Indonesian Journal of Electrical Engineering and Computer Science
Vol. 37, No. 1, January 2025, pp. 48~55
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v37.i1.pp48-55

Internet of things enabled landfill pollution gas monitoring

Mochammad Junus, David Fydo Putradi, Farida Arinie Soelistianto, Mohammad Abdullah Anshori, Rizky Ardiansyah
Department of Electrical Engineering, State Polytechnic of Malang, Malang, Indonesia

Article Info

Article history:

Received Jul 4, 2024
Revised Sep 4, 2024
Accepted Sep 29, 2024

Keywords:

Environmental safety
Internet of things
Landfill gas
Monitoring
Waste management technology

ABSTRACT

Due to the increasing concern on how to manage wastes and ensure environmental safety across the globe, a new tool that assists in the monitoring of methane, humidity, and temperature in the landfill using internet of things (IoT) has been created. This system uses ESP32 microcontroller and MQ-4 and DHT-22 sensors to measure environmental conditions at three different spots in a landfill. The samples of data are collected at three times a day, that is, in the morning at 7:00 am, at midday at 12:00 pm and in the evening at 5:00 pm and the data is transmitted to an online sheet where the public can access it in real time hence increasing transparency in the management of wastes. The tool shows a very good precision and effectiveness and the parameters are 94. 6% data integrity over three months testing period. The first findings show that the mean methane concentration is the highest at midday, which is related to the temperature and underlines the role of temperature in the methane emission process. The presented IoT based monitoring system also enhances the accuracy and efficiency in the monitoring of landfill gas and at the same time reduces the intervention of human effort and increases the capability to make prompt adjustments to changes in the environment. Used as an instrument for obtaining accurate and easily understandable data, it is hoped that this tool will in some way help to enhance global environmental health and safety standards, and help pave a way for methane storage for renewable energy purposes.

Corresponding Author:

Mochammad Junus
Department of Electrical Engineering, State Polytechnic of Malang
Malang, East Java, 65141, Indonesia
Email: mochammad.junus@polinema.ac.id

1. INTRODUCTION

The internet of things (IoT) is changing the way connectivity and data are collected [1]-[12]. This has opened up new possibilities for environmental monitoring. A very important area of IoT application is the creation of smart waste management systems that employ sensors and communication devices to measure the level of gas emissions in real time. Monitoring of the landfill gas is important because high levels of the gases such as methane are dangerous to the environment and human health [13]-[21].

The current practices in the monitoring of landfill gas are tedious and involve regular measurements by the environmental staff. This not only puts a lot of stress on the personnel but also puts them in a position where they can easily overlook changes in the gas level which if left unchecked can lead to formation of dangerous situations [22]. The World Health Organization (WHO) standards for landfill emissions are very strict and this underlines the need to monitor the landfill emissions frequently and effectively [23], [24].

To address these challenges, the research has proposed an IoT-based landfill gas monitoring tool that is efficient, accurate, and user-friendly. This tool connects digital gas sensors which are accurate with notification systems and data acquisition systems [25]-[31]. Through the use Google Sheets for storing historical records, the tool avails important information on gas emissions to the environmental professionals and the community in a timely manner.

From the case of using this IoT-based monitoring tool, it has been evident that the monitoring of landfill gases has been enhanced in terms of accuracy and efficiency. From the first observations, it is possible to conclude that the amount of manual work has been decreased and the ability to respond to changes in the gas level has been improved. This tool enhances the management of environmental issues that focus on sustainability and health.

2. METHOD

2.1. System design

The purpose of this system is to explain how a three point landfill gas monitoring system works. It includes an ESP32 microcontroller, an MQ-4 methane sensor, and a DHT-22 temperature and humidity sensor for monitoring the environmental conditions at a landfill. The locations of the sensor readings are depicted in Figure 1. Each subsystem is located roughly 5 meters apart from each other.

