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Air Quality Analysis of the Capitol City in Developing Countries During COVID-19 Emergency Care Based on Internet of Things Data

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Abstract

This paper attempts to develop statistical modeling for air-conditioning analysis in Jakarta, Indonesia, during an emergency state of community activity restrictions enforcement (Emergency CARE), using a variety of parameters such as PM_{10}, $PM_{2.5}$, SO_2, CO, O_3, and NO_2 from five IoT-based air monitoring systems. The parameters mentioned above are critical for assessing the air quality conditions and concentration of air pollutants. Outdoor air pollution concentration variations before and after the Emergency CARE, which was held in Indonesia during the COVID-19 pandemic on July 3-21, 2021, were studied. An air quality monitoring system based on the IoT generates sensor data that is collected from a government-integrated data portal, and that can be analyzed statistically. There are two main types of ANOVA (Analysis of Variance): one-way (or unidirectional) and two-way, which are applied to the collected sensor data and hypotheses calculated using ANOVA. ANOVA one-way was found to be more effective for analyzing air quality condition data. During emergency CARE, the average concentrations of PM_{10}, $PM_{2.5}$, and O_3 from the air quality monitoring system show values that have exceeded the standard Air Quality Index (AQI), while the concentrations of CO, NO_2, and SO_2 are still below the applicable AQI values. It stated that air pollution in Jakarta worsened during the implementation of Emergency CARE.

Keywords: Air quality, COVID-19 pandemic, IoT, Statistical analysis.

1. Introduction

The Coronavirus Disease 2019, also referred to as “COVID-19,” was named by the WHO, or World Health Organization, as a virus that manifested symptoms in the first known case of pneumonia (with an unknown etiology) in Wuhan City, Hubei Province, China [1]. SARS-CoV-2 causes COVID-19, an infectious disease caused by the coronavirus. Most infected with the virus will suffer from mild to moderate respiratory illnesses and recover without special treatment. However, some individuals will become gravely ill and require medical care. People who are older or who have pre-existing conditions such as cardiovascular disease, diabetes, chronic respiratory disease, or cancer are more likely to develop serious illnesses. At any age, anyone can contract COVID-19 and become gravely ill or die [2].

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As of May 1, 2022, this virus had infected approximately 226 countries and territories worldwide [3]. This virus is known to be extremely dangerous and is one of the world's deadliest viruses. The World Health Organization (WHO) declared the COVID-19 pandemic an international public health emergency on January 30, 2020. This is a big problem for countries with weak health systems [4].

1.1 COVID-19 Pandemic in Indonesia

The Republic of Indonesia is one of the most populated nations worldwide and among the largest countries by total area [5]. Indonesia is the world's largest island country and the 14th largest country by area, at 1,904,569 square kilometers (km^2) (735,358 square miles), Java Island, where Indonesia is located, is home to more than half of the country's population. According to official population data from 2010, Indonesia has eleven cities with populations over one million. Estimates from 2014, though, show that there are now fourteen cities with more than a million people [6].

The COVID-19 pandemic in Indonesia is part of a global pandemic of the coronavirus disease, which has been causing severe acute respiratory syndrome (SARS-CoV-2) since 2019 [7]. Although surrounded by infected nations such as the Philippines, Malaysia, Australia, and Singapore, Indonesia reported zero cases of COVID-19 from January to February 2020. Additionally, flight schedules continued to operate from countries with high infection rates, such as Thailand and South Korea. Researchers from Harvard University have expressed concern that Indonesia is unprepared for an outbreak and that COVID-19 cases may go undetected [8].

It was confirmed on March 2, 2020, that the virus had spread to Indonesia after a dance instructor and her mother tested positive for the virus. Both were exposed to the virus by Japanese citizens [9]. By April 9, 2020, the COVID-19 pandemic had covered almost 34 provinces in Indonesia. Jakarta, West Java, and Central Java are the provinces hardest hit, accounting for nearly half of all cases nationwide [10].

1.2 Government Response

The governments of each nation have implemented diverse lockdown tactics to prevent the spread of the COVID-19 virus. The government of the Republic of Indonesia used large-scale social restrictions (PSBB/LSRR) in areas with a high risk of virus spread as a strategic action to reduce the risk of virus spread [11].

With this situation and conditions, all modes of public transportation must still operate with reduced hours and capacities, but stores and offices that are not essential must close. Restaurants and food stalls are only open for takeout and delivery, while essential and market businesses are permitted to operate within a social distance. Depending on the region, private transportation passenger restrictions and mask requirements will be in effect [12], [13], [14], and [15]. The local government implements the restrictions with approval from the Ministry of Health.

It includes measures such as the closure of public spaces and schools, the restriction of public transportation, and the limitation of travel to and from restricted areas. Instead of implementing a lockdown and a nationwide curfew, the Republic of Indonesia implemented "large-scale social restrictions" (Indonesian: Pembatasan Sosial Berskala Besar, abbreviated as PSBB). The Ministry of Home Affairs changed the name of the measure in Java and Bali on January 7,

2021. It is now called the Community Activities Restrictions Enforcement, or CARE (Indonesian: Pemberlakuan Pembatasan Kegiatan Masyarakat, or PPKM) [16].
The Indonesian government implemented CARE for the first time on January 11–25, 2021. CARE was implemented for two weeks in Java and Bali in accordance with the instructions of Minister of Home Affairs No. 1, 2021. On July 21, 2021, Tito Karnavian, the Minister of Home Affairs, finally announced the new term for the CARE mechanism, namely the first-through-fourth level of CARE shown in Table 1.

