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Design of environmental detector system application aims to promote awareness of pollution on campus

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ABSTRACT

Politeknik Negeri Medan (POLMED) was involved in the UI GreenMetric world rankings. The UI GreenMetric committee assessed green campus activities and environmental sustainability. The UI GreenMetric aims to raise awareness about sustainable campus greening, and social impacts of these endeavors. Based on the concept, an environmental detection system (EDS) was developed using internet of things (IoT) technology. The EDS can detect and monitor environmental parameters remotely such as carbon dioxide (CO_2), noise levels, light intensity, air temperature, relative humidity, and dust particle density in real-time via the internet. Measurements of environmental parameters were conducted at one location in POLMED. The average CO_2 level was 485 ppm. The average noise level was 53.40 dB. The average light intensity was 129 lux. The average air temperature was 26.60 °C. The average of relative humidity was 63.8% RH. The average of PM2.5 dust particle densities was 23 µg/m^3. The average of PM10 dust particle densities was 29 µg/m^3. Based on these results, the air quality has begun to be polluted because this value is already above the threshold clean quality air set by the Government of the Republic of Indonesia (310–330 ppm).

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1. INTRODUCTION

Many institutions of higher education including colleges, universities, polytechnics participate in the UI GreenMetric World University Rankings. They assessed the performance of higher education institutions with regard to sustainability. The objective of the UI GreenMetric was to raise awareness of the contributions of higher education institutions with regard to sustainable development, sustainable research, and campus greening, and the social impacts of such contributions [1], [2]. In general, the UI GreenMetric assessed higher educational institutions with regard to their environmental impact, including the utilisation of natural resources, the implementation of environmental management strategies and the mitigation of pollution [3], [4]. The economic aspects of the business include considerations of profit and efficiency [5], [6]. The social aspects encompass education, community, and social involvement [7], [8].

The UI GreenMetric assessed the environmental performance of an institution according to six domains: setting and infrastructure (SI), energy and climate change (EC), waste (WS), water (WR), transportation (TR), and education and research (ED) [9], [10]. One of the EC criteria was the implementation of smart buildings on campus. The construction of smart building involves the integration of smart features into building such as the incorporation of automation systems, security systems, comfort and environmental control systems, as well as the efficient use of renewable energy sources [11], [12]. Three elements that need to be considered for building comfort and environmental control systems, namely, water, land, and air [13], [14].

Unintentionally, pollution or contamination of these elements often occurs on campus. Institutions of higher education still rely on groundwater to meet daily water needs. Waste from laboratories and workshops was disposed of immediately without treatment process. The term "contamination" was defined as the deterioration of land surfaces and underground levels due to solid and liquid wastes that contaminate both soil and groundwater [15], [16]. Moreover, the use of private vehicles on campus contributes to air pollution. Pollution significantly impacts the environmental sustainability of campus. The lack of development of green space open areas. Even though, that was useful to support recreational activities, diverse organisms' habitat, rainwater catchment areas, mitigating floods. That was some challenges faced by campus [17], [18].

The Government of The Republic of Indonesia has enacted regulations aimed at safeguarding the environment. Maximum threshold of carbon dioxide (CO_2) in the air was 3,180 ppm [19]. Maximum of noise level was 97 dB [20]. The threshold of temperature was 26–30 °C [21]. The threshold of relative humidity was 65%–95% RH [22]. According to Indonesian National Standart No. 03-6575-2001, range of light intensity was 100-200 lux.

Internet of things (IoT) system was capable to detect and monitor of environmental parameters remotely such as CO_2, noise level, light intensity, air temperature, relative humidity, and dust particle density [23], [24]. The data collected from these environmental parameters can serve as a big data for developing policies to protect and mitigating actions [25], [26].

Therefore, this study focused on developing environmental detection system (EDS) using IoT technology. A data logger was used to record and store data. Then, it was transmitted to a cloud server. Communication between the data logger and the cloud server uses a global system for mobile communication (GSM) network. User applications were developed by Android and website programming. The big data will provide valuable insight into effective policies at campus. That was contributing to the achievement of environmental sustainability goals.