In Figure 2 it is explained that the operational process begins with theIt has an automatic time table for the collection of data under the system. When triggered, the MQ-4 sensor detects the concentration of methane gas within the landfill site, while the DHT-22 sensor captures the temperature and humidity of the site. These sensors capture information that is relayed to the ESP32 microcontroller where the analog signals are quantised. The processed data is then shown on an LCD which is installed in the system to give the user feedback on what is happening. Furthermore, with the help of the built-in Wi-Fi capability of the ESP32 [32], this data is transferred to an online server for computation and storage. The data is stored at Google Spreadsheet where the landfill gas parameters are updated frequently and the historical data can be accessed.

Figure 1. System location in Batu landfill

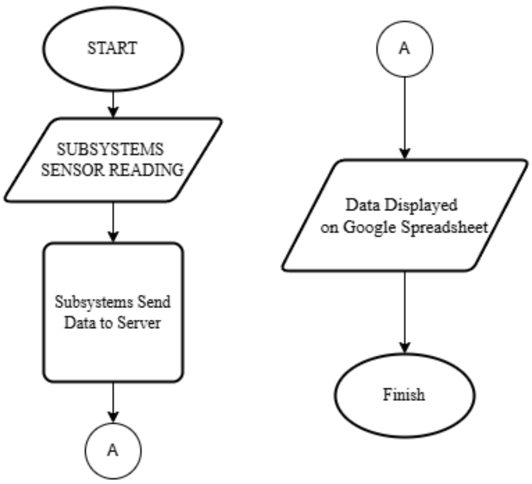

Figure 2. System flowchart

The schematic and system architecture is depicted in Figure 3 where it shows that the system comprises of three subsystems that is strategically located at three different point in the landfill. The ESP32 microcontroller is integrated with each subsystem, and it is accompanied by an LCD display module for user parameter result output. The subsystems transmit their sensor data to be displayed through Google Spreadsheet employing ESP32 wifi connection.

In scientific context, this system is an example of a control and data acquisition system applicable in automation applications in Electronic Engineering and Environmental Informatics. It properly and adequately controls the emission of landfill gas, uses the microcontroller to process signals and data, identifies gases using the methane sensor, and measures environmental temperature and humidity. This integrated system guarantees the efficient control and prompt notification of the condition of the landfill sites, contributing to the safety and efficiency of the data collected.

