Coverage Sensitivity of High-Rise Tower NIES Monitoring System

A Effendi¹², B Budianto¹, G S Immanuel¹, A Rakhman¹, S A K W Kinasih¹ and R Boer¹

¹ Center for Climate Risk and Opportunity Management in Southeast Asia Pacific (CCROM-SEAP), IPB University, Bogor, Indonesia
² Department of Geophysics and Meteorology, Faculty of Mathematics and Natural Sciences, IPB University, Bogor, Indonesia

Abstract. National Institute for Environmental Studies (NIES) and Centre for Climate Risk and Opportunity Management in Southeast Asia Pacific (CCROM-SEAP) working together to develop a beneficial monitoring system for measuring air pollutants. The monitoring system consists of system control units and instrument for measuring pollutants and located in a high-rise tower. This system can count how much anthropogenic and nature emission in this region. The primary sources of pollutants from the anthropogenic activity are traffic from vehicular transportation. This research focuses on air pollutants in the form of particulate matter (PM₁₀ and PM₂.₅), Ozone (O₃), methane (CH₄), nitrogen oxide (NOₓ), sulphur dioxide (SO₂), and carbon monoxide (CO). This research aims to measure the spatial coverage sensitivity of this NIES monitoring system in capturing the effect of the nearest traffic in Bogor. The method used is a sampling method using one day of data with the criteria of no rain and wind speed below two m/s to avoid washing out pollutants and turbulence from these pollutants. The data used are pollutants data on Saturday, June 6th 2020, as sampling data and data traffic in Bogor City. The result from this research is NIES monitoring system can catch air pollutants in Bogor and can measure as far a radius of 0.01 degrees from the NIES monitoring system.

Keywords: air quality, traffic, pollutant, Bogor.

1. Introduction
Measurement of air pollutant concentration is crucial because it could give information on air quality in the region. Usually, big cities like Jakarta, Bandung, and Makassar have poor air quality due to high mobility in those regions. Bogor City is also one of the metropolitan cities with high mobility that causes high traffic. High traffic results in vehicle combustion that produces pollutants such as NOₓ, CO, SO₂ and, CO₂. Moreover, green spaces in Bogor City are continuously decreasing, which further exacerbated air pollution in Bogor City because air quality is directly proportional with green spaces [1]. Higher pollutant reduces air quality and brings negative consequences to human health such as respiratory disease. However, society’s awareness of air quality is still low because the information is still scarce. Air quality information is crucial as a reference to whether the region is safe or not for human health.
Air quality information could be obtained through an air pollutant monitoring system. Centre for Climate Risk and Opportunity Management in Southeast Asia Pacific (CCROM-SEAP) utilizes an air pollutant monitoring system from National Institute for Environmental Studies (NIES) Japan. This monitoring system is a ground-based comprehensive monitoring system of air pollutants and GHGs with the inlets installed in the tower (40 m above the ground) [2]. A high-rise tower monitoring system is expected to have high spatial coverage of air pollutants. Therefore, this research aims to spatial coverage sensitivity of this NIES monitoring system in capturing the effect of nearest traffic in Bogor. In other words, we want to know how far this high-rise tower monitoring system could record the air pollutant sources from the nearest traffic. This research focuses on CO₂, CH₄, O₃, NOx, SO₂, PM₁₀, dan PM₂.₅.

In the previous studies, the information of this monitoring system could be accessed through the web to societies regarding air quality in Bogor city and two other cities [3]. The data presented on the web are real-time to minimalize data manipulation. The information from the NIES monitoring system could help policymakers to determine actions on reducing air pollution in Bogor City.