2. RESEARCH METHOD

The research about detection of environmental pollution levels on campus has been carried out in 2021 [13]. It has been done detection and monitoring various environmental parameters such as dust particle densities, temperature and humidity, illumination, CO_2, and noise levels. This research is used as a basis for further research development.

2.1. System design

EDS block diagram consists of five blocks, namely sensors block, server block, connectivity block, IoT gateway block, and application block. EDS block diagram was created in compliance with the guidelines shown in Figure 1. The type of sensor used has a built-in socket specifically designed to connect the long range (LoRa) node via cable pin. The sensors were CO_2 sensor type Renke RS-CO2*-*-2-EX, light intensity sensor and temperature humidity sensor type Renke RS-GZ*-*-2-EX, noise sensor type Renke RS-ZS-N01-*-EX, PM2.5 and PM10 sensor type Renke RS-PM-*-2. Every sensor sent the data to LoRa node. LoRa node saved the data and then it was transmitted to cellular LoRa gateway type King Pigeon S281. The transmission ranges up to 2 km as transmit distance between LoRa node and cellular LoRa gateway. This transmission did not use data packets, but it used a radio frequency network. It was an innovation for efficiency measures to save costs in research.

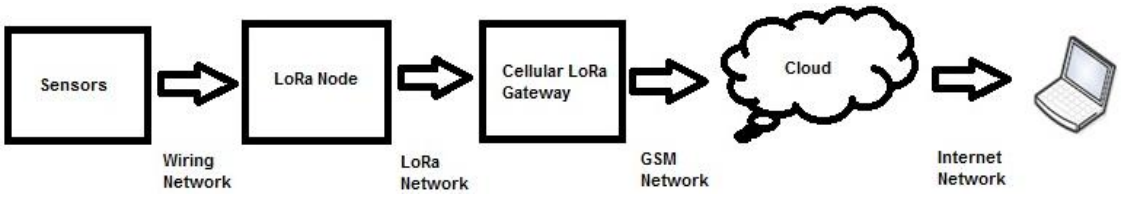

Figure 1. EDS block diagram

Next, the communication between cellular LoRa gateway and cloud server using a GSM network. It was caused by better features of the GSM network, which offers a wider network coverage in Indonesia. A significant proportion of campus locations were located close to urban centers. It was expected the GSM network will be easier to access environmental data from very long distance.

This research used https://app.microthings.id/ as key performance index (KPI) software platform. It can be utilized for the operation of web-based and Android/iOS applications. This platform was to create KPI indicators for laptop and smartphone users. This dashboard can be utilized for monitoring daily activities as well including the results in environmental pollution due to interactive system, accuration, analytical system, and real-time monitoring of activities. That was a novelty in this research.

2.2. Bracket design

The bracket was intended to be used to hold and stand of EDS's components. The welding of the frame iron seat or holder was required for this design. The design of EDS's bracket was straight-profiled with rooftop rectangle was bent 45 degrees to form an V-shaped inverted. The EDS's bracket was designed in Figure 2.