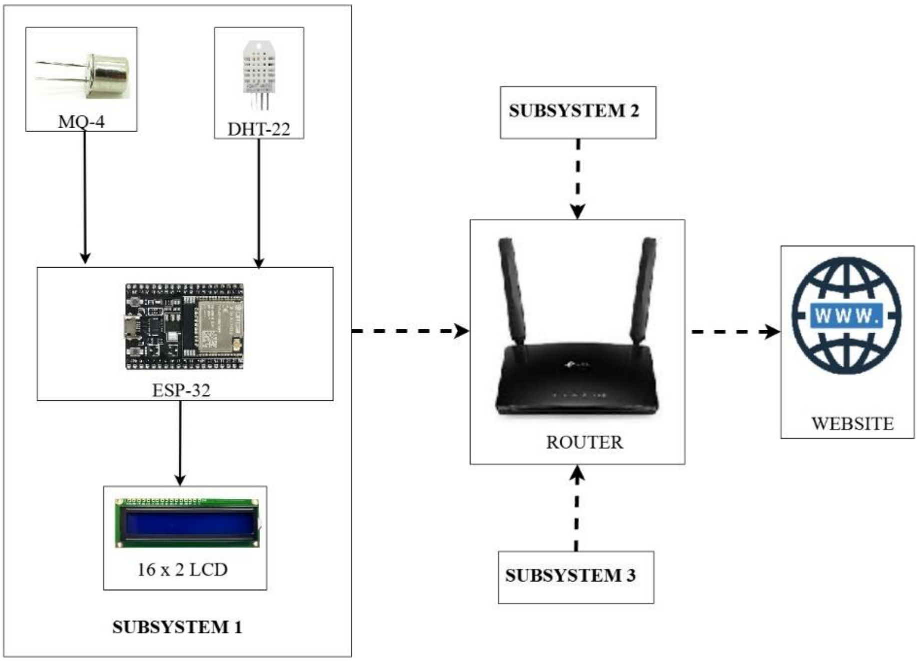

Figure 3. System architecture

2.2. Linear regression

To determine the correlation between the data obtained using MQ-4 and DHT-22 sensors and the environmental conditions they record, linear regression was used [33]-[35]. The MQ-4 sensor measures the concentration of the gas present in the environment like the carbon dioxide while the DHT-22 sensor measures temperature and humidity. Because these sensors offer raw voltage outputs, it is significant to convert these voltage levels into meaningful and accurate environmental data. Linear regression, therefore, enables one to develop the right calibration equations in order to accomplish this.

Linear regression is a parametric technique that tries to establish the linear relationship between one or more independent variables (e.g. sensor voltage readings) and one dependent variable (e.g. gas concentration, temperature, or humidity) within a dataset. In this study, there was a correlation done between the sensor outputs of MQ-4 and DHT-22 with the environment. The basic concept comprises assuming linear equations that contain the fundamentals of the observed data in order to facilitate predictive modeling and inferential analysis. In its simplest form, a simple linear regression model is expressed with (1):

$$y = \beta_0 + \beta_1 x + \epsilon \quad (1)$$

where y is the dependent variable (e.g., gas concentration, temperature, or humidity), x is the independent variable (voltage reading from the sensor), β_0 is the intercept, β_1 is the slope, and ϵ is the error term. The primary objective in linear regression is to optimize the parameters β_0 and β_1 to minimize the residual sum of squares.

2.3. Data integrity

The system was tested for 3 months, starting from April 1st – July 1st 2024. A data is sampled three times a day at 7 am, 12 pm, and 5 pm. At 7 am, the garbage collection trucks just arrived at the landfill and dump the load for the day. At 12 pm the sun is at its peak, and at 5 pm, the sun is starting to set. The integrity of the data means all data from all three subsystems must be recorded on the Google Sheet. There are 92 days from April 1st to July 1st. This means the total data can be calculated using (2).

$$Ideal = n \times subsystems \times s \quad (2)$$

where:
$Ideal$: the total number of data
n : total days
$subsystems$: the number of subsystems deployed
s : sampling number

3. RESULTS AND DISCUSSION

3.1. Sensor calibration

MQ-4 sensor for methane is calibrated using combination of two methods: testing the sensor using known methane calibration gas and using calibrated methane measuring tool. Figure 4 shows the relationship between methane reading of MQ-4 sensor and controlled methane level. The Y label represents MQ-4 sensor reading and the X axis represents the known methane level from calibration kit and other measurement instrument. The calibration result MQ-4 sensor is using (3).

$$x = \frac{y}{2.0207} + 7.2579 \quad (3)$$

DHT-22 sensor for temperature and humidity is calibrated using a hygrometer for humidity and a temperature gun for temperature reading. The testing for the temperature function and humidity function of DHT-22 are done separately. Figure 5 shows the relationship between the temperature reading of the DHT-22 sensor and the temperature gun. The Y label represents DHT-22 sensor reading and the X axis represents the known temperature from the measurement instrument. The calibration result for DHT-22 temperature reading is obtained in (4).

$$x = \frac{1000y}{942} - 3.51 \quad (4)$$

Figure 6 shows the relationship between humidity reading of DHT-22 sensor and hygrometer reading. The Y label represents DHT-22 sensor reading and the X axis represents the known humidity from measurement instrument. The calibration result for DHT-22 temperature reading is obtained in (5).