2. Method

This research uses a sampling method, and the selection of the sample is based on two criteria which are no rain and wind speed below two m/s. Those criteria are chosen to prevent the phenomena of pollutant wash-off and turbulence. The chosen sample data based on those criteria is data on Saturday, June 6th 2020, and traffic data in Bogor City. Traffic data used in this research are around Bogor Botanical Garden (KRB) and Jakarta highway road area. The traffic data are classified into 4 class with green color indicates no traffic, yellow represents dense traffic, red shows congestion and maroon indicates heavy traffic. Then, the classified data become index with value 1 for green class, 2 for yellow class, 3 for red class, and 4 for maroon. Traffic 1 has the number of vehicles under 25 vehicles per minutes. Traffic 2 has the number of vehicles between 25 and 50 vehicles per minutes. Traffic 3 has the number of vehicles between 50 and 100 vehicles per minutes. Traffic 4 has the number of vehicles above 100 vehicles per minutes. We are using correlation between traffic density per blocks and air pollutant volume that NIES monitoring system record in IPB Baranangsiang. The pollutant data are obtained from a high-rise tower NIES monitoring system located in IPB Baranangsiang, Bogor.

![Figure 1. Traffic data with the selected index. Orange square is NIES tower place](image-url)
The pollutant and traffic data (.csv format) are processed by using Jupyter Notebook. The .csv format is converted into .xlsx format and further analyzed by using Microsoft Excel. We cut the data within the area of KRB and Jakarta highway road. The cleaning data process is done to remove unnecessary values or indices and make the plotting and analysis become easier. The traffic data are cut into five blocks with plotted indices and roads. The result of traffic indices is compared with pollutant data on June 6th, 2020. The correlation of traffic data and pollutant data is analyzed by using data analysis in Microsoft Excel. The result of correlation in data analysis becomes the reference of how big the spatial coverage sensitivity of the NIES monitoring system in capturing the effect of traffic to air pollutant concentration in Bogor City.

3. Result and Discussion

Air pollution is a big problem for environmental that can affect living things such as humans, animals, and plants. Traffic density and population have a fairly high correlation where urban environments have more air pollution compare to rural environments [6]. Measurement of seven pollutants is done to know how far NIES monitoring system could capture pollutants around Bogor City. The pollutant concentrations that being analyzed is CO₂, CH₄, O₃, NOₓ, SO₂, PM₁₀, dan PM₂,₅. NIES monitoring system is installed 40 m above the ground to capture pollutants from a further distance, although there is relatively a high time lag.

The result of correlation value between pollutants and traffic is pretty varied. Based on the result of coefficient value, it shows that distance and traffic condition are quite affecting the spatial coverage sensitivity of the NIES monitoring system. This condition can be seen from traffic in block one, which is higher than the other four blocks. NIES monitoring system is located in block 4. However, the value of correlation is lower than block 1 because there is no traffic in block 4. The correlation coefficient value in blocks 2, 3, and 5 is relatively low because the distance is too far away from the NIES monitoring system.

3.1. CO₂

| Pollutant | Block | Correlation | Time lag (minute) |
|-----------|-------|-------------|------------------|
| CO₂       | 1     | -0.56834    | 0                |
|           | 2     | -0.2884     | 0                |
In 2012, CO₂ emission reached 2,536,861 ton with CO₂ absorption around 113,893 ton [1]. This emission sources from anthropogenic and industrial activity. NIES monitoring system that is installed 40 m above the ground could capture CO₂ in the atmosphere of Bogor City. Based on the sampling result in 5 blocks that have been mapped, the correlation between traffic and the result of CO₂ concentration from the NIES monitoring system is relatively high but has negative values. The highest value is in block three traffic with a correlation value of -0.59921. NIES monitoring system is located in block 4. However, the correlation in block 4 is only -0.51382. This condition is because there is no traffic in block 4, while in block three, there is traffic. Block 1 also has pretty a high correlation, which is -0.56834, because the distance between block one and NIES is quite close.