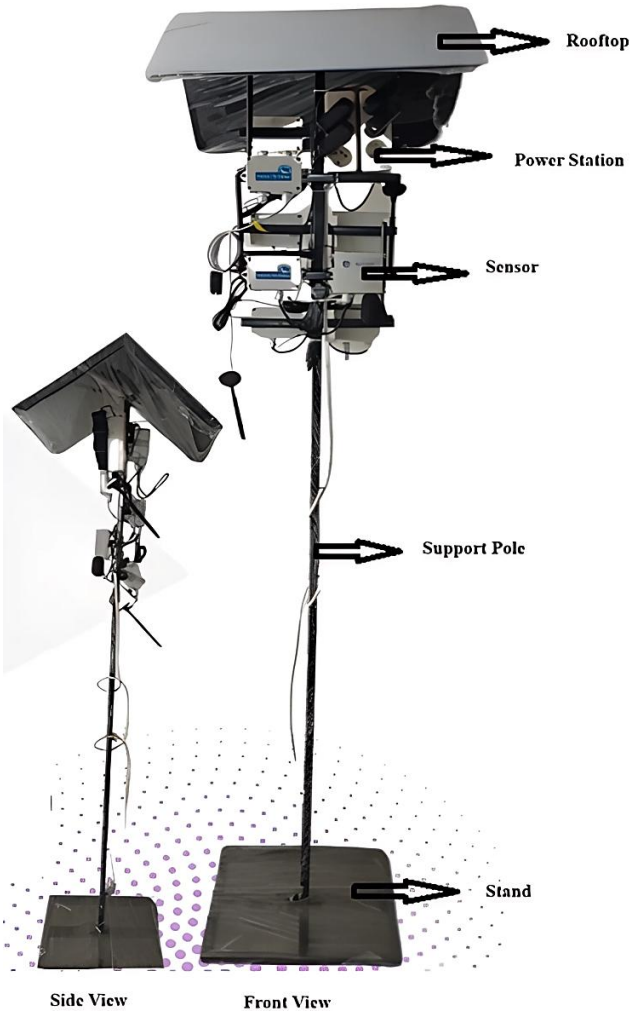

Figure 2. EDS with bracket

3. RESULTS AND DISCUSSION

Environmental parameters were measured as shown in Tables 1 and 2. Parameters are CO_2 levels, noise levels, light intensity, air temperature, relative humidity, and dust particle densities. Environmental parameters were measured on one location in Politeknik Negeri Medan (POLMED). The measurements were conducted at 10.00 a.m. (Western Indonesian Time) and the results were summarized in Tables 1 and 2. These data was measured on February 13, 2024.

Table 1. Measurement results for CO_2 and noise levels and light intensity

Date and time	Measurement results		
	CO_2 level (ppm)	Noise level (dB)	Light intensity (lux)
2024-02-13 10.17.15	485	52.87	129
2024-02-13 10.17.17	489	52.44	130
2024-02-13 10.17.19	490	55.27	130
2024-02-13 10.17.21	482	54.07	128
2024-02-13 10.17.23	486	54.16	128
2024-02-13 10.17.25	487	53,56	130
2024-02-13 10.17.27	485	55.67	128
2024-02-13 10.17.29	483	52.82	129
2024-02-13 10.17.31	482	53.25	130
2024-02-13 10.17.33	484	52.87	129
2024-02-13 10.17.35	485	53.44	128
2024-02-13 10.17.37	489	55.92	128
2024-02-13 10.17.39	490	53.35	129
2024-02-13 10.17.41	482	52,92	129
2024-02-13 10.17.43	486	53.97	129
2024-02-13 10.17.45	489	53.33	128
2024-02-13 10.17.47	485	51.78	127
2024-02-13 10.17.49	483	53.51	129
2024-02-13 10.17.51	482	53.38	129
2024-02-13 10.17.53	484	53.27	130
2024-02-13 10.17.55	485	51.78	129
2024-02-13 10.17.57	489	53.81	129
2024-02-13 10.17.59	490	51.44	128
2024-02-13 10.18.01	482	53.25	129
2024-02-13 10.18.03	486	55.09	129
2024-02-13 10.18.05	482	53.09	130
2024-02-13 10.18.07	486	52.61	130
2024-02-13 10.18.09	487	53.28	129
2024-02-13 10.18.11	485	53.24	129
2024-02-13 10.18.13	483	52.69	128
Mean	**485**	**53.40**	**129**

Table 2. Measurement results for air temperature, relative humidity, and dust particle densities