$$x = \frac{y}{1.0081} + 0.3035 \quad (5)$$

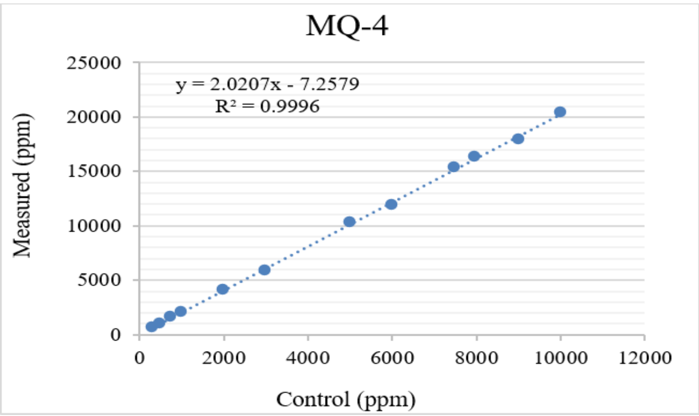

Figure 4. MQ-4 calibration

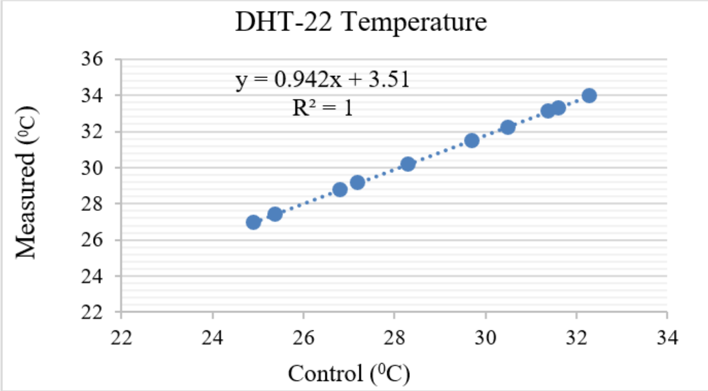

Figure 5. DHT-22 temperature calibration

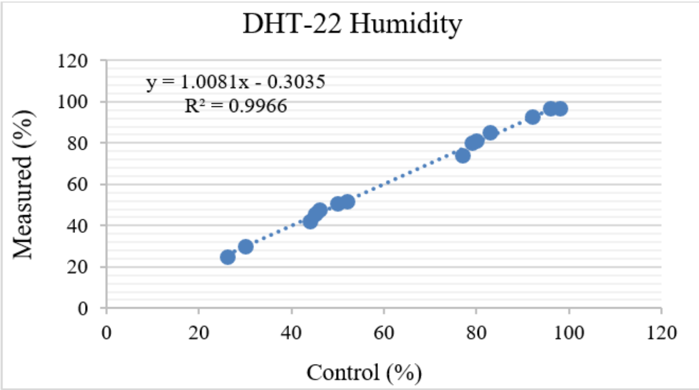

Figure 6. DHT-22 humidity calibration

3.2. Data integrity test

The number of data combined methane, temperature, and humidity passed through during the testing in ideal condition is calculated in (6). In ideal condition, the number of data collected should be 828 data divided on three subsystems. These data will be stored in Google Spreadsheet.

$$\Sigma_{data} = 92 \times 3 \times 3 \qquad (6)$$
$$\Sigma_{data} = 828$$

After three months of experiments, we obtain 784 data stored in Google Spreadsheet. This means the efficiency of this system can be calculated using (7). The overall efficiency of the IoT system is 94.6%. This means in average each subsystem losts around 14 data points monthly.

$$Efficiency = \frac{\Sigma_{data}}{Ideal} \times 100\% \qquad (7)$$
$$Efficiency = \frac{784}{828} \times 100\% = 94.6\%$$

3.3. Data corelation

After three months of testing, the trends can be seen in Table 1. We take the average of each testing time to see the correlation between time, temperature, and humidity in landfil setting. From the data above we can get several angles. We can see that methane level in the landfill is higher at 12 pm. This is 60.3% higher than at 7 am and 47.8% higher than at 5 pm. This findings correlate with the temperature trend. At high noon, the average temperature is at its peak. This means temperature is proportional with methane level, as decomposition rate of the landfill trash speeds up with heat. But relative humidity on the other hand is perpendicular with temperature. It falls as the temperature rises.