We also use time lag to measure how long and how sensitive the NIES monitoring system could capture pollutants from its surrounding area. A time lag of the NIES monitoring system towards CO₂ is quite varied from no time lag to 100 minutes time lag. Block 5 has the highest time lag with relatively a high correlation value. Block 1 and 2 have no time lag, but the value of correlation is between these two is different. This result indicates that the sensitivity of the NIES monitoring system towards CO₂ is relatively high and reactive to CO₂ with a varied time lag and have negative correlation values.

3.2. CH₄

| Pollutant | Block | Correlation | Time lag (minute) |
|-----------|-------|-------------|------------------|
| CH₄       | 1     | -0.21354    | 90               |
|           | 2     | -0.12209    | 80               |
|           | 3     | -0.35477    | 100              |
|           | 4     | -0.22983    | 60               |
|           | 5     | -0.18297    | 100              |

CH₄ is one of the pollutants that highly influence atmosphere conditions because it could damage the atmosphere of the earth. The result shows that block 3 has the highest correlation value (-0.35477) compared to other blocks. Block 4 has the second-highest correlation value, which is -0.22983. Block 1, 3, and 5 have pretty low correlation coefficient values than block 3 and block 4. This result indicates that the concentration of CH₄ is not affected by the level of traffic. A time lag of the NIES monitoring system towards CH₄ is almost similar for every block, which is around 60-100 minutes, and the movement of CH₄ in the air is unpredictable because of time lag. This result could indicate that the spatial coverage sensitivity of the NIES monitoring system towards CH₄ is not high and have negative correlation values.

3.3. NOx

| Pollutant | Block | Correlation | Time lag (minute) |
|-----------|-------|-------------|------------------|
| NOx       | 1     | -0.6696     | 0                |
|           | 2     | -0.30545    | 0                |
|           | 3     | -0.52847    | 20               |
|           | 4     | -0.57912    | 0                |
|           | 5     | -0.36187    | 60               |
NOx pollutant sources from human activity such as transportation, industrial activity, and waste dumping are giving negative effect to Bogor City. This condition can be seen from the high correlation coefficient value between the NIES monitoring system and traffic. The highest correlation coefficient value is located in block one, which is -0.6696. Then, block 4 has a lower value than block one, which is -0.57912. Similar to other pollutants, block 1 has a higher correlation than a closer block (block 4) due to high traffic in the block 1 area. The correlation values in blocks 3, 5, and 2 are the lowest.

A time lag of the NIES monitoring system towards NOx is varied from 0 minutes to 60 minutes. Block 5 has a time lag of 60 minutes, while block 4 is closer to the NIES monitoring system has the lowest time lag, which is only 0 minutes. Block 1 and 2 also have the lowest time lag, which is only 0 minutes. This result indicates that the sensitivity of the NIES monitoring system towards NOx is relatively high and reactive to NOx with 0-60 minutes time lag and have negative correlation values.

3.4. O₃

| Pollutant | Block | Correlation | Time lag (minute) |
|-----------|-------|-------------|------------------|
| O₃        | 1     | 0.847991    | 30               |
|           | 2     | 0.399808    | 30               |
|           | 3     | 0.572645    | 20               |
|           | 4     | 0.641934    | 120              |
|           | 5     | 0.38451     | 120              |

O₃ is a pollutant that brings a negative impact on the environment and human health. O₃ is a pollutant with almost 70% of chemical oxidant that reacts with CO. CO, or carbon monoxide are emitted from fossil fuel combustion in industrial activity. Bogor City is a quite dense metropolitan city with various industrial activities and human activity on the road, so that the concentration of O₃ in Bogor City is relatively high.

The highest correlation value located in block 1 and block 4. The distance of block 1 and block 4 with the NIES monitoring system is different but still one way. Although the NIES monitoring system is located in block 4, the correlation value in this block is 0.641934. O₃ have any time lag at all with every plotted block with 20-30 minutes time lag, except block 4 and 5 which is time lag in these blocks are 120 minutes. This condition is similar with other pollutants which has relatively high time lag. Therefore, it could indicate that the NIES monitoring system’s sensitivity towards O₃ is very high and have positive correlation values.

