Available *online* at : http://jnte.ft.unand.ac.id/

Jurnal Nasional Teknik Elektro

| ISSN (Print) 2302-2949 | ISSN (Online) 2407-7267 |

Correlation of Vehicle Traffic to Air Quality, Temperature, and Noise in Malang City Through an Internet of Things (IoT) Approach

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ARTICLE INFORMATION

Received: October 16, 2024
Revised: November 15, 2024
Accepted: November 25, 2024
Available online: November 30, 2024

KEYWORDS

Urban Air Quality, Outdoor Monitoring System, Internet of Things, Firebase

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A B S T R A C T

In response to the issues of air pollution, temperature, and noise, this project attempts to create an air quality, temperature, and noise monitoring system using Internet of Things (IoT) technology. This system will comprise physical components and a web platform that delivers real-time environmental reports. Users can readily obtain information regarding air quality, temperature, and noise levels via this platform, which takes advantage of the internet's accessibility. This Internet of Things-based device monitors environmental quality in six high-traffic areas in Malang, Indonesia. The system uses various sensors to monitor air quality, temperature, humidity, dust levels, carbon monoxide (CO), carbon dioxide (CO2), and noise pollution in real-time. Data was collected during peak traffic hours, demonstrating the direct influence of car emissions on air quality. The findings show that some regions' CO and particulate matter levels surpass safe criteria, notably during peak traffic periods, but CO2, humidity, and noise levels are below acceptable norms. These findings highlight the necessity for urban air pollution reduction initiatives. Additional sensor calibration and communication modifications are recommended to increase system accuracy and dependability. This study gives significant insights for local authorities to manage urban environmental quality and safeguard human health.

INTRODUCTION

Today's advancements in transportation technology have completely changed the significance of distance. Intercontinental travel is now feasible in hours, which was challenging to achieve a century ago. Motorized vehicles have made fast advances in negotiating varied terrains while delivering more comfort to their operators. The public transportation industry has likewise made tremendous strides during the last few decades[1]. Transport plays an important role in a region's economic growth, but it is also one of the leading contributors to air pollution due to car emissions[2], [3]. This is becoming a global concern as the resulting pollution rises, significantly damaging the surrounding ecosystem if it surpasses the permissible concentration threshold. However, the advancement of transportation technology has had a detrimental effect on the environment[4]. Exhaust emissions from individual vehicles are currently the leading source of air pollution, accounting for around 70% of overall pollution[5], [6]. People's air quality is gradually deteriorating without recognizing it, and the negative consequences are only realized later. In recent years, there has been an increasing awareness of the environmental issues of unsustainable transportation [7]**.** The detrimental impacts of air pollution necessitate substantial attention to its control from the government and society. One management effort is to give simple access to air quality information, often provided by the government via the Air Pollution Standard Index (ISPU) recorded at air quality monitoring stations [8]. According to the World Health Organization (WHO), this is vital in preserving public health and the environment. Every year, air pollution kills almost seven million people worldwide, with nine out of ten individuals exposed to air that exceeds permissible levels [9], [10]. According to the 2019 report by the World Health Organization (WHO), air pollution causes approximately 4.2 million premature deaths globally each year [15]. Noise is an unpleasant sound produced by a business or activity at a specific volume and time. Aside from noise, one of the functions of humidity in life is related to health. Humid air and irregular climatic fluctuation, particularly in tropical Indonesia, can induce various diseases heavily influenced by humidity levels [11]. Several noise-related legislation have been enacted in the Republic of Indonesia, including one that addresses the Noise Level Standard. Generally, the noise intensity in residential areas is roughly 55 decibels[12]. A noise threshold is 85dB for only 8 hours of exposure. Based on the problems of air pollution, temperature, and noise, this research aims to develop a monitoring system for air quality, temperature, and noise using Internet of Things (IoT) technology. The system will

https://doi.org/10.25077/jnte.v13n3.1259.2024

consist of hardware and a website providing real-time reports on environmental conditions[24]. Through this website, users can easily access information about air quality, temperature, and noise, utilizing the ease of access offered by the internet[14]. The Internet of Things (IoT) is a concept used to enhance continuous internet connectivity, enabling efficient data collection and exchange. The Internet of Things (IoT) refers to a network of smart devices that are interconnected, allowing them to gather and share information effortlessly [14, 16]. According to [15,25] the Internet of Things (IoT) integrates global infrastructure with communities, delivering advanced services by connecting physical and virtual objects (things) over the Internet of technology, allowing all devices to speak with one another. IoT often uses a variety of sensors depending on the need. If possible, the data from sensors will be encrypted using the Advanced Encryption Standard (AES) method, which, according to the Internet of Things (IoT), is one of the modern cryptographic methods used to replace the 56-bit block Data Encryption Standard (DES) algorithm, which is considered insecure[17], [18]. The criteria for picking this algorithm are based on its properties, security, cost of use, and implementation. It is envisaged that the design of this IoT-based air quality, temperature, and noise monitoring system will facilitate the assessment of air quality in ports and other areas.