Table 1. Sensor reading data

Average	Methane (parts per million)	Temperature (°C)	Humidity (%)
7 am	2120	23	43
12 pm	3400	30	32
5 pm	2300	25	41

4. CONCLUSION

In conclusion, this research introduces an IoT based landfill gas monitoring. This system can transmit data from three points in a landfill. Each reading points consists of an ESP32 as the processor, MQ-4 sensor to read methane level, and DHT-22 sensor to read environment temperature and humidity. There are three times of reading which are at 7 am, 12 pm, and 5 pm. All three points are connected via wifi which then send the data to be stored in a Google Spreadsheet which can be monitored in real time. This system can achieve 94.6% efficiency in data transmission accross three months of testing. From the study, we can conclude that methane level is directly proportional with the surrounding temperature. When the sun is at its peak at 12 pm, the temperature rises, as well as the methane level. But the temperature is the inversely related to relative humidity. When the temperature rises, the humidity falls. Additional studies could focus on expanding the monitoring system to include additional environmental parameters, such as air quality indices and other greenhouse gases. Moreover, the methane monitoring can be used to integrating methane storage for renewable energy purposes.

ACKNOWLEDGEMENTS

This research has been carried out under the support of Higher Education, the Ministry of Education and Culture of Indonesia in 2024, through the Innovation Implementation Research scheme, that was funded by Internal independent budget State Polytechnic of Malang.

REFERENCES

[1] T. B. da Silva, R. P. S. Chaib, C. S. Arismar, R. R. Righi, and A. M. Alberti, "Toward future internet of things experimentation and evaluation," *IEEE Internet of Things Journal*, vol. 9, no. 11, pp. 8469–8484, Jun. 2022, doi: 10.1109/JIOT.2021.3114540.

[2] Q. Huang, R. Wen, Y. Han, C. Li, and Y. Zhang, "Intelligent fault identification for industrial internet of things via prototype-guided partial domain adaptation with momentum weight," *IEEE Internet of Things Journal*, vol. 10, no. 18, pp. 16381–16391, Sep. 2023, doi: 10.1109/JIOT.2023.3267830.

[3] H. Tran-Dang, N. Krommenacker, P. Charpentier, and D.-S. Kim, "Toward the internet of things for physical internet: perspectives and challenges," *IEEE Internet of Things Journal*, vol. 7, no. 6, pp. 4711–4736, Jun. 2020, doi: 10.1109/JIOT.2020.2971736.

[4] B. Setiawan, E. S. Putra, I. Siradjuddin, M. Junus, D. Dewatama, and S. Wiyanto, "Study of LoRa (Long Range) communication for monitoring of a ship electrical system," *Journal of Physics: Conference Series*, vol. 1402, no. 4, p. 044022, Dec. 2019, doi: 10.1088/1742-6596/1402/4/044022.

[5] B. Setiawan, F. Ronilaya, D. K. P. Aji, A. Setiawan, and E. S. Putra, "Online monitoring and data logging power quality parameters of low voltage distribution panel (LVDP) on industrial system," *IOP Conference Series: Materials Science and Engineering*, vol. 830, no. 3, p. 032032, Apr. 2020, doi: 10.1088/1757-899X/830/3/032032.

[6] M. Junus, R. A. Wijayanti, and N. Hidayati, "Wireless sensor network for monitoring windmills at State Polytechnic of Malang," in *2021 International Conference on Electrical and Information Technology (IEIT)*, IEEE, Sep. 2021, pp. 162–166. doi: 10.1109/IEIT53149.2021.9587373.

