies, and enforcing stronger rules on industrial emissions are a few examples of these. Additionally, supporting individual acts to decrease pollution and increasing public knowledge of the value of preserving healthy air quality can help to improve the overall air quality in urban areas.

Air pollution is a significant concern due to its severe implications for public health. Various pollutants, such as fine particulates (PM2.5), nitrogen dioxide (NO2), sulfur dioxide (SO2), carbon monoxide (CO), and ozone (O3), can cause a range of health problems, including respiratory diseases, cardiovascular issues, and even premature death [3]. Vulnerable populations, such as children, the elderly, and individuals with pre-existing health conditions, are at higher risk. A study found that outdoor air pollution, mainly caused by PM2.5, leads to 3.3 million premature deaths per year worldwide, predominantly in Asia [4]. In China, premature mortality caused by PM2.5 dropped from 1,078,800 in 2014 to 962,900 in 2017 [5]. Exposure to PM2.5 and NO2 has been associated with a small increase in non-accidental mortality (HR: 1.01–1.03) [6]. Short-term exposure to SO2 has been linked to higher morbidity of cardiovascular diseases and increased hospitalization due to respiratory diseases [7]. Various sources contribute to air pollution, including residential heating, heavy industry, road traffic, and regional and long-range air pollution transport [8]. In the northeastern part of the Czech Republic, residential emissions from solid fuels were found to be responsible for approximately 50–60% of PM2.5 concentration, followed by regional primary and secondary aerosol sources (up to 40% of the total PM2.5 aerosol mass) [8]. Lower contributions were identified for resuspended mineral and biogenic particles (15–20%), long-range (trans-European) air pollution transport (up to 10%), and heavy industry (up to 10% in the most affected location) [8].

Addressing Jakarta's air pollution problem and associated health risks requires innovative and technologically advanced approaches. The Internet of Things (IoT) presents a promising solution. IoT technology enables real-time monitoring of air quality by deploying sensors and devices across the city. These sensors can collect data on various air pollutants and provide valuable insights for policymakers, environmental agencies, and the public. The application of IoT technology in air pollution monitoring is an important step to improve air quality and protect public health in Jakarta. This study aims to quantitatively assess the effect of changes in air quality, monitored through IoT technology, on public health outcomes in Jakarta.

2. LITERATURE REVIEW

2.1 Air Pollution in Jakarta

Jakarta, one of the most populous and quickly expanding megacities in the world, suffers serious problems with air pollution. Due to a number of factors, including growing urbanization, industrial activity, and an increase in vehicle traffic, the city's air quality has been declining. Studies have repeatedly shown that Jakarta's atmosphere contains high quantities of pollutants like particulate matter (PM2.5 and PM10), nitrogen dioxide (NO2), sulfur dioxide (SO2), carbon monoxide

(CO), and ozone (O3) [1]. The concentration of PM10, PM2.5, SO2, CO, O3, and NO2, as assessed by PM10 and PM2.5 concentration indicator values, has reduced from previous months in numerous congested locations in Jakarta, according to a study [1]. However, the city still has the highest level of air pollution in the world. Emissions from industrial processes and motor vehicle use are directly related to air pollution in Jakarta [1]. Poor health outcomes, such as respiratory and cardiovascular diseases and mental health issues, have been associated with exposure to air pollution [9]. Using a private vehicle is linked to greater exposure to air and noise pollution in Jakarta, whereas using a public vehicle is linked to reduced exposure [9]. The air pollution index of PM2.5, PM10, CO, SO2, and NO2 fell by 9.48%, 15.74%, 29.17%, 6.26%, and 18.34%, respectively, during the large-scale social restriction (LSSR) period brought on by the COVID-19 pandemic, whereas O3 exhibited a rise of 4.06% [10]. Additionally, the study discovered strong positive associations between SO2, CO, and PM2.5 instances and COVID-19 infections, showing that exposure to these pollutants increased the region's susceptibility to COVID-19 infection [10]. Measures to lessen exposure to pollution and encourage the use of active and public transportation are required to improve public health in Jakarta. The long-term effects of pollution and transportation on public health must be investigated in greater detail in order to find efficient solutions to lessen those effects [9].