METHODS

Research Methodology

The first step carried out is a field study by identifying problems and determining methods at the research location, then a literature study on the research topic, then the process of designing the tool and conducting testing and pre-collection of data [19,]26]. If the tool successfully displays data, it will continue. Otherwise, it will be checked again on the tool design. After the process goes well, data processing and analysis will be carried out.

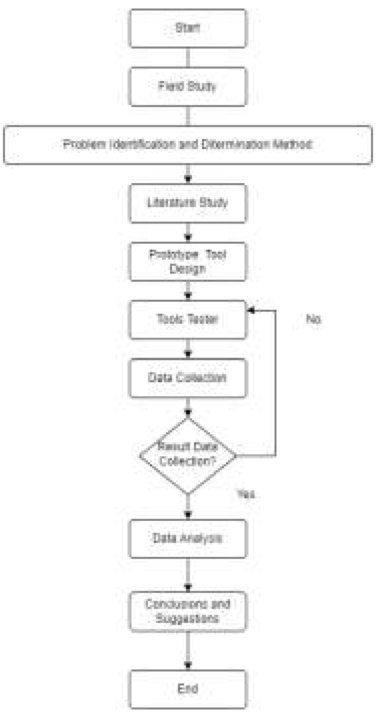

Figure 1. Research Flowchart

Research Operational Variable

Control variables include the location of the research (six locations in Malang), the sensors used (air sensors type MQ-135 and MQ-7, temperature sensor type DHT11, sound sensor type GP 2Y10, dust particulates sensor type GY MAX4466)[21], and the distance between the road shoulder and the inquiry sensor tool (approximately ± 3 meters). Manipulation variables include the time indicated by the number of vehicles passing by, which is done around 07.00, 13.00, and 16.00 WIB, to obtain research responses, as well as Air Quality, Noise Levels, Temperature, Humidity, and Dust Particulate matter Levels witnessed by measurement tools that have been made with determined variables.

Data Collection Technique

The data is collected after the tool is assembled and set correctly. Data collection is carried out in the morning at 06.00 WIB - 07.00 WIB, during the day at 11.00 WIB 12.00 WIB, and in the afternoon at 15.00 WIB - 16.00 WIB. Data collection location points are shown in Table 1.

Table 1. Data Collection Location Point

Data Collection Point	Location	Latitude	Longitude
Point 1	Tanggulmas	-7.92619	112.6016
Point 2	Gajayana	-7.94312	112.6103
Point 3	Sutami	-7.95646	112.6131
Point 4	Sukarno Hatta	-7.9499	112.6156
Point 5	Blimbing	-7.94171	112.6421
Point 6	La Sucipto	-7.94375	112.6483

Data is taken over several days to capture different situations. The research data will be recorded and stored on the SD Card Module. The system overview of the prototype used can be seen in Figure 2.

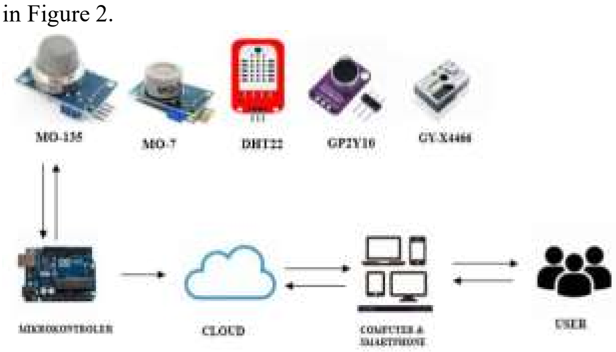

Figure 2. System Overview

Figure 2 is an overview of the IoT-based air quality monitoring system, where the sensors to be used are MQ-7, MQ-135, DHT22, GP2Y1010AUF, GY-MAX4466 sensors that can detect air quality from gases that pollute the environment or endanger health such as ammonia, aromatic compounds, sulfur, benzene vapor, smoke, NH3, NOx, alcohol, CO2, and others[22], [23].

The same method was also used by Edwin Collado [17]; they also used the DHT22 module to measure humidity and concentrations of pollutants such as carbon monoxide (CO), nitrogen dioxide (NO2), and sulfur dioxide (SO2). After the sensor obtains the data, it will be sent to the cloud. Cloud technology makes the internet the server center for managing data[27]. The cloud makes it easy for users to run programs without installing applications first and allows users to access data and information via the internet [25], . After that, users can access and monitor via the web to monitor. The complete of outdoor air quality monitoring system can be seen in Figure 3 below.