[7] M. Junus, S. Wirayoga, and S. A. Putri, "Wireless sensor network for energy monitoring based on hybrid power plants AH buildings," in *2022 International Conference on Electrical and Information Technology (IEIT)*, IEEE, Sep. 2022, pp. 160–164. doi: 10.1109/IEIT56384.2022.9967876.

[8] E. A. Prastyo, M. Junus, and E. Rohadi, "Design and development of a micro inverter power monitoring system to enhance photovoltaic system performance by integrating LoRaWAN and IoT," *E3S Web of Conferences*, vol. 473, p. 01011, Jan. 2024, doi: 10.1051/e3sconf/202447301011.

[9] B. Setiawan, I. Siradjuddin, A. D. W. Sumari, W. Widjanarko, E. Mandyatma, and D. F. Putradi, "Identification of CNN hyper-parameters for tobacco leaf quality classification on Nvidia Jetson Nano," *Eastern-European Journal of Enterprise Technologies*, vol. 6, no. 2 (126), pp. 17–24, Dec. 2023, doi: 10.15587/1729-4061.2023.289017.

[10] I. G. M. N. Desnanjaya and I. M. A. Nugraha, "Real-time monitoring system for blood pressure monitoring based on internet of things," *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 35, no. 1, p. 62, Jul. 2024, doi: 10.11591/ijeecs.v35.i1.pp62-69.

[11] M. Kumar *et al.*, "Healthcare internet of things (H-IoT): current trends, future prospects, applications, challenges, and security issues," *Electronics (Basel)*, vol. 12, no. 9, p. 2050, Apr. 2023, doi: 10.3390/electronics12092050.

[12] U. Tariq, I. Ahmed, A. K. Bashir, and K. Shaukat, "A critical cybersecurity analysis and future research directions for the internet of things: a comprehensive review," *Sensors*, vol. 23, no. 8, p. 4117, Apr. 2023, doi: 10.3390/s23084117.

[13] C. Özlü and C. Yalçin, "Effects of methane emissions on multiple myeloma-related mortality rates: A World Health Organization perspective," *Medicine*, vol. 103, no. 15, p. e37580, Apr. 2024, doi: 10.1097/MD.0000000000037580.

[14] V. M. Sheba, J. Jayaprakash, P. G. Nisha, B. B. Prasath, S. Debora, and T. N. Begum, "Influence of seasons and environmental variables on methane dynamics in the Muthukuda Mangrove sediments of Tamil Nadu," *Journal of Environmental Biology*, vol. 45, no. 4, pp. 438–445, Jun. 2024, doi: 10.22438/jeb/45/4/MRN-5213.