Table 1: CARE levels.

Level	Case Confirmed (people)	In Patient (people)	Victim Dead (people)	Risk Level
I	Less than 20	Less than 5	Less than 1	Low
II	20-50	5 - 10	Less than 2	Intermediate
III	50-100	10 – 30	2 – 5	High
IV	More than 150	More than 30	More than 5	Very High

Based on a region's transmission rate and COVID-19 active cases, the government can determine whether CARE can be implemented. Each case was counted in terms of 100,000 people per week [17, 18]. There are CARE implementations such as "applied CARE," "micro-scale CARE," "Emergency CARE," and "CARE Levels 1-4." The government implemented a number of policies in response to the COVID-19 pandemic. During pandemic lockdowns, it was believed that the decrease in human mobility and economic activities would reduce air pollution because there would be less traffic and industrial activities, and restrictions on human activities during the lockdown purportedly contributed to the reduction of global carbon emissions [19].

1.3 Related Works

Indonesia's capital, Jakarta, is the fifth most polluted capital in 2019 because Jakarta is the largest city of industry and mobility in Indonesia [20]. Several studies have examined the impact of lockdowns on air quality in several countries. Bao [21] and Wang [22] investigated the effect of lockdown on six air pollutants ($PM_{2.5}$, PM_{10}, CO, SO_2, NO2, and O_3) in northern China. During the lockdown, they discovered that the air quality improved due to decreased emissions from cars and secondary emissions from industry sectors.

Mahato [23] studied the impact of the COVID-19 pandemic, the lockdown in New Delhi, and India's air quality. PM_{10} and $PM_{2.5}$ both decreased by fifty percent, while NO_2 and CO decreased by fifty-two percent and thirty-three percent, respectively.

Adam [24] also conducted research to determine the air quality impact of the lockdown in Ontario, Canada. The results revealed that the concentration of $PM_{2.5}$ did not change from before, whereas the concentrations of O_3 and NO_2 decreased moderately and significantly, respectively. Similar research has also been undertaken in a number of other nations, such as Iraq by Hashim [25], the United Kingdom by Ropkins [26], the United States by Chen [27], Bangladesh by Rahman [28], and Egypt by Aboud El-Magd [29]. Some nations had a considerable decrease in several air pollutants, while others did not.

According to the author's knowledge, no statistical modeling and analysis studies on air conditioning analysis in Indonesia have been conducted as of yet, especially in Jakarta, one of the capital cities in developing countries. Consequently, this study aimed to examine the air quality during Emergency CARE in Jakarta. An ANOVA statistic was used to analyze the air quality of the data collected from the IoT system [30]. These analyses can also educate the IoT system to make decisions whenever any air pollution parameters indicate an abnormal change.

2. Material

2.1 Study Area

Air pollution is a decrease in air quality, resulting in a decrease in the air's usability to the point where it can no longer serve its intended purpose. As a source of pollution, this item is both a source of movable and immovable activity. Monitoring ambient and emitted air quality, followed by evaluation and analysis, is one of the methods for controlling air pollution. Local governments are required by the Minister of the Environment's Regulation No. 12 of 2010 to conduct air quality monitoring and evaluate the results of ambient air quality monitoring [31]. Table 2 shows a brief description of each air pollutant parameter.

Table 2: Air pollutant parameter

No	Air Pollutant	Description
1	Particulate Matter (PM_{10})	PM_{10} is a mixture of particles suspended in the air that do not exceed 10 micrograms in diameter. In urban areas, the primary sources of PM_{10} are construction, transportation, and industrial activities, particularly the metal industry.
2	Particulate Matter ($PM_{2.5}$)	$PM_{2.5}$ is a mixture of particles suspended in the air that do not exceed 2.5 micrograms in diameter. It has very subtle physical characteristics, can enter the inner respiratory tract, and has a long-term negative effect on human health.
3	Sulfur Dioxide (SO_2)	Sources of SO_2 are generally from fuels containing sulfur, such as diesel-fueled motor vehicles, and from industries that have fossil fuel combustion activities.
4	Carbon Monoxide (CO)	Sources of CO emissions are mainly from motorized vehicles (traffic density) when incomplete fuel combustion occurs. The presence of high levels of CO in the air has an impact on public health.
5	Ozone (O_3)	Ozone is a secondary air pollutant formed in the presence of nitrogen oxide compounds and VOCs, assisted by solar radiation energy. In cities with high temperatures. In general, the reaction rate for the formation of O_3 is high, with the precursor source being dominated by motor vehicles.
6	Nitro dioxide (NO_2)	Nitrogen dioxide (NO_2) is a pollutant that also has a close relationship with emissions from burning fuel oil, such as in motor vehicles and industry.

The development of infrastructure and transportation sectors in the Jakarta area will have positive and negative impacts on the community. One of the negative impacts that arise is air pollution, in the form of a decrease in ambient air quality and noise. When air pollution happens, it can hurt people's health, especially their lungs, and it will also have an effect on the environment [19].

Therefore, the Jakarta Provincial Government has continuously monitored ambient air quality and has set the Air Pollution Standard Index (ISPU), which is shown in Figure 1. ISPU is a description of ambient air quality conditions in certain locations based on the impact on human health, aesthetic value, and other living things [11].