Date and time	Measurement results			
	Air temperature (°C)	Relative humidity (%)	Dust particle density for PM2.5 (µg/m^3)	Dust particle density for PM10 (µg/m^3)
2024-02-13 10.18.00	26.2	64.5	23	30
2024-02-13 10.18.02	26.3	65.4	24	31
2024-02-13 10.18.04	26.8	65.3	22	29
2024-02-13 10.18.06	26.7	65.3	21	28
2024-02-13 10.18.08	26.2	65.1	24	32
2024-02-13 10.18.10	26.2	65.1	25	30
2024-02-13 10.18.12	26.3	65.2	23	27
2024-02-13 10.18.14	26.3	65.9	23	30
2024-02-13 10.18.16	26.4	65.3	24	31
2024-02-13 10.18.18	26.5	65.6	22	29
2024-02-13 10.18.20	26.6	64.1	21	28
2024-02-13 10.18.22	26.2	65.1	23	28
2024-02-13 10.18.24	26.7	64.1	25	30
2024-02-13 10.18.26	26.7	63.9	23	28
2024-02-13 10.18.28	26.7	63.3	22	27
2024-02-13 10.18.30	26.6	63.7	21	26
2024-02-13 10.18.32	26.6	63.5	24	30
2024-02-13 10.18.34	26.6	63.4	22	28
2024-02-13 10.18.36	26.6	62.8	21	28
2024-02-13 10.18.38	26.7	62.5	24	31
2024-02-13 10.18.40	26.7	62.3	23	30
2024-02-13 10.18.42	26.7	62.7	24	30
2024-02-13 10.18.44	26.7	62.3	22	27
2024-02-13 10.18.46	26.8	62.3	21	28
2024-02-13 10.18.48	26.8	62.1	24	31
2024-02-13 10.18.50	26.8	62.4	23	30
2024-02-13 10.18.52	26.9	62.3	26	30
2024-02-13 10.18.54	26.9	62.7	22	31
2024-02-13 10.18.56	27.3	62.3	24	32
2024-02-13 10.18.58	26.9	63.6	22	29
Mean	**26.6**	**63.8**	**23**	**29**

The graphical user interface used to select the environmental parameters for display was shown in Figure 3. While the graphical user interfaces used to monitor the air temperature and relative humidity were shown in Figures 4 and 5.

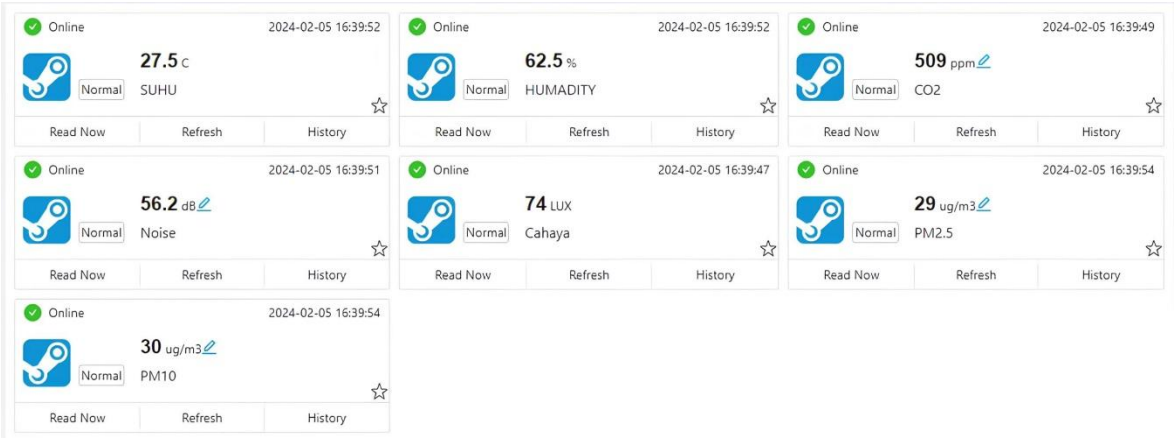

Figure 3. Graphical user interface showing the environmental parameters to be monitored

Figure 4. Graphical user interface showing the variation of the air temperature with respect to date and time. (Note that the word suhu means temperature)