[15] A. V Shadrin, "Outburst danger criteria for acoustic prediction methods at the initial and final stages of preparing sudden coal and gas outburst," *IOP Conference Series: Earth and Environmental Science*, vol. 823, no. 1, p. 012007, Jul. 2021, doi: 10.1088/1755-1315/823/1/012007.
[16] J. Liu, D. Yu, P. Li, X. Sun, and X. Chen, "Characteristics of explosion hazards in methane–air mixtures diluted by hydrogen," *Energies (Basel)*, vol. 16, no. 18, p. 6416, Sep. 2023, doi: 10.3390/en16186416.
[17] L. Li, T. Liu, Z. Li, X. Chen, L. Wang, and S. Feng, "Different prevention effects of ventilation dilution on methane accumulation at high temperature zone in coal mine goafs," *Energies (Basel)*, vol. 16, no. 7, p. 3168, Mar. 2023, doi: 10.3390/en16073168.
[18] J. L. Black, T. M. Davison, and I. Box, "Methane emissions from ruminants in Australia: mitigation potential and applicability of mitigation strategies," *Animals*, vol. 11, no. 4, p. 951, Mar. 2021, doi: 10.3390/ani11040951.
[19] K. A. Mar, C. Unger, L. Walderdorff, and T. Butler, "Beyond CO2 equivalence: the impacts of methane on climate, ecosystems, and health," *Environmental Science & Policy*, vol. 134, pp. 127–136, Aug. 2022, doi: 10.1016/j.envsci.2022.03.027.
[20] B. Króliczewska, E. Pecka-Kiełb, and J. Bujok, "Strategies used to reduce methane emissions from ruminants: controversies and issues," *Agriculture*, vol. 13, no. 3, p. 602, Mar. 2023, doi: 10.3390/agriculture13030602.
[21] J. Liu, D. Yu, P. Li, X. Sun, and X. Chen, "Characteristics of explosion hazards in methane–air mixtures diluted by hydrogen," *Energies (Basel)*, vol. 16, no. 18, p. 6416, Sep. 2023, doi: 10.3390/en16186416.
[22] S. Nanda and F. Berruti, "Municipal solid waste management and landfilling technologies: a review," *Environmental Chemistry Letters*, vol. 19, no. 2, pp. 1433–1456, Apr. 2021, doi: 10.1007/s10311-020-01100-y.
[23] K. O. A. Amano, E. Danso-Boateng, E. Adom, D. K. Nkansah, E. S. Amoamah, and E. Appiah-Danquah, "Effect of waste landfill site on surface and ground water drinking quality," *Water and Environment Journal*, vol. 35, no. 2, pp. 715–729, May 2021, doi: 10.1111/wej.12664.
[24] J. Nyika, M. Dinka, and E. Onyari, "Effects of landfill leachate on groundwater and its suitability for use," *Materials Today: Proceedings*, vol. 57, pp. 958–963, 2022, doi: 10.1016/j.matpr.2022.03.239.
[25] M. Jualayba, K. Regio, H. Quiozon, and A. Destreza, "Hazardous gas detection and notification system," in *2018 IEEE 10th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM), IEEE*, Nov. 2018, pp. 1–4. doi: 10.1109/HNICEM.2018.8666358.
[26] K. Aparna, D. H. Dayajanaki, D. Rani P, D. Devu, S. P. Rajeev, and B. S. D. Sreeja, "Design and implementation of methane gas detection and estimation sensor network," in *2023 9th International Conference on Advanced Computing and Communication Systems (ICACCS), IEEE*, Mar. 2023, pp. 662–667. doi: 10.1109/ICACCS57279.2023.10112797.
[27] B. T. Philip, D. S. Kelley, E. A. Solomon, and J. R. Delaney, "Monitoring methane emissions at Southern Hydrate Ridge using an OOI cabled array acoustic doppler current profiler," in *OCEANS 2016 MTS/IEEE Monterey, IEEE*, Sep. 2016, pp. 1–5. doi: 10.1109/OCEANS.2016.7761469.
[28] Y. Fan, Z. Tian, K. Wang, and D. Fan, "Simulation of water saving and methane mitigation potential of paddy fields under alternate wetting and drying irrigation regime in China," in *2021 9th International Conference on Agro-Geoinformatics (Agro-Geoinformatics), IEEE*, Jul. 2021, pp. 1–5. doi: 10.1109/Agro-Geoinformatics50104.2021.9530342.
[29] J.-P. Gagnon, V. Farley, and S. Boubanga-Tombet, "Comprehensive summary of methane airborne quantification results," in *IGARSS 2022 - 2022 IEEE International Geoscience and Remote Sensing Symposium, IEEE*, Jul. 2022, pp. 7363–7366. doi: 10.1109/IGARSS46834.2022.9884894.
[30] M. Aboughaly and I. M. R. Fattah, "Environmental analysis, monitoring, and process control strategy for reduction of greenhouse gaseous emissions in thermochemical reactions," *Atmosphere (Basel)*, vol. 14, no. 4, p. 655, Mar. 2023, doi: 10.3390/atmos14040655.
[31] C. A. Arinze, O. A. Ajala, C. C. Okoye, O. C. Ofodile, and A. I. Daraojimba, "Evaluating the integration of advanced it solutions for emission reduction in the oil and gas sector," *Engineering Science & Technology Journal*, vol. 5, no. 3, pp. 639–652, Mar. 2024, doi: 10.51594/estj.v5i3.862.
[32] V. B.Vales, O. C. Fernández, T. Domínguez-Bolaño, C. J. Escudero, and J. A. García-Naya, "Fine time measurement for the internet of things: a practical approach using ESP32," *IEEE Internet of Things Journal*, vol. 9, no. 19, pp. 18305–18318, Oct. 2022, doi: 10.1109/JIOT.2022.3158701.
[33] C. G. Raju, V. Amudha, and G. Sajiv, "Comparison of linear regression and logistic regression algorithms for ground water level detection with improved accuracy," in *2023 Eighth International Conference on Science Technology Engineering and Mathematics (ICONSTEM), IEEE*, Apr. 2023, pp. 1–6. doi: 10.1109/ICONSTEM56934.2023.10142495.
[34] H. Heng, "Nitrogen dioxide sensor calibration based on local linear model," in *2022 2nd International Signal Processing, Communications and Engineering Management Conference (ISPCEM), IEEE*, Nov. 2022, pp. 280–283. doi: 10.1109/ISPCEM57418.2022.00062.
[35] Y. Romero, R. M. A. Velásquez, and J. Noel, "Development of a multiple regression model to calibrate a low-cost sensor considering reference measurements and meteorological parameters," *Environmental Monitoring and Assessment*, vol. 192, no. 8, p. 498, Aug. 2020, doi: 10.1007/s10661-020-08440-w.