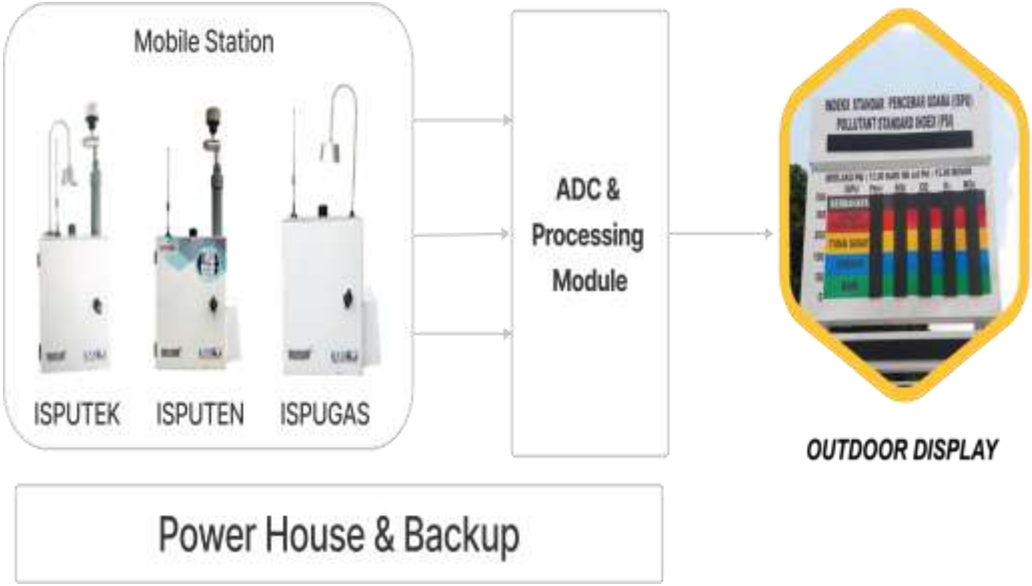


Figure 1: ISPU block diagram

The ISPU value is obtained from an automatic air quality monitoring system (AQMS) that has been installed at 5 locations, namely the Bundaran Hotel Indonesia (HI), Lubang Buaya, Jagakarsa, Kelapa Gading, and Kebon Jeruk. So, it is hoped that the air quality will be depicted in the 5 administrative city areas in Jakarta, as shown in Figure 2.

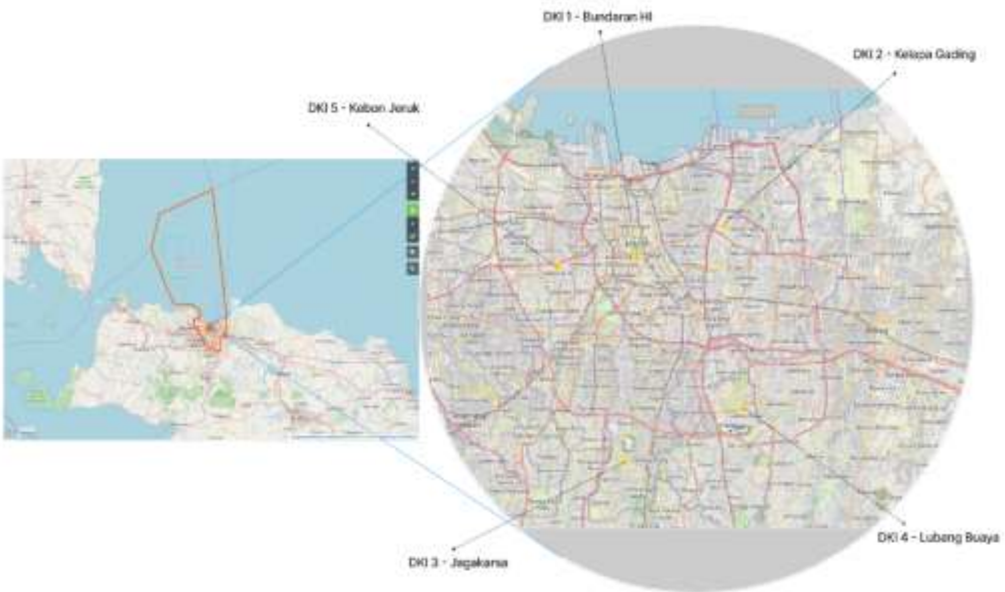


Figure 2: Reference map of AQMS Jakarta

Table 3: AQMS Jakarta

Station Code	Location	Coordinates
DKI1	Bundaran HI – Jakarta Pusat (road area)	106.8235; -6.19466
DKI2	Kelapa Gading – North Jakarta (commercial area)	106.9108; -6.15357
DKI3	Jagakarsa – South Jakarta (housing area)	106.8037; -6.35693
DKI4	Lubang Buaya – East Jakarta (mixed area)	106.9092; -6.28889
DKI5	Kebon Jeruk – West Jakarta (housing area)	106.7525; -6.20737

2.2 Sampling

The Indonesian government implemented CARE for the first time on January 11–25, 2021. The two-week CARE implementation was carried out in Java and Bali in accordance with Instruction No. 1 (2021) of the Minister of Home Affairs. Several provinces had previously implemented large-scale social restrictions (LSSR) to prevent the spread of COVID-19 in 2020.