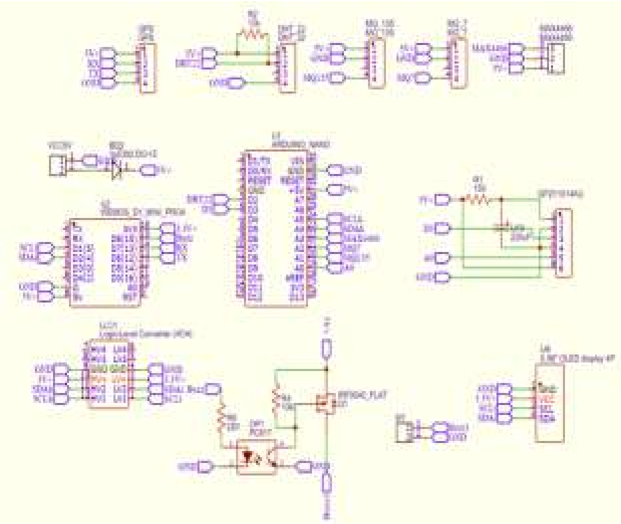

Figure 3. Schematic Air Quality Monitoring System

Figure 3 is a complete schematic of the Internet of Things (loT)-based Air Quality, Temperature, and Noise Monitoring System. In the figure, the workings of the circuit built using 5 sensors can be seen in full. namely the carbon monoxide sensor, carbon dioxide sensor, temperature and humidity sensor, particulate dust sensor Pm 2.5, and noise sensor. Each sensor will send data to the Arduino nano microcontroller. Then, it will be processed by the microcontroller, and then it will be sent to the Firebase platform with the help of Wemos D1, which is connected wirelessly to a Wi-Fi modem[26]. from the data capture, it will be sent again to the spreadsheet, where the spreadsheet results will be processed and interpreted in the form of tables and graphs.

Data Analysis Technique

Simple regression analysis was used to identify relationships between variables (e.g., CO2 levels and number of cars). Time-Series Analysis: Data was sorted by collection time to examine temporal trends and compare air quality and noise levels during peak hours.Site Comparison Analysis: We analyzed data from each location point to identify patterns of variations between neighborhoods.

RESULTS AND DISCUSSION

Humidity

Based on the humidity result data in Table 2 and Figure 4, it can be seen that the highest daily average humidity was recorded at 06:00-07:00 at Tanggul Mas (68%), followed by Gajayana (62%), Sutami and Soekarno Hatta (59%), LA Sucipto (55%), and Belimbing (53%). The data shows that these values are still considered good, as air humidity should be kept within the range of 45%-66%. The study by [20] shows similar results. They investigated humidity, and the ambient hourly temperature range during testing was between 24°C and 26°C. The vast majority of the hourly relative humidity measurements were between 55% and 60%[28].

Table 2. Humidity Results

Humidity, %							
		Tanggul mas	Gajaya na	Sutami	Suhat	Belimb ing	La Sucipto
Max	06:00-07:00	68	62	59	60	55	53
	11:00-12:00	43	40	49	54	43	39
	15:00-16:00	43	42	48	48	48	48
Min	06:00-07:00	63	59	57	55	39	42
	11:00-12:00	37	35	44	42	38	33
	15:00-16:00	33	38	39	39	39	39
Average	06:00-07:00	65	60	58	58	47	49
	11:00-12:00	37	35	44	42	38	33
	15:00-16:00	33	38	39	39	39	39

Temperature

Based on the temperature data in Table 3 and Figure 5, it can be seen that the highest daily average temperature was recorded at 11:00-12:00 at LA Sucipto (34^{o}C). In addition, an average temperature of 32^{o}C was recorded at 15:00-16:00 in almost all locations. The data shows that this value is still considered high compared to the average daily temperature of Malang city

Table 3. Temperature Results

Temperature, ºC							
		Tanggul mas	Gajaya na	Suta mi	Suh at	Belimbi ng	La Sucipto
Max	06:00-07:00	24	33	27	31	33	34
	11:00-12:00	34	34	33	35	34	34
	15:00-16:00	34	34	34	35	34	34
Min	06:00-07:00	21	24	25	24	27	27
	11:00-12:00	24	32	27	31	31	31
	15:00-16:00	32	32	31	31	31	31
Average	06:00-07:00	23	25	26	26	30	30
	11:00-12:00	33	33	31	32	33	32
	15:00-16:00	33	33	32	32	32	33

Particulates

Based on the particulate data in Table 4 and Figure 6, it can be seen that the highest daily average dust levels were recorded at 15:00-16:00 at LA Sucipto (124 µg/m^3). At the same time, the lowest daily average dust level was recorded at Soekarno Hatta with a concentration of 32 µg/m^3. According to [28] investigate the performance of PM2.5 measurements and concluded that if the levels of PM2.5 are greater than 250 µg/m^3, it indicates that the readings have reached the highest level of risk[15]. Compared to this study, the values are still below the maximum limit. The

https://doi.org/10.25077/jnte.v13n3.1259.2024

data shows that these values are suspected to exceed the established threshold of 65 µg/m³