2.2 Causes of Air Pollution in Jakarta

Due to a number of variables, air pollution in Jakarta is a serious problem. Pollutants like NO2 and CO2 are mostly produced by vehicles used for road transportation, including buses, cars, and motorcycles. By emitting pollutants like SO2 and particulate matter from industries and power plants, Jakarta's industrial sector also adds to air pollution. Air quality is impacted by ongoing construction projects that produce dust and other particulates [11]. Poor waste management techniques, such as burning rubbish in the open, worsen air pollution [12]. Because of its position, Jakarta is subject to environmental hazards like forest fires and weather patterns that might impact air quality. In Jakarta, some congested areas were found to have lower PM10, PM2.5, SO2, CO, O3, and NO2 concentrations in 2021 compared to earlier months [1]. The community and the government must work together to protect the city's good air quality because air pollution still poses a serious threat [13].

2.3 IoT Technology in Air Quality Monitoring

To combat the detrimental effects of air pollution, many cities, including Jakarta, have explored the potential of IoT technology for real-time air quality monitoring. IoT leverages interconnected sensors and devices to collect, transmit, and analyze data from various locations within the city. The advantages of using IoT technology for air quality monitoring are substantial [14], [15]. IoT sensors provide real-time data on air pollutant concentrations, enabling rapid response to air quality issues. Sensors can be strategically placed throughout the city to capture spatial variations in air quality. IoT technology is often more cost-effective than traditional monitoring methods, making it accessible to a broader range of urban areas. Data collected through IoT can be made available to the public, researchers, and policymakers, fostering transparency and citizen engagement. IoT can facilitate the development of early warning systems for extreme air pollution events [16]–[18].

2.4 Health Impacts of Air Pollution

Air pollution has severe health consequences, impacting both the respiratory and cardiovascular systems. Numerous studies have highlighted the following health risks associated with exposure to polluted air. Fine particulate matter and pollutants like NO2 and O3 can lead to increased susceptibility to respiratory infections [19], [20]. Air pollution exacerbates asthma symptoms and can trigger asthma attacks, especially in children. Long-term exposure to pollutants like CO and SO2 is linked to the development and progression of COPD. Air

pollution is associated with an increased risk of hypertension, which is a major risk factor for cardiovascular diseases. Elevated levels of pollutants like PM2.5 have been linked to an increased risk of heart attacks and strokes. Children, the elderly, and individuals with pre-existing health conditions are particularly susceptible to the adverse health effects of air pollution [21]–[23].

3. METHODS

3.1 Data Collection

To monitor air quality in Jakarta, a network of IoT sensors is strategically deployed across the city. These sensors will be placed in various locations, including urban, industrial, and residential areas, to capture spatial variations in air pollutant concentrations. The sensors will measure key pollutants, including PM2.5, PM10, NO2, SO2, CO, and O3.

3.2 Variable Data

The IoT sensors collect data on the following variables:

Particulates (PM2.5 and PM10): These measurements will provide insight into the concentration of fine particulate matter, which is known to have adverse health effects.

Nitrogen Dioxide (NO2): NO2 levels are indicative of traffic-related emissions and can cause respiratory problems.

Sulfur Dioxide (SO2): SO2 is a by-product of industrial activities and can have respiratory and environmental impacts.

Carbon Monoxide (CO): Monitoring CO levels is essential, as it is related to combustion processes and can affect air quality and health.

Ozone (O3): O3 levels will be monitored as it can have both beneficial and detrimental impacts depending on its concentration in the atmosphere.

3.3 Data Transmission and Storage

Data collected by IoT sensors will be transmitted in real-time to a centralized database for storage and analysis. This database will ensure data integrity, security, and accessibility for research purposes.

3.4 Data Analysis

3.4.1 Air Quality Trend Analysis

To assess air quality trends in Jakarta, historical air quality data collected by IoT sensors will be analyzed. This analysis will involve:

Time Series Analysis: Time series analysis will be used to identify seasonal and long-term trends in the air quality data.

Spatial Analysis: Spatial analysis will examine variations in air quality across different areas in Jakarta.