The first phase of CARE has been implemented in seven provinces on the Java and Bali islands, namely Jakarta, Banten, West Java, Central Java, Yogyakarta, East Java, and Bali. The government has extended CARE through the Instruction of the Minister of Home Affairs No. 2, 2021. The second stage of CARE took place between January 26 and February 8, 2021. In this second phase, the operating hours of shopping centers or malls are changed and should be closed at 8:00 PM WIB.

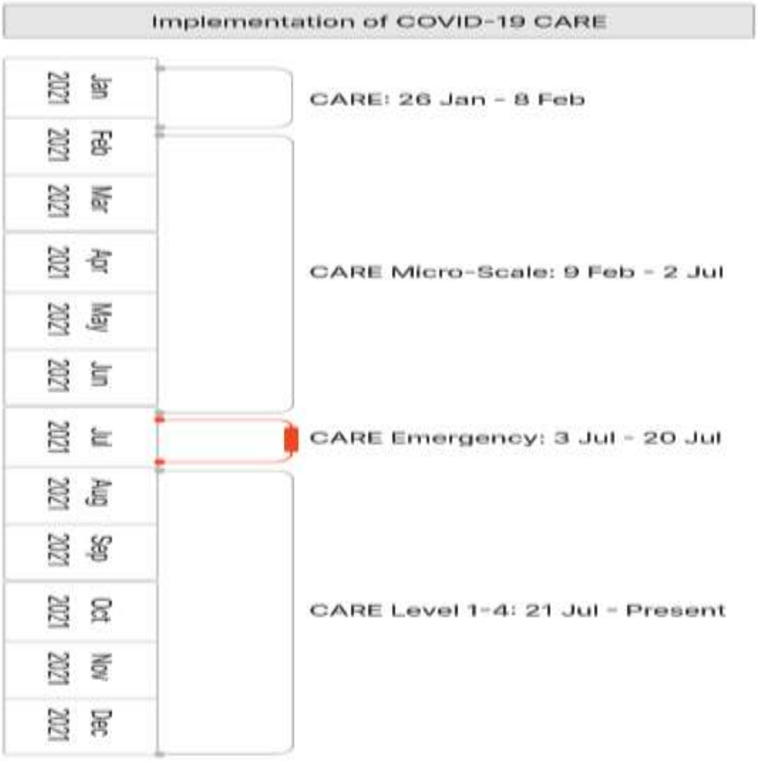


Figure 3: Implementation of CARE COVID-19 Jakarta

CARE has reverted back to micro-based CARE on February 9–22, 2021, following the implementation of two previous iterations that produced economically ineffective results. As in the past, a number of provinces and municipalities have implemented micro-PPKM. In micro-PPKM, arrangements have been made for the establishment of COVID-19 handling posts at the village and sub-district levels; the operating hours of shopping centers or malls are less strictly regulated, specifically until 9:00 PM WIB; and there are fewer office restrictions, with fifty percent of employees permitted to work from home (WFH).

Emergency CARE is in effect from July 3, 2021, through July 25, 2021, and aims to reduce daily confirmed case additions to below 10,000. This government program was put into place in 136 cities across the Republic of Indonesia. The level of care was based on the assessment value and the number of hospital beds, as well as transmission rate and response capacity indicators.

The CARE levels 1 through 4 were determined based on an evaluation of the pandemic COVID-19 situation, which serves as an indicator for intensifying or reducing efforts to prevent and defeat the COVID-19 pandemic. It's possible that a particular area was at level 3 one day but rose to level 4 the following week due to non-compliance with health protocols, overcrowding at the community level, etc.

To analyze the air quality in Jakarta during Emergency CARE, air quality parameter data such as PM_{10}, $PM_{2.5}$, SO_2, CO, O_3, and NO_2 were extracted from the results of air quality monitoring stations (AQMS) located in five areas. The Jakarta Provincial Integrated Data Portal [32] was used to obtain air quality data.

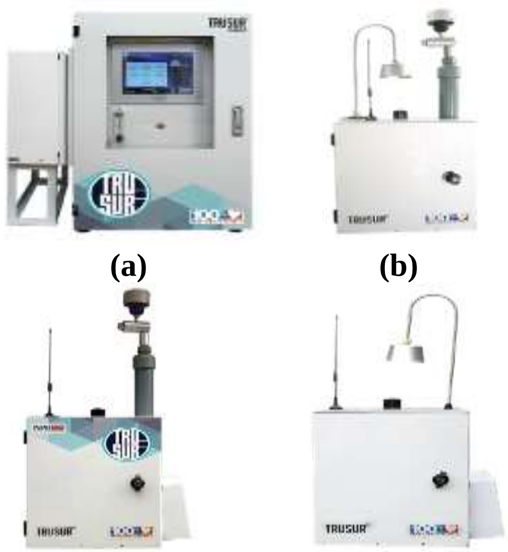
The data was divided into three groups: Pre-Emergency CARE (June 2021), During Emergency CARE (July 2021), and Post Emergency CARE (August 2021). On July 12, 2021, there were 460 available records and 1 missing record at DKI4, which was completed via interpolation due to unknown causes.

Table 4 : Missing data on AQMS during Jun-Aug 2021

Station Code	PM_{10}	$PM_{2.5}$	SO_2	CO	O_3	NO_2
DKI4	0	0	0	0	0	0

2.3 IoT System Specification

Based on research done by the author [33], PT. Trusur Superior Teknusa built the DKI Jakarta province's Air Quality Monitoring System (AQMS). The Internet of Things (IoT) is nothing more than enabling actual physical objects to communicate over the internet. Creating a network of physical objects that can communicate, sense, collaborate, and interact using embedded technology is the definition of the Internet of Things (IoT).IoT could be a network of interconnected computing devices, mechanical and digital machines, objects, animals, or those with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. Figure 4 shows the sensor device that is used by AQMS Trusur® [34].