Table 4. Dust Particulate Results

Dust Particulate, µg/m³							
		Tanggulmas	Gajayana	Sutami	Suhat	Belimbing	La Sucipto
Max	06:00-07:00	89	99	95	92	93	94
	11:00-12:00	98	101	99	95	87	103
	15:00-16:02	94	99	112	124	116	118
Min	06:00-07:00	61	51	81	32	41	56
	11:00-12:00	61	100	22	46	76	81
	15:00-16:00	115	95	100	51	76	76
Average	06:00-07:00	173	194	198	171	214	219
	11:00-12:00	165	188	180	167	222	238
	15:00-16:00	213	211	191	189	172	172

Carbon dioxide

Based on the CO2 data in Table 5 and Figure 7, it can be seen that the highest daily average CO2 concentration was recorded at 15:00-16:00 at La Sucipto, with a concentration of 80 ppm. Meanwhile, the lowest CO2 concentration was recorded at Soekarno Hatta at 11:00-12:00 with a value of 8 ppm. The data shows that the value is still safe because the concentration is <5,000 ppm. In the investigation [29], they also measured air quality in 84 homes and presented data for CO2 levels similar to our results, which were <5000 ppm, with a range of 473–1885 ppm

Table 5. Carbon Dioxide Results

Carbon Dioxde, ppm							
		Tanggulmas	Gajayana	Sutami	Suhat	Belimbing	La Sucipto
Max	06:00-07:00	49	63	63	58	55	37
	11:00-12:00	28	20	31	25	26	28
	15:00-16:00	68	36	32	80	80	80
Min	06:00-07:00	22	16	22	11	20	12
	11:00-12:00	17	11	11	8	11	10
	15:00-16:00	31	19	15	11	11	11
Average	06:00-07:00	34	42	33	27	31	18
	11:00-12:00	22	15	16	13	16	16
	15:00-16:00	43	24	20	28	38	38

Carbon monoxide

Based on the CO data in Table 6 and Figure 8, it can be seen that the highest daily average CO concentration was recorded at 15:00-16:00 at Belimbing, with a concentration of 347 ppm. In contrast, at the 11.00-12.00, the lowest CO concentration was observed at Suhat, averaging 51 ppm. The carbon monoxide (CO) gas concentration threshold for safe limits is at <70 ppm, for awareness limits at 70-150 ppm, and dangerous if the concentration is >150 ppm. Based on observations made at several points, it can be seen that the concentration of CO in Malang City is classified as dangerous and deadly at peak time, with values almost mostly >70 ppm. As a comparison, in a study conducted [16], the testing process was carried out in Semarang City on April 14, 2024, from 08:00 Western Indonesia Time to 22:00 Western Indonesia Time. The test results also showed CO2 levels below 5,000 ppm and CO gas levels below 25 ppm.

Table 6. Carbon Dioxide Results

Carbon Dioxide, ppm							
		Tanggulmas	Gajayana	Sutami	Suhat	Belimbing	La Sucipto
Max	06:00-07:00	178	189	267	319	319	377
	11:00-12:01	199	185	190	200	111	111
	15:00-16:02	265	215	188	252	347	347
Min	06:00-07:00	267	167	127	84	84	84
	11:00-12:01	142	143	113	51	61	61
	15:00-16:02	124	141	243	127	143	143
Average	06:00-07:00	117	162	199	181	155	223
	11:00-12:01	186	154	379	101	82	81
	15:00-16:02	143	132	356	190	224	224

Noise

Based on the noise data attached in Table 7and Figure 9, it can be observed that the highest daily average noise value was recorded at 15:00-16:00 at the Blimbing and LA Sucipto location points with a value of 80 dB. The value is still below the set threshold of 85 dB. The noise results are also similar to the study by [30]. They conducted their work using a CZE-15E sound sensor at five locations in India and reported that the average noise levels during normal days and the festival season ranged from 30 to 81 dB, which is similar to our results.

Table 7. Noise Results

		Noise, db					
		Tanggulmas	**Gajayana**	**Sutami**	**Suhat**	**Belimbing**	**La Sucipto**
Max	06:00 - 07:00	89	81	77	87	91	78
	11:00 - 12:00	98	77	83	97	92	76
	15:00 - 16:00	78	83	66	64	80	80
Min	**06:00 - 07:00**	**34**	**31**	**27**	**30**	**36**	**27**
	11:00 - 12:00	38	29	30	40	35	31
	15:00 - 16:00	32	39	30	43	56	56
Average	06:00 - 07:00	54	47	48	48	61	46
	11:00 - 12:00	56	46	47	55	49	46
	15:00 - 16:00	52	58	48	71	80	80

CONCLUSIONS

The IoT system for environmental quality measurement at 6 high-traffic locations has been implemented and works well. Data from each sensor can be accessed through the on-site LCD and the app in real time. The next step is to refine the calibration and improve the stability of IoT communication. From the observations at 6 locations, the overall data shows that the air quality and pollution levels in Malang City, especially during peak hours, require serious attention. The air quality and environment in several locations in Malang City, especially in areas with high vehicle density, tend to deteriorate. Increased temperatures, dust concentrations and especially CO at certain times, show the direct impact of high vehicle activity. Although in terms of humidity it is still relatively good, with CO2 and noise still relatively safe and below the threshold. These findings are important to be used as a reference in efforts to mitigate air pollution in Malang City. The city government and related parties need to consider policies to reduce vehicle emissions, improve air quality, and maintain public health, especially in locations prone to air and noise pollution.