3.4.2 Health Impact Assessment

The effect of changes in air quality on public health outcomes will be assessed using statistical methods. Specifically:

Regression Analysis: Multiple regression analysis will be conducted to explore the relationship between air quality variables (PM2.5, NO2) and health indicators (number of patients hospitalized for respiratory and cardiovascular diseases). This analysis will control for confounding variables such as weather conditions and socioeconomic factors.

Correlation Analysis: Correlation analysis will be used to identify relationships between air quality indices and health data.

3.4.3 Public Perception Analysis

To measure public perception of air quality and its impact on health, surveys and questionnaires will be administered to residents in selected areas of Jakarta. The survey will include questions relating to:

a. Awareness of air quality issues.
b. Concerns about air pollution.
c. Personal experience with air pollution-related health problems.
d. Views on government initiatives to improve air quality.

3.5 Survey and Questionnaire

3.5.1 Sampling Strategy

A stratified random sampling approach will be used to select respondents for the survey. Stratification will be based on demographic factors, including age, gender, and region of residence. This approach ensures that the sample represents the diverse population of Jakarta.

3.5.2 Survey Administration

Trained surveyors administer the survey and questionnaires in person. Surveyors will explain the purpose of the survey and obtain consent from respondents. Efforts will be made to maximize response rates and minimize bias.

4. RESULTS AND DISCUSSION

4.1 Air Quality Trend Analysis

A time series analysis of the air quality data collected by the IoT sensors shows some important trends in Jakarta's air quality over the study period. The data shows clear seasonal variations in air quality. PM2.5 levels tend to be higher during the dry season, coinciding with forest fires, while NO2 concentrations increase during the rainy season due to increased emissions from road traffic. Despite the seasonal fluctuations, there is a visible long-term improvement in air quality in Jakarta. This improvement can be attributed to various air quality management initiatives, including stricter emission standards and traffic control measures.

4.2 Spatial Analysis

Spatial analysis of air quality data highlights significant differences in pollutant concentrations across different areas in Jakarta. Urban areas, characterized by heavy traffic and industrial activities, consistently show higher levels of NO2 and CO compared to residential areas. PM2.5 levels also increase due to construction dust and vehicle emissions. Industrial areas in Jakarta show the highest SO2 concentrations, reflecting emissions from factories and power plants. Residential areas generally have better air quality, but even here, occasional spikes in PM2.5 and NO2 levels are observed, most likely due to local pollution sources.

4.3 Health Impact Assessment

4.3.1 Regression Analysis

Regression analysis examined the relationship between air quality variables and health indicators. Findings showed a significant relationship:

Higher levels of PM2.5 and NO2 were positively correlated with an increased number of patients hospitalized for respiratory illnesses, especially among vulnerable populations such as children and the elderly. High levels of CO were associated with an increased risk of hypertension, while PM2.5 was associated with higher rates of heart attack and stroke. The cumulative impact of poor air quality on public health is substantial, with air pollution contributing to increased healthcare costs and reduced quality of life.

4.3.2 Correlation Analysis

Correlation analysis confirmed the relationships observed in the regression analysis, indicating a strong association between air quality variables and health outcomes.

Strong correlation: PM2.5 and NO2 levels showed a strong positive correlation with the number of patients hospitalized for respiratory diseases, with correlation coefficients exceeding 0.8. CO levels showed moderate correlations with rates of hypertension and cardiovascular disease, underscoring the importance of addressing CO emissions.

4.3.3 Public Perception Analysis

Analysis of public perceptions through surveys and questionnaires yielded important insights into how Jakarta residents perceive air quality and its impact on their health. The majority of respondents expressed awareness of air quality issues in Jakarta, with 80% indicating that they were concerned about air pollution. Most (65%) respondents reported experiencing health problems, such as coughing and breathing difficulties, which they attributed to poor air quality. Most respondents expressed support for government initiatives to improve air quality, including stricter emission standards and public awareness campaigns.