(a) (b) (c) (d)

Figure 4 : Trusur® IoT sensor (a) Trusur AQMS® (b) ISPUTEK® (c) ISPUTEN® (d) ISPUGAS®

- Trusur AQMS®: an air quality monitoring system and instrumentation that operates continuously and in real time.
- ISPUTEK®: mobile station with gas parameters: PM_{10}, SO_2, CO, O_3, and NO_2 and also weather parameters (temperature, humidity, speed, and wind direction), GPS.
- ISPUTEN®: mobile station with particulate parameters (PM_{10} and/or $PM_{2.5}$), which are equipped with weather, temperature, humidity, wind speed and direction, and GPS parameters.
- ISPUGAS®: mobile station with gas parameters O_3, CO, NO_2, SO_2, and the ability to accommodate an additional parameter. The additional options are HC, VOC, NH_3, or H_2S.

3. Methodology

We have used statistical methods for air-conditioning quality analysis. Analysis of variance (ANOVA) is a collection of statistical models and their associated estimation procedures (such as "variation" among and between groups) that are used to analyze the differences between means. Ronald Fisher, a statistician, developed the analysis of variance [35]. Analysis of variance (ANOVA) is a statistical technique used to determine if the means of two or more groups differ significantly. ANOVA examines the effect of one or more variables by comparing the sample means. In other words, we can use a statistical method to compare these three treatment samples and illustrate how dissimilar they are from one another. In an ANOVA, the observed variance in a particular variable is decomposed into its various components based on the sources of variance. We use multivariate analysis to determine whether there is a significant difference between the means. The F-statistic is the computed variance between means divided by the variance of the sample. Figure 5 shows the hypothesis check for analysis.

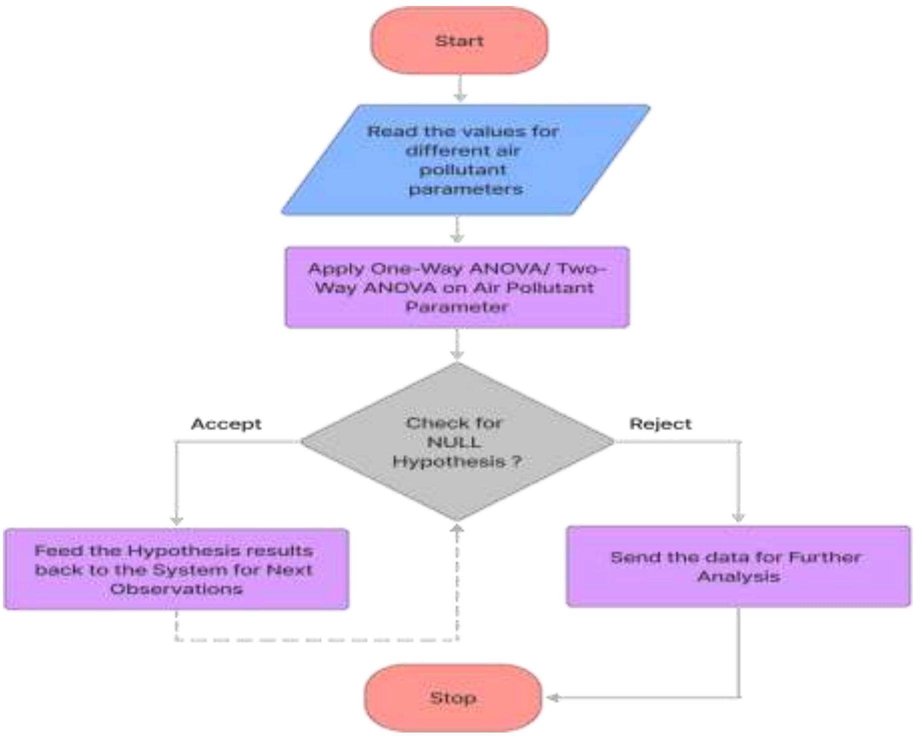


Figure 5: The hypothesis check for analysis

4. Results Discussion

4.1 ANOVA One-way

We apply ANOVA one-way statistical analysis for air quality parameters such as particulate matter (PM_{10}, $PM_{2.5}$), sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), and nitrous dioxide (NO_2). These parameters are categorized by the AQMS station location. Our investigation is divided into three COVID-19 CARE periods: pre-emergency care (June 2021), emergency care (July 2021), and post-emergency care (Aug 2021). Emergency CARE is in effect in Jakarta from July 3-25, 2021.

ANOVA one-way on the samples and evaluate the prediction with regard to each individual air pollution parameter by determining the null hypothesis, i.e., the p-value must be bigger than the value.

We can make research hypotheses H_0 and H_1 as follows:

H_0: there is no effect of the air parameter value generated by the IoT sensor on the air quality of DKI Jakarta during Emergency CARE.

H_1: there is an effect of the air parameter value generated by the IoT sensor on the air quality at DKI Jakarta during Emergency CARE.