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Appendix

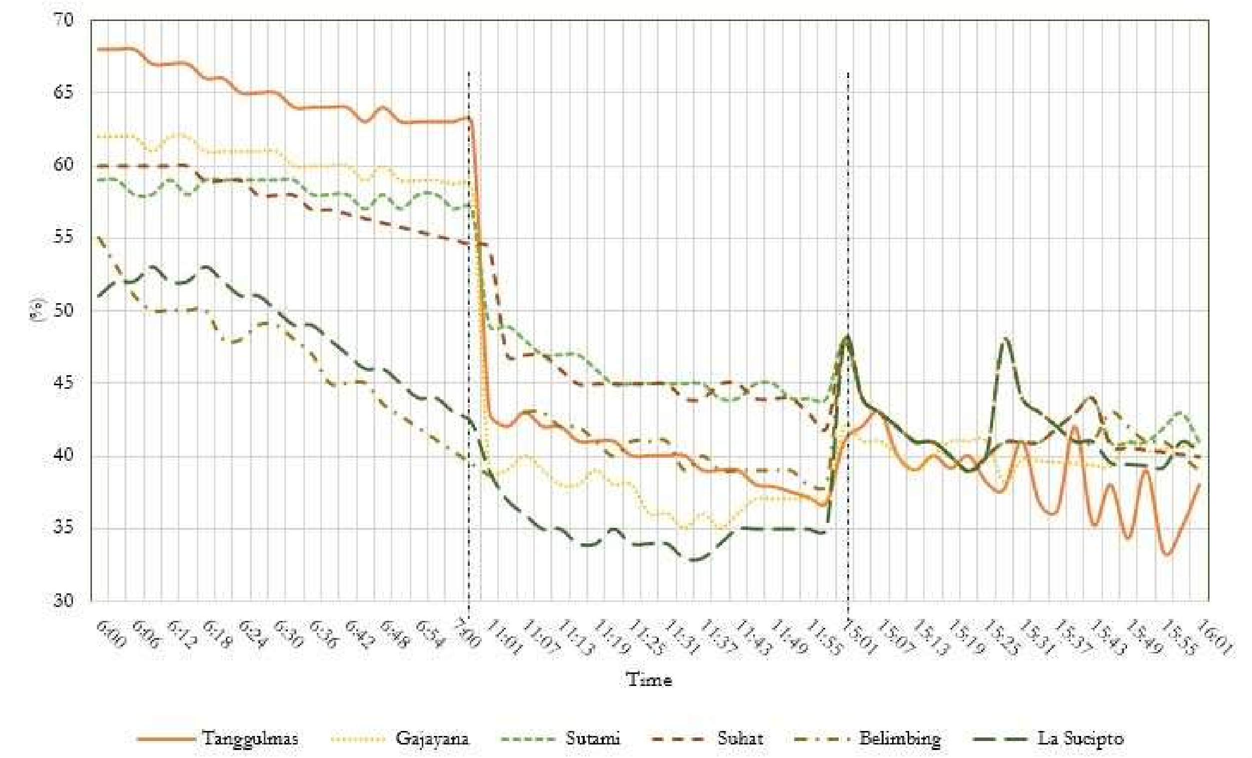

Figure 4. Humidity Monitoring Data Chart