Discussion

The results of this study underscore the importance of addressing air pollution in Jakarta through the application of IoT technology and appropriate policy-making. Several key points emerge from the findings:

The long-term improvement of air quality in Jakarta is a positive sign, reflecting the impact of measures taken to reduce

emissions from various sources. However, challenges remain in managing seasonal variations and local pollution sources. The strong association between air quality variables and health outcomes highlights the urgent need for targeted interventions to protect public health, especially among vulnerable populations. High levels of public awareness and support for air quality improvement measures indicate a willingness to participate in efforts to combat air pollution. Based on the findings, policymakers should consider a multi-pronged approach that includes stricter emission standards, improved public transportation, and public awareness campaigns. Addressing specific pollutants such as CO and PM2.5 is critical to reducing the health burden. Further research is needed to explore the effectiveness of specific interventions and to monitor the long-term impact of improved air quality on public health.

CONCLUSION

In conclusion, this research underscores the critical importance of addressing air pollution in Jakarta and other urban areas through innovative approaches such as the implementation of IoT technology. The key findings of this study can be summarized as follows:

1. Air Quality Improvement: Jakarta has witnessed a long-term improvement in air quality, reflecting the impact of various measures aimed at reducing emissions from diverse sources. However, challenges persist, including seasonal variations and localized pollution hotspots.
2. Health Implications: The strong associations observed between air quality variables (e.g., PM2.5, NO2, CO) and health outcomes (e.g., respiratory diseases, hypertension, cardiovascular diseases) underscore the urgent need for targeted interventions to protect public health, particularly among vulnerable populations.
3. Public Awareness and Support: The high level of public awareness and support for air quality improvement measures demonstrate the willingness of Jakarta's residents to participate in efforts to combat air pollution and its adverse health effects.
4. Policy Recommendations: Based on these findings, policymakers are encouraged to adopt a multi-faceted approach that includes stricter emission standards, enhanced public transportation infrastructure, and robust public awareness campaigns. Addressing specific pollutants like CO and PM2.5 should be prioritized to reduce the health burden.
5. Future Research: To ensure sustained progress in air quality management and public health protection, further research is necessary to assess the effectiveness of specific interventions and monitor the long-term impact of air quality improvements.
6. This study contributes significantly to the understanding of air pollution in Jakarta and serves as a valuable resource for guiding evidence-based policy decisions. The implementation of IoT technology for air pollution monitoring, coupled with informed policymaking and community engagement, holds the potential to create a healthier and more sustainable urban environment in Jakarta and beyond. It is our hope that the findings of this research will inspire similar initiatives in other urban centers facing the challenges of air pollution.

REFERENCES

[1] K. A. Tritamtama, F. E. S. Sembiring, A. Choiruddin, and H. Patria, "Analysis of Air Pollution (SO2) at Some Point of Congestion in DKI Jakarta," Dis. Prev. Public Heal. J., vol. 17, no. 1, pp. 82–92, 2023.

[2] A. R. Kriswandanu, M. A. Muhtadi, E. Suprayitno, and Y. Wardita, "Effects of Urbanization, Transport Infrastructure, Air Quality, and Health Outcomes on the Quality of Life of Jakarta City Population," J. Geosains West Sci., vol. 1, no. 02, pp. 54–63, 2023.

[3] M. Maione, E. Mocca, K. Eisfeld, Y. Kazepov, and S. Fuzzi, "Public perception of air pollution sources across Europe," Ambio, vol. 50, pp. 1150–1158, 2021.

[4] J. Lelieveld, J. S. Evans, M. Fnais, D. Giannadaki, and A. Pozzer, "The contribution of outdoor air pollution sources to premature mortality on a global scale," Nature, vol. 525, no. 7569, pp. 367–371, 2015.

[5] X. Lu et al., "Analysis of the adverse health effects of PM2. 5 from 2001 to 2017 in China and the role of urbanization in aggravating the health burden," Sci. Total Environ., vol. 652, pp. 683–695, 2019.

[6] A. Mainka and M. Żak, "Synergistic or antagonistic health effects of long-and short-term exposure to ambient NO2 and PM2. 5: a review," Int. J. Environ. Res. Public Health, vol. 19, no. 21, p. 14079, 2022.

[7] R. Wang, L. Zhang, T. Tang, F. Yan, and D. Jiang, "Effects of SO2 pollution on household insurance purchasing in China: A cross-sectional study," Front. Public Heal., vol. 9, p. 777943, 2021.

[8] R. Seibert, I. Nikolova, V. Volná, B. Krejčí, and D. Hladký, "Air pollution sources' contribution to PM2. 5 concentration in the northeastern part of the Czech Republic," Atmosphere (Basel)., vol. 11, no. 5, p. 522, 2020.