4.1.1 Pre emergency CARE

In the Pre-Emergency CARE period, while almost all cities and regions in Indonesia were still implementing CARE on a micro-scale, it was observed that the hot weather covered Jakarta, and the following observations were made:

i. PM_{10}: Among all stations, station DKI5 has the lowest mean PM_{10} at 56.77 μ/m3 (Figure 6a), while station DKI3 has the highest variance at 102.88 μ/m3 (Figure 6b). Maximum mean PM_{10} levels of 67.23 μ/m3 were recorded at station DKI2.

ii. $PM_{2.5}$: Station DKI1 has the lowest mean $PM_{2.5}$ value of 80,57 μ/m^3, and DKI5 has the largest variance of 1100,37 μ/m^3 among all stations (Figure 6b); station DKI4 has the highest mean $PM_{2.5}$ value of 105,67 μ/m^3, followed by station DKI2 with a value of 88,87 μ/m^3 (Figure 6a).

iii. SO_2: Station DKI1 has the smallest mean value of 26,30 μ/m^3 SO_2, and DKI4 has the largest variance of 63.38 μ/m^3 (Figure 6b); the mean SO_2 at station DKI2 was the highest at 54,33 μ/m^3, followed by DKI3 stations with values of 48,87 μ/m^3, respectively (Figure 6a).

iv. CO: The smallest mean CO value of 8,33 μ/m^3 was observed at DKI3, while the largest variance of 44,95 μ/m^3 was recorded at station DKI4 (Figure 6b); station DKI1 also recorded the highest mean CO of 16,97 μ/m^3 (Figure 6a).

v. O_3: Station DKI1 had the lowest mean O_3 at 19,97 μ/m^3, and station DKI2 had the largest variance at 128,02 μ/m^3 (Figure 6b); station DKI2 had the highest mean O_3 at 55,33 μ/m^3, followed by station DKI4 with a value of 27,20 μ/m^3 (Figure 6a).

vi. NO_2: Station DKI3 had the lowest mean NO_2 of 17,83 μ/m^3, and station DKI5 had the greatest variance of 154,05 μ/m^3, among all stations (Figure 6b); station DKI1 recorded the highest mean NO_2 value of 35,07 μ/m^3 (Figure 6a).

(a) (b)

Figure 6: Pre emergency CARE (a) Mean (b) Variance

After doing statistical analysis using ANOVA one-way on the dataset for the air pollutant parameter, we can draw conclusions from the observations in Table 5 that: The p value of the air pollutant is 0.000 and was less than α value of 0.05, so null hypotheses can be rejected.

Table 5: ANOVA pre emergency care

SUMMARY				
Groups	**Count**	**Sum**	**Average**	**Variance**
PM_{10}	150	9211	61,40667	73,71942
$PM_{2.5}$	150	13387	89,24667	470,8045
SO_2	150	5836	38,90667	149,6154
CO	150	2025	13,5	29,04362
O_3	150	4350	29	244,9262
NO_2	150	4069	27,12667	92,59459

ANOVA						
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	571843,9	5	114368,8	646,941	4,7E-294	2,224116
Within Groups	158044,9	894	176,784			
Total	729888,8	899				

Using the results of the calculations in the table above, it can be concluded that there are significant differences for each column of air parameters (PM_{10}, $PM_{2.5}$, SO_2, CO, O_3, and NO2), which means that all air parameter values generated by the IoT sensor have an influence on air quality in Jakarta during Pre Emergency PPKM.
$PM_{2.5}$ has the largest mean value when compared to other types of air pollutants. DKI4 station on Lubang Buaya in Jakarta, close to a mixed area. At this location, domestic activities in the form of community activities are the dominant source of nearby air pollution.

4.1.2 *During emergency CARE*
Jakarta was one of the Indonesian cities that implemented Emergency CARE during the period, and the following observations were made:

i. PM_{10}: Among all stations, station DKI5 has the lowest mean PM_{10} at 60.74 μ/m^3 (Figure 7a), while station DKI2 has the highest variance at 292.75 μ/m^3 (Figure 7b). Maximum mean PM_{10} levels of 72.29 μ/m^3 were recorded at station DKI2.

ii. $PM_{2.5}$: Station DKI1 has the lowest mean $PM_{2.5}$ value of 86,32 μ/m^3, and DKI2 has the largest variance of 1435,64 μ/m^3 among all stations (Figure 7b); station DKI4 has the highest mean $PM_{2.5}$ value of 127,26 μ/m^3, followed by station DKI5 with a value of 101,58 μ/m^3 (Figure 7a).

iii. SO_2: Station DKI1 has the smallest mean value of 29,32 μ/m^3 SO_2, and DKI3 has the largest variance of 52,65 μ/m^3 (Figure 7b); the mean SO_2 at station DKI2 was the highest at 53,77 μ/m^3, followed by DKI3 stations with values of 46,42 μ/m^3, respectively (Figure 7a).

iv. CO: The smallest mean CO value of 7,71 μ/m^3 was observed at station DKI3, while the largest variance of 19,91 μ/m^3 was recorded at station DKI4 (Figure 7b); station DKI5 also recorded the highest mean CO of 11,61 μ/m^3 (Figure. 7a).

v. O_3: Station DKI1 had the lowest mean O_3 at 24,42 μ/m^3, and station DKI2 had the largest variance at 89,73 μ/m^3 (Figure 7b); station DKI2 had the highest mean O_3 at 54,00 μ/m^3, followed by station DKI5 with a value of 26,74 μ/m^3 (Figure 7a).

vi. NO_2: Station DKI3 had the lowest mean NO_2 of 16,84 μ/m^3, and station DKI5 had the greatest variance of 80.12 μ/m^3, among all stations (Figure 7b); station DKI1 recorded the highest mean NO_2 value of 26,19 μ/m^3 (Figure 7a).