BIOGRAPHIES OF AUTHORS

Mochammad Junus is an associate professor at Electrical Engineering Department, State Polytechnic of Malang, Indonesia. He received the B.Sc. degree in telecommunication engineering from Institut Teknologi Sepuluh Nopember, Indonesia, the M.Sc. degree in electrical engineering from the Brawijaya University, Indonesian and the Ph.D. degree in Environmental Science from Brawijaya University, Indonesia. He used to hold several administrative posts with Electrical Engineering Department. His research areas are renewable energy, IoT, and mobile networking. He can be contacted at email: mochammad.junus@polinema.ac.id.

David Fydo Putradi received his B.Eng. degree in Electrical Engineering from State Polytechnic of Malang, Indonesia. His higher study the M.Eng. degree in Control Systems and Robotics from State Polytechnic of Malang from 2022-2024. His research interests are image processing, deep learning, and control systems. He can be contacted at email: 1941170061@student.polinema.ac.id.

Farida Arinie Soelistianto is a senior lecturer at Electrical Engineering Department, State Polytechnic of Malang. She received the B.Sc. degree in electrical engineering from the Widya Gama University, Indonesia, the M.Sc. degree in Electrical Engineering from the Brawijaya University, Indonesia. And the Ph.D. degree in Environmental Science from The Brawijaya University, Indonesia. Her research interests include IoT and digital networking. She can be contacted at email: farida.arinie@polinema.ac.id.

Mohammad Abdullah Anshori is a senior lecturer at Electrical Engineering Department, State Polytechnic of Malang. He received the B.Sc. degree in degree in Electrical Engineering from Brawijaya University. His research interests are instrumentation, digital telecommunication, and education. He can be contacted at email: anshori_ma@polinema.ac.id.

Rizky Ardiansyah is a lecturer at Electrical Engineering Department, State Polytechnic of Malang. He received the B.Sc. degree in Computer Science in 2013 and M.Sc. degree in Electrical Engineering in 2016, both from Brawijaya University. His research interests are artificial intelligence and computer vision. He can be contacted at email: rizkyardiansyah@polinema.ac.id.