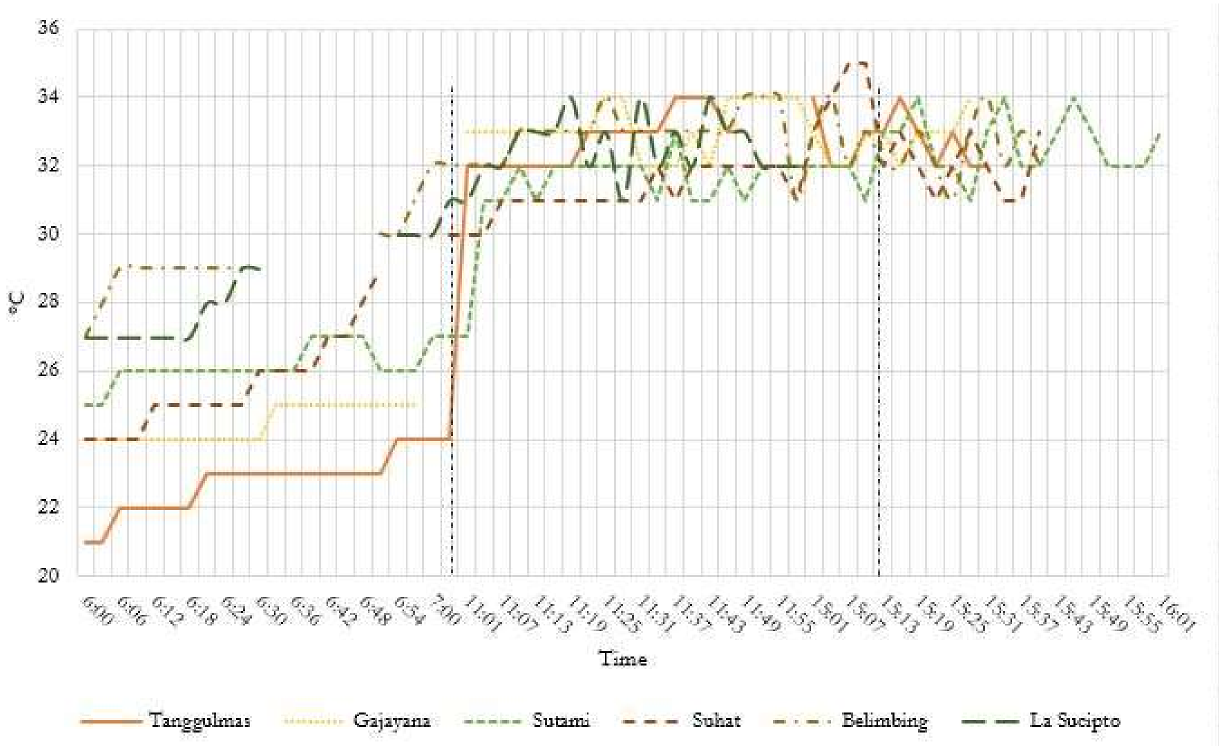

Figure 5. Temperature Monitoring Data Graph

https://doi.org/10.25077/jnte.v13n3.1259.2024

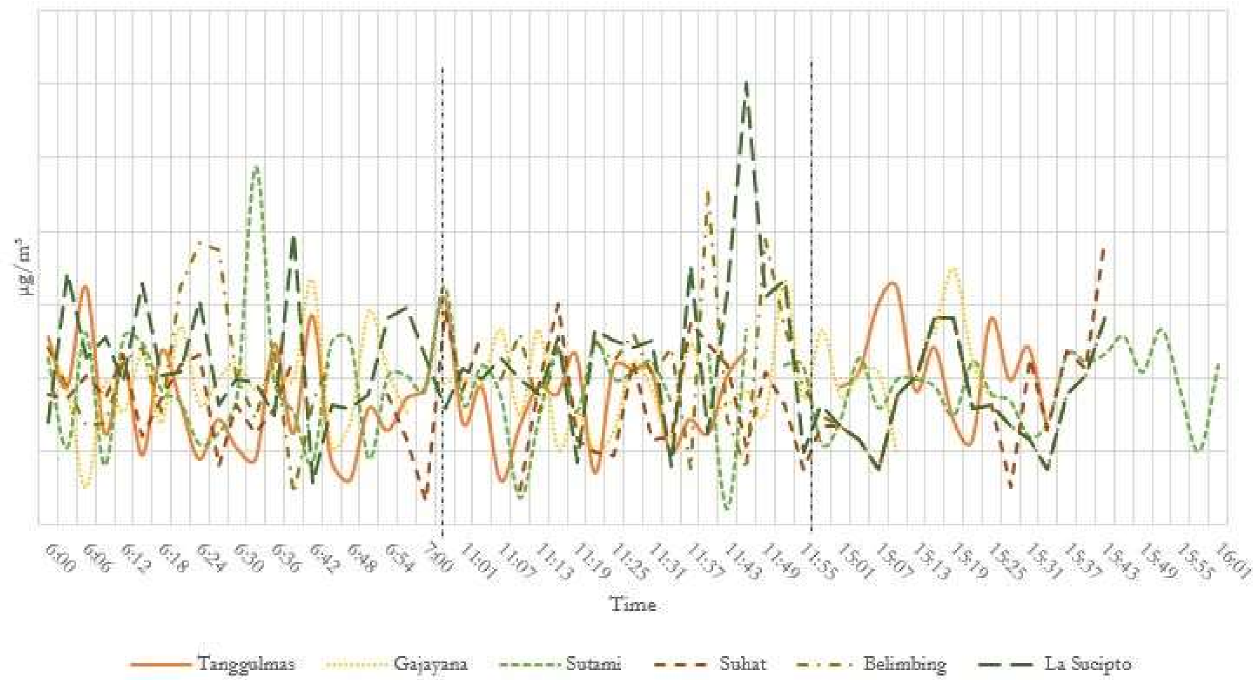