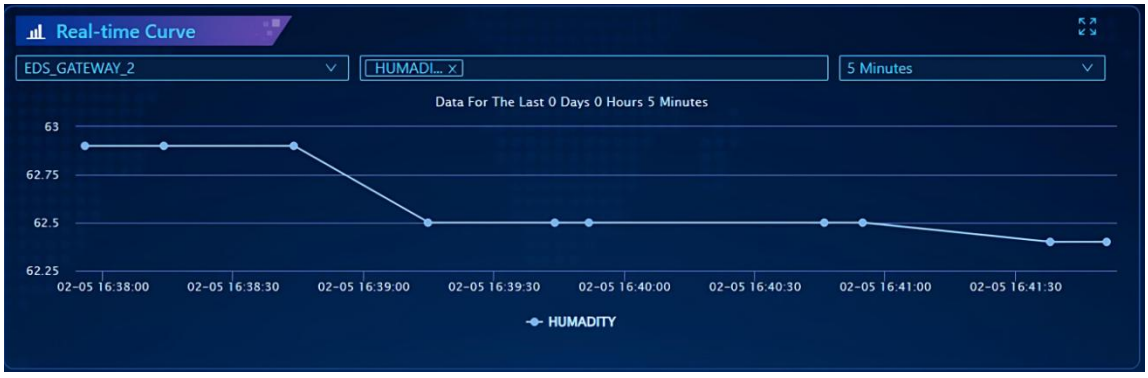

Figure 5. Graphical user interface showing the variation of the relative humidity with respect to date and time

The measurements were conducted in the morning in the vicinity of POLMED campus. It was necessary to measure the data results considering the regulatory standards established by the Indonesian government such as regulation no. 12/2010 of the Minister of Environment with maximum density of PM-2.5 dust particles was 66 µg/m³ and permissible concentration of CO_2 in outdoor was 350–700 parts per million (ppm). According to Minister of Health regulation no. 70/2016, lighting minimum was 150 lux. According to

regulation no. 13/2011 of the Minister of Manpower and Transmigration that the maximum noise level was 97 dB. Based on Minister of Manpower, Transmigration, and Cooperation regulation No. 1/1978, the ideal temperature range was between 26 ºC and 30 ºC, and humidity range of 65% to 95% RH.

Variation for assessment with respect to date and time. Level of CO_2 measured within the range of 482-490 ppm. The average was 485 ppm. According to the Ministry of Environment regulation no.12/2010, outdoor air in POLMED was considered polluted. It was caused by many vehicles passing through POLMED. Many students drove their own vehicle to the campus. The graphic result was shown in Figure 6. Despite the fewer number of vehicles passed through POLMED at the time. The CO_2 levels were measured, but the outdoor air was still polluted. Thus, policies need to be developed to tackle air pollution in POLMED such as prohibiting students from bringing their private vehicles to campus. That was directly correlated with the quantity of cars on campus. In addition, POLMED needs to consider the development of green spaces (i.e., open spaces with plenteous grass, trees, shrubs, or other vegetation), covering 30% of the campus area. POLMED has an area of 8 ha and therefore, the area of the green spaces should be at least 2.4 ha.

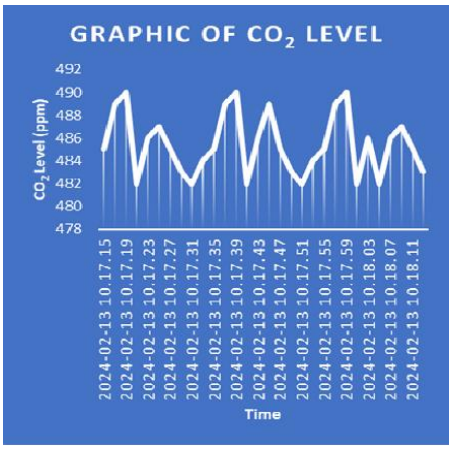

Figure 6. Variation for CO_2 level with respect to date and time

Noise level measured within the range of 51.78-55.92 dB. The average was 53.40 dB. This value was still below the maximum noise level of 85 dB with an exposure time of 8 hours. It was indeed expected since the noise level measurements were made at 10.00 a.m. because students still studied on this time. It needs to be considered by POLMED to ensure that the noise levels will never exceed the maximum noise because it can disrupt the teaching and learning process. The graphic result was shown in Figure 7.