(a) (b)

Figure 7: During emergency CARE (a) Mean (b) Variance

After doing statistical analysis using ANOVA one-way on the dataset for the air pollutant parameter, observations are listed in Table 6. The following air quality parameters are affected:

The p value of the air pollutant is 0.000 and was less than α value of 0.05, so null hypotheses can be rejected.

Table 6: ANOVA during emergency care

SUMMARY						
Groups	**Count**	**Sum**	**Average**	**Variance**		
PM_{10}	155	10263	66,2129	176,9089		
$PM_{2.5}$	155	15432	99,56129	1004,196		
SO_2	155	6203	40,01935	106,6165		
CO	155	1644	10,60645	14,461		
O_3	155	4949	31,92903	175,1962		
NO_2	155	3527	22,75484	46,47197		
ANOVA						
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	821522,7	5	164304,5	646,9317	7,9E-299	2,22379
Within Groups	234673	924	253,9751			
Total	1056196	929				

Using the results of the calculations in the table above, it can be concluded that there are significant differences for each column of air parameters (PM_{10}, $PM_{2.5}$, SO_2, CO, O_3, and NO_2), which means that all air parameter values generated by the IoT sensor have an influence on air quality in Jakarta during Emergency CARE. The concentration of $PM_{2.5}$ in January–December

2021 was measured to be very volatile, both between times and between monitoring station locations. The DKI4 location has a higher average daily concentration than other locations. In July 2021, almost all AQMS locations had an average daily PM concentration value that exceeded the standard value. This condition is supported by the dry season and decreased rainfall.

4.1.3 *Post emergency CARE*

In the Post Emergency CARE period, the air quality in Jakarta is stagnant due to the dry season still existing, and the following observations were made:

i. PM_{10}: Among all stations, station DKI1 has the lowest mean PM_{10} at 56,74 µ/m^3 (Figure 8a), while station DKI5 has the highest variance at 102,45 µ/m^3 (Figure 8b). Maximum mean PM_{10} levels of 63,74 µ/m^3 were recorded at station DKI2.
ii. $PM_{2.5}$: Station DKI1 has the lowest mean $PM_{2.5}$ value of 77,58 µ/m^3, and DKI3 has the largest variance of 407,91 µ/m^3 among all stations (Figure 8b); station DKI4 has the highest mean $PM_{2.5}$ value of 102,29 µ/m^3, followed by station DKI5 with a value of 88,13 µ/m^3 (Figure 8a).
iii. SO_2: Station DKI1 has the smallest mean value of 27,87 µ/m^3 SO_2, and DKI3 has the largest variance of 46,04 µ/m^3 (Figure 8b); the mean SO_2 at station DKI2 was the highest at 52,16 µ/m^3, followed by DKI3 stations with values of 44,65 µ/m^3, respectively (Figure 8a).
iv. CO: The smallest mean CO value of 9,39 µ/m^3 was observed at station DKI5, while the largest variance of 10,11 µ/m^3 was recorded at station DKI5 (Figure 8b); station DKI3 also recorded the highest mean CO of 10,90 µ/m^3 (Figure 8a).
v. O_3: Station DKI4 had the lowest mean O_3 at 24,71 µ/m^3, and station DKI2 had the largest variance at 125,75 µ/m^3 (Figure 8b); station DKI2 had the highest mean O_3 at 43,71 µ/m^3, followed by station DKI5 with a value of 26,48 µ/m^3 (Figure 8a).
vi. NO_2: Station DKI3 had the lowest mean NO_2 of 14,71 µ/m^3, and station DKI5 had the greatest variance of 86,93 µ/m^3, among all stations (Figure 8b); station DKI1 recorded the highest mean NO_2 value of 27,19 µ/m^3 (Figure 8a).

(a) **(b)**

Figure 8: Post emergency CARE (a) Mean (b) Variance

After doing statistical analysis using ANOVA one-way on the dataset for each air pollutant parameter, observations are listed in Table 7. The following air quality parameters are affected:

The p value of the air pollutant is 0.000 and was less than α value of 0.05, so null hypotheses can be rejected.

Table 7: ANOVA post emergency care

SUMMARY							
Groups		Count	Sum	Average	Variance		
PM_{10}		155	9087	58,62581	80,6253		
$PM_{2.5}$		155	13414	86,54194	315,6135		
SO_2		155	6111	39,42581	87,50582		
CO		155	1576	10,16774	7,374277		
O_3		155	4646	29,97419	100,9863		
NO_2		155	3241	20,90968	55,53724		
ANOVA							
Source of Variation		SS	df	MS	F	P-value	F crit
Between Groups		598766,8	5	119753,4	1109,44	0	2,22379
Within Groups		99736,94	924	107,9404			
Total		698503,7	929				

From the results of the calculations in the table above, we can conclude that there are significant differences for each column of air parameters (PM_{10}, $PM_{2.5}$, SO_2, CO, O_3, and NO_2), which means that all air parameter values generated by the IoT sensor have an influence on air quality in Jakarta in Post Emergency CARE. Entering August 2021, the concentration value also decreases; although it is still the dry season, it has started to rain, so it is wetter, and the concentration of pollutants in the air is decreasing.