Figure 6. Dust Particulates Monitoring Graph

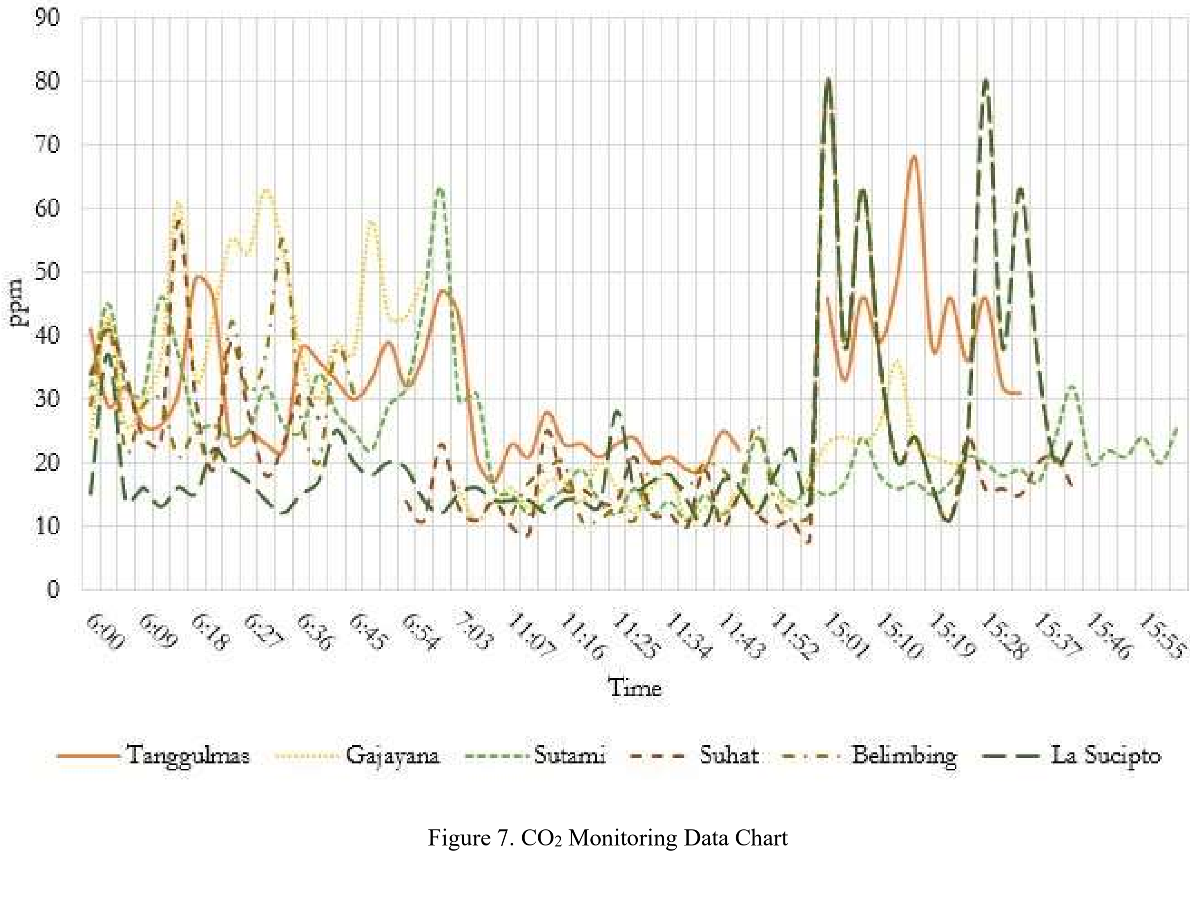

Figure 7. CO_2 Monitoring Data Chart

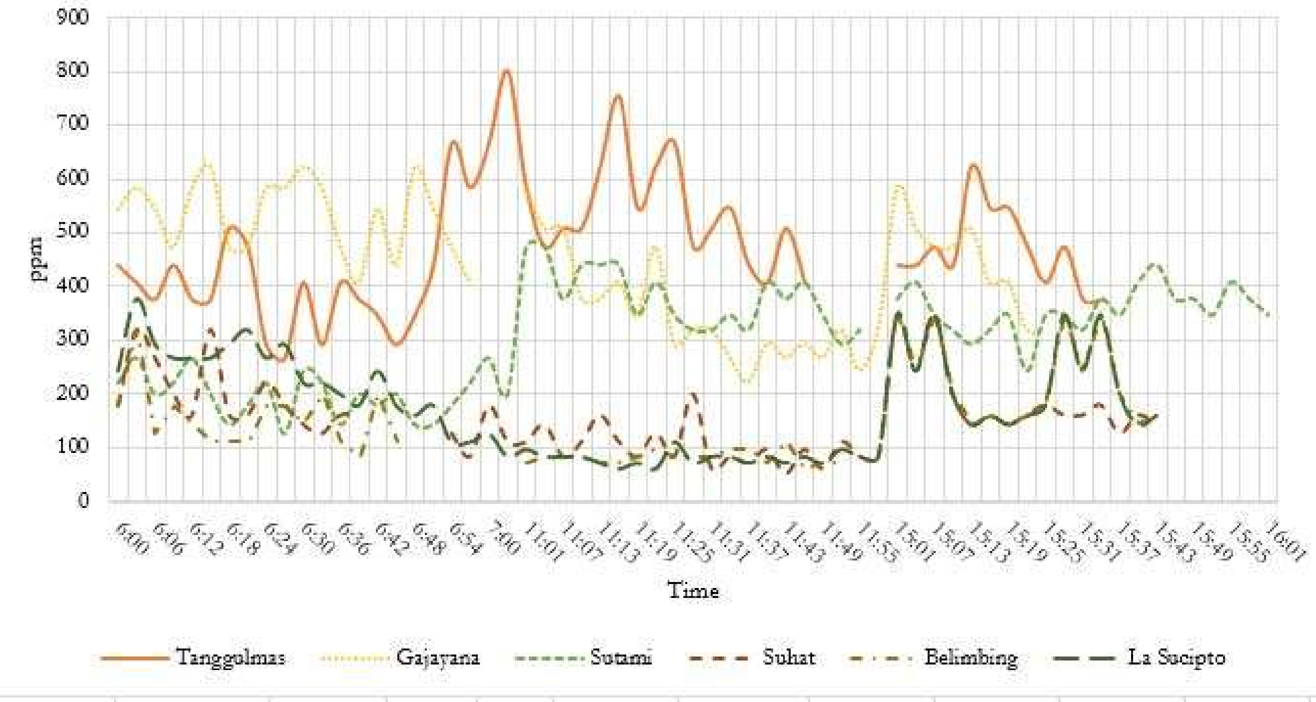