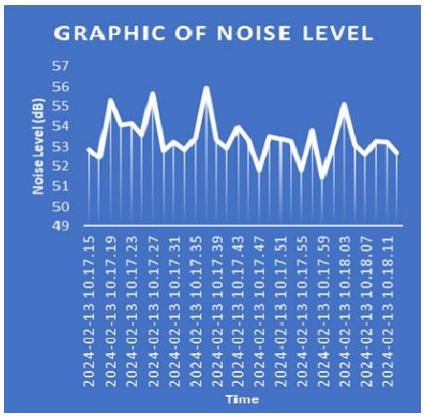

Figure 7. Variation for noise level with respect to date and time

Light intensity measured within the range of 127-130 lux. The average was 129 lux. There was a need to improve indoor lighting conditions because the average light intensity of 129 lux was found to be lower than the minimum indoor light intensity of 150 lux set by the Indonesian Government. The graphic result was shown in Figure 8.

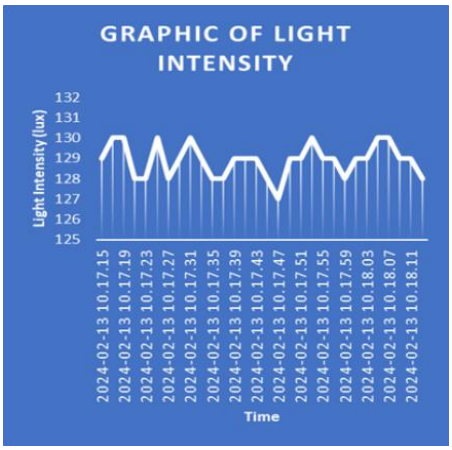

Figure 8. Variation for light intensity with respect to date and time

Air temperature was measured within the range of 26.2 °C-26.9 °C and relative humidity was measured within the range of 62.1% RH-65.9% RH. The average of air temperature was 26.6 °C, and the average of relative humidity was 63.8% RH. These values were in the range of 26 °C-30 °C and 65%-95% RH respectively. The condition was normal as Indonesia a tropical and humid country. The graphic result of temperature was shown in Figure 9. The graphic result of relative humidity was shown in Figure 10.

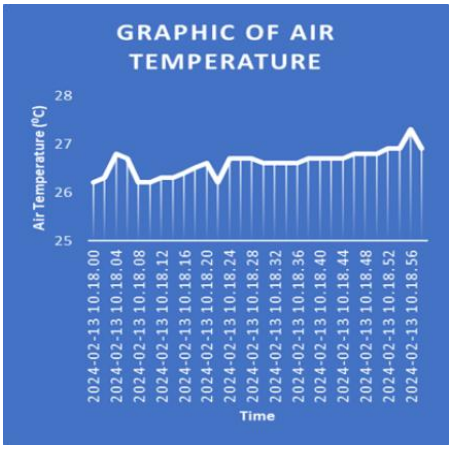

Figure 9. Variation for air temperature with respect to date and time

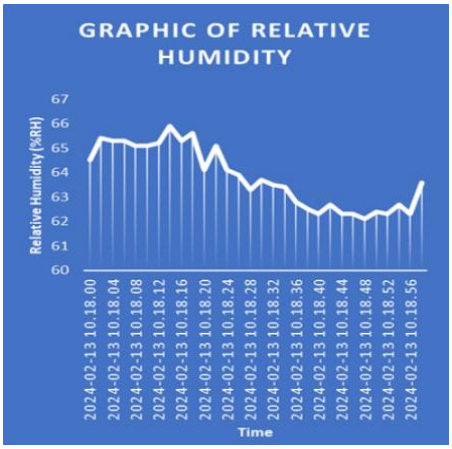

Figure 10. Variation for relative humidity with respect to date and time

Dust particle density for PM2.5 was measured within the range of 21 µg/m^3-26 µg/m^3. The average was 23 µg/m^3. The graphic result was shown in Figure 11. Dust particle density for PM10 was measured within the range of 27 µg/m^3-32 µg/m^3. The average was 29 µg/m^3. The graphic result was shown in Figure 12. According to regulation no. 12/2010 of the Minister of Environment with maximum density of PM-2.5 dust particles was 66 µg/m³.