4.2 ANOVA Two-way

In our ANOVA two-way statistical analysis, we attempt to assess the influence of the air pollution parameter on the observing stations. The following conclusions can be drawn from Table 8 below:

i. PM_{10}, $PM_{2.5}$, SO_2, CO, O_3, and NO_2 at each station: The finding shows that for the data, there is a statistically significant difference between *F* and the *F-critical* value, and the *P-value* is extremely low in comparison to the α value (0.05).

ii. Although there is difference value between *F-critical* and *F* for columns, *P-value* is less than α value.

iii. Interaction showing that as an independent air parameter, the Particulate Matter (PM) air pollution parameter is unacceptable due to the wide variance in F value, F-critical value, and *P-value*; it is acceptable as a group because there is little fluctuation in *F* value and *F-critical* value.

Table 8: ANOVA two-way

SUMMARY	PM_{10}	$PM_{2.5}$	SO_2	CO	O_3	NO_2	Total
DKI1 (Bunderan HI)							
Count	92	92	92	92	92	92	552
Sum	5427	7498	2562	1174	2141	2707	21509
Average	58,98913	81,5	27,84783	12,76087	23,27174	29,42391	38,96558
Variance	53,32955	154,7582	12,32824	19,39274	34,81546	52,79634	614,7157

DKI2 (Kelapa Gading)							
Count	92	92	92	92	92	92	552
Sum	6234	8145	4914	1084	4689	2022	27088
Average	67,76087	88,53261	53,41304	11,78261	50,96739	21,97826	49,07246
Variance	145,4587	550,5374	9,981366	6,567606	139,1967	41,05447	824,2452
DKI3 (Jagakarsa)							
Count	92	92	92	92	92	92	552
Sum	5808	7846	4289	827	2473	1513	22756
Average	63,13043	85,28261	46,61957	8,98913	26,88043	16,44565	41,22464
Variance	108,2465	671,194	37,3372	11,879	59,95258	14,84317	868,6718
DKI4 (Lubang Buaya)							
Count	92	92	92	92	92	92	552
Sum	5746	10286	3469	1034	2385	2121	25041
Average	62,45652	111,8043	37,70652	11,23913	25,92391	23,05435	45,36413
Variance	146,7783	605,1481	40,42941	21,56856	40,99415	18,73328	1280,555
DKI5 (Kebon Jeruk)							
Count	92	92	92	92	92	92	552
Sum	5346	8458	2916	1126	2257	2474	22577
Average	58,1087	91,93478	31,69565	12,23913	24,53261	26,8913	40,90036
Variance	93,39465	617,6221	25,42284	27,39274	54,36156	130,9111	869,8721
Total							
Count	460	460	460	460	460	460	
Sum	28561	42233	18150	5245	13945	10837	
Average	62,08913	91,81087	39,45652	11,40217	30,31522	23,5587	
Variance	120,2818	627,4522	113,9044	18,92069	173,6542	71,03141	
ANOVA							
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*	
Sample	36567,4	4	9141,849	69,49464	4,18E-56	2,375188	
Columns	1976471	5	395294,2	3004,953	0	2,217375	
Interaction	120795,2	20	6039,758	45,91312	2,5E-155	1,57438	
Within	359124,8	2730	131,5475				
Total	2492958	2759					

Based on data analysis of the daily average concentration of air pollutants, the daily average concentration value throughout Jakarta in Emergency CARE period (Jun-Aug 2021) for particulates matter PM_{10} is 62,09 µ/m3 and $PM_{2.5}$ is 91,81 µ/m3.

The highest PM_{10} 95 µ/m3 and $PM_{2.5}$ 174 µ/m3 measured in DKI4 on Jul 15, 2021. The daily average concentration value of SO_2 is 39,46 µ/m3, CO is 11,04 µ/m3, O_3 is 30,32 µ/m3, and NO_2 is 23,56 µ/m3.

The highest SO_2 concentration, 66 µ/m3 was measured in DKI2 (Kelapa Gading). The highest concentrations of CO were in DKI5 (Kebon Jeruk) with values of 30 µ/m3 and O_3 was in DKI2 (Kelapa Gading) with a value of 81 µ/m3. Then, for NO_2, 63 µ/m3 were measured in DKI5 (Kebon Jeruk).

5. Conclusions

The goal of the Internet of Things (IoT)-based Air Quality Monitoring System (AQMS) being developed is to track Jakarta's air quality. The AQMS, which was built by Jakarta's government, was used for collecting sensor data from designated stations for various air quality parameters, including PM_{10}, $PM_{2.5}$, SO_2, CO, O_3, and NO_2, in order to provide a dataset used to assess air quality. The collected data were effectively utilized to evaluate the air quality using ANOVA one-way, which evaluates a specific parameter and predicts the air quality based on the value collected. ANOVA two-way was employed to investigate two parameters as separate entities and as a pair. We concluded that the analysis results suggested that an ANOVA one-way was optimal for training the IoT systems. The observations revealed that all air quality parameters play an important role in at least monitoring the air quality during one of the Emergency CARE periods. During Emergency CARE, the average concentrations of PM_{10}, $PM_{2.5}$, and O_3 from the air quality monitoring system show values that have exceeded the standard Air Quality Index (AQI), while the concentrations of CO, NO_2, and SO_2 are still below the applicable AQI values. It stated that air pollution in Jakarta worsened during the implementation of Emergency CARE.

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