Figure 8. CO Monitoring Data Graph

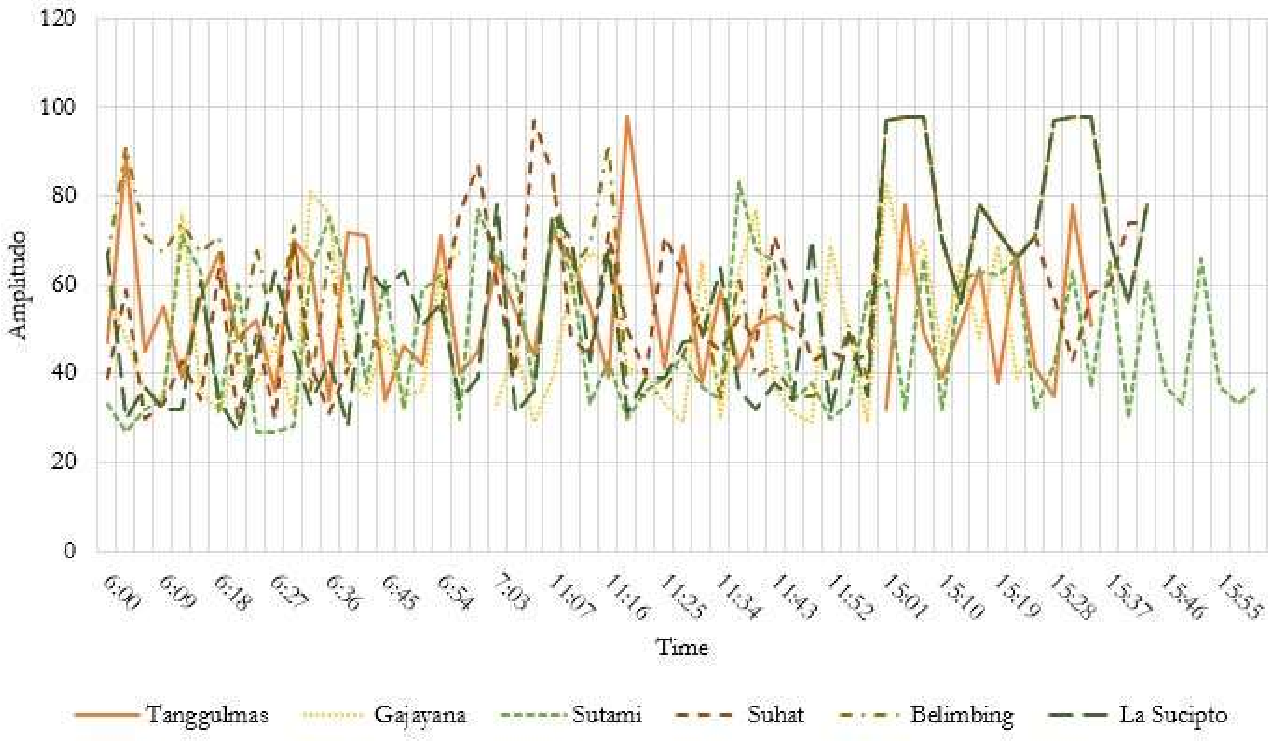

Figure 9. Noise Monitoring Data Chart

https://doi.org/10.25077/jnte.v13n3.1259.2024