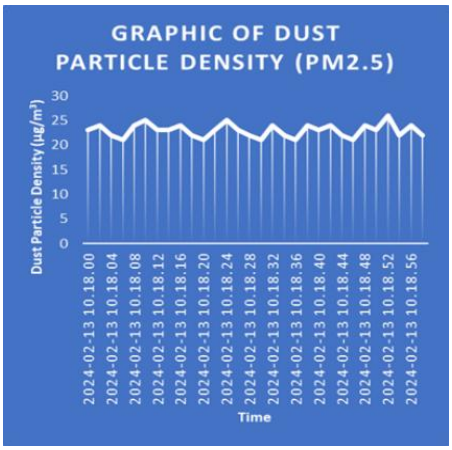

Figure 11. Variation for dust particle density for PM2.5 with respect to date and time

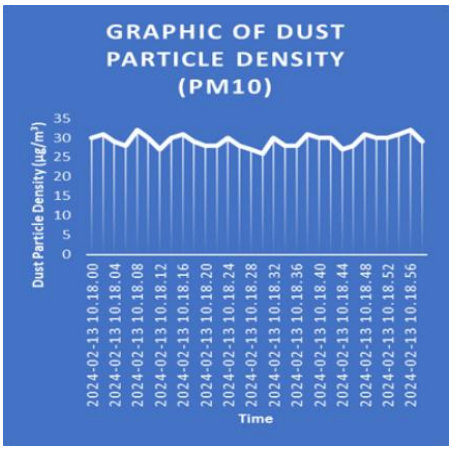

Figure 12. Variation for dust particle density for PM10 with respect to date and time

4. CONCLUSION

An EDS has been developed by using IoT technology. This device was developed to detect and monitor environmental parameters such as CO_2 and noise levels, light intensity, air temperature, relative humidity, and dust particle densities (PM2.5 and PM10) remotely by real-time. Based on the results, it can be concluded that most of the environmental parameters measured were still recommended by the Indonesian regulation, excepted for CO_2 level and light intensity. The average of CO_2 level was 485 ppm. It was found to exceed the CO_2 threshold for clean outdoor air in range 310–330 ppm. It was a warning since higher CO_2 levels in the air contribute to the greenhouse effect (i.e., the trapping of heat in the Earth's atmosphere due to high CO_2 levels). The POLMED campus area was only 8 ha, where 30% of the land was used as parking space. It would have been more desirable if the land was used to develop green spaces, which would help reduce CO_2 levels. In addition, the CO_2 levels can be reduced by prohibiting students from not bringing their private vehicles to campus. The average light intensity was determined to be 129 lux. This value was less than the minimum indoor light intensity specified by the Indonesia regulation (150 lux). The most of lecture and students worked in their classes. There was need to improve the lighting conditions indoors, which will help promote the well-being of the building occupants and ensure a productive work environment. Finally, POLMED needs to focus on environmental sustainability, which involves ensuring the health and well-being of current and future generations through the responsible use of natural resources, minimization, and

management of wastes, and ensuring that human activities will not cause detriment to the environment and biological diversity. It can be achieved by detecting and monitoring environmental parameters using the EDS development as a start to develop and implement effective environmental sustainability policies in POLMED. An EDS will be developed in the future by adding more sensors so that more environmental parameters can be detected and monitored. These environmental parameters are in the air, soil, and water.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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Banu Afwan Pribadi	✓		✓			✓	✓	✓		✓		✓		✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all persons included in this research.

DATA AVAILABILITY

The data in this study is finding accessible in https://app.microthings.id. The dataset includes all parameters used for environmental monitoring system such as carbon dioxide (CO_2), noise levels, light intensity, air temperature, relative humidity, and dust particle density. Environmental parameters were measured on one location in POLMED. The measurements were conducted at 10.00 a.m. (Western Indonesian Time) and these data was measured on February 13, 2024.

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