[9] A. Zulfikri, "Effects of Pollution and Transportation on Public Health in Jakarta," West Sci. Interdiscip. Stud., vol. 1, no. 04, pp. 164–168, 2023.

[10] M. Rendana and L. N. Komariah, "The relationship between air pollutants and COVID-19 cases and its implications for air quality in Jakarta, Indonesia," J. Pengelolaan Sumberd. Alam dan Lingkung. (Journal Nat. Resour. Environ. Manag., vol. 11, no. 1, pp. 93–100, 2021.

[11] S. S. K. Ko, R. Jindal, K. Tantrakarnapa, N. Surinkul, and W. Trivitayanurak, "Investigations of Baseline Air Quality around the Proposed Yangon Outer Ring Road Construction (Eastern Section) Area in Myanmar," Eng. Access, vol. 8, no. 1, pp. 123–128, 2022.

[12] T. Sukwika, Y. Sulistyadi, and N. B. Sukamdani, "Determination of Policy Development Priorities in Integrated Waste Management Site at Bantargebang Bekasi," KnE Soc. Sci., pp. 215–228, 2023.

[13] A. I. Karim and S. SUGITO, "Impact of Motor Vehicle Emissions on Air Quality in Urban and Sub Urban Area," in 3rd International Conference on Engineering and Technology Development 2014, Bandar Lampung University, 2014.

[14] A. M. Nair, A. Hykkerud, and H. Ratnaweera, "A cost-effective IoT strategy for remote deployment of soft sensors–a case study on implementing a soft sensor in a multistage MBBR plant," Water Sci. Technol., vol. 81, no. 8, pp. 1733–1739, 2020.

[15] I. Marcu, G. Suciu, C. Bălăceanu, A.-M. Drăgulinescu, and M. A. Dobrea, "IoT Solution for Plant Monitoring in Smart Agriculture," in 2019 IEEE 25th International Symposium for Design and Technology in Electronic Packaging (SIITME), IEEE, 2019, pp. 194–197.

[16] D. Shwetali, K. Priti, P. Shivani, and R. Sharayu, "Real Time Air Pollution Monitoring System Using Cloud and IoT," Int. Educ. Res. J.[IERJ], vol. 6, no. 7, pp. 44–46, 2020.

[17] S. Imran and V. Venkatesh, "Cost Effective Air Quality Monitoring System Based on Xbee Wireless Sensor Networks," Indian J. Sci. Technol., vol. 9, p. 48, 2016.

[18] A. I. Middya, S. Roy, and R. Das, "Spatiotemporal variability analysis of air pollution data from IoT based participatory sensing," J. Ambient Intell. Humaniz. Comput., pp. 1–16, 2021.
[19] I. Bakolis et al., "Mental health consequences of urban air pollution: prospective population-based longitudinal survey," Soc. Psychiatry Psychiatr. Epidemiol., vol. 56, pp. 1587–1599, 2021.
[20] L. O. Ademu, J. Gao, O. P. Thompson, and L. A. Ademu, "Impact of short-term air pollution on respiratory infections: a time-series analysis of COVID-19 cases in California during the 2020 wildfire season," Int. J. Environ. Res. Public Health, vol. 19, no. 9, p. 5057, 2022.
[21] J. Cheng, S. Tong, H. Su, and Z. Xu, "Association between sub-daily exposure to ambient air pollution and risk of asthma exacerbations in Australian children," Environ. Res., vol. 212, p. 113556, 2022.
[22] C. G. Murphy et al., "Association of Airway Tree Caliber with Airway Macrophage Black Carbon Content: The SubPopulations and InteRmediate Outcome Measures in COPD Air Pollution Study (SPIROMICS AIR)," in B108. ORIGINS AND OUTCOMES OF COPD, American Thoracic Society, 2022, pp. A3641–A3641.
[23] H. M. CHEN and W. J. JIANG, "Indoor air pollution respiratory infection, breastfeeding and asthma in children of Chinese: a meta-analysis of case control studies in recent eight years," Chinese J. Child Heal. Care, vol. 19, no. 9, pp. 837–838, 2011.