3.5. SO₂

| Pollutant | Block | Correlation | Time lag (minute) |
|-----------|-------|-------------|------------------|
| SO₂       | 1     | 0.813929    | 60               |
|           | 2     | 0.346018    | 100              |
|           | 3     | 0.480485    | 50               |
|           | 4     | 0.60523     | 120              |
|           | 5     | 0.353549    | 120              |

SO₂ stands for sulphur dioxide, which is a pollutant that sources from fossil fuel combustion that contains sulphur. Fossil fuel sources from a vehicle in Bogor City. A high number of vehicles in Bogor City is one of the causes of a high level of SO₂ in Bogor City. Based on the correlation value between traffic and pollutant data, it can be seen that block 1 has the highest correlation value. This is expected because blocks 1 has the highest traffic as compared to other blocks. The correlation value for other
block ranges from 0.3 to 0.6. The differences between blocks are pretty high, which is around three folds. This condition shows that traffic conditions immensely affect the concentration of SO2. NIES monitoring system could capture SO2 quite well with a variation time lag from 50-120 minutes. Therefore, SO2 could capture directly and shows that sensitivity towards SO2 is very high and have positive correlation values.

3.6. \( PM_{10} \) and \( PM_{2.5} \)

PM have meaning particulate matter. PM has two parts namely \( PM_{10} \) and \( PM_{2.5} \). \( PM_{10} \) has a size 10 micrometers and smaller. Meanwhile, \( PM_{2.5} \) has a size 2.5 micrometers and smaller [7]. \( PM_{10} \) and \( PM_{2.5} \) are recorded every 3 hours, and thus, correlation analysis between \( PM_{10} \) and \( PM_{2.5} \) to analyze the spatial coverage sensitivity could not be done. However, the NIES monitoring system can still capture \( PM_{10} \) and \( PM_{2.5} \).

![Figure 3. Variation of minutes pollutant and blocks](image)

The correlation value between pollutants and traffic is negative and positive. The negative correlation values are for CO2, CH4, and NOx, while the positive correlation values are for O3 and SO2. Then, traffic during the day and night has a difference where the traffic during the day is higher than at night. If we correlate traffic with pollutants, it can be concluded that the correlation of the two variables is consistent with real-time events.

Plants can photosynthesize, which requires CO2 gas as their raw material, and the results of photosynthesis are in the form of oxygen and food substances needed by plants and other living things [4]. The photosynthesis process requires sunlight during the day so that the absorption of CO2 by plants during the day is higher than at night because it is assisted by sunlight. This causes the concentration of CO2 during the day to decrease and is inversely proportional to traffic during the day, which has increased compared to that at night.

The fluctuation pattern in NOx is almost the same as that of CO2. During the day, the NOx concentration decreases and rises again at night. CH4 has a relatively lower concentration than CO2 because the global warming potential of CH4 in the atmosphere is 21 times greater than that of CO2 [5]. The increase in CH4 concentrations was caused by natural sources, namely geological and plant emissions. CH4 can also be derived from humans, such as mining, farming activities, and waste disposal.
4. Conclusion

NIES monitoring system at IPB Baranangsiang, which is installed 40 m above the ground, could capture several pollutants such as CO₂, CH₄, NOx, SO₂, O₃, PM₁₀, dan PM₂.₅. Based on the result of the correlation value, the spatial coverage sensitivity of the NIES monitoring system is varied. Block 1, which is located at Jalan Otto Iskandar Dinata, has the highest coefficient correlation value for almost every pollutant. NIES monitoring system, which is located at block 4, has a lower correlation value is compared to block 1. Block five and block two, which is the furthest area from the NIES monitoring system, have relatively a low correlation value. Block 3 also has a low coefficient correlation value but not as low as to blocks 5 and 2. This condition shows that NIES monitoring system can still capture pollutant that reaches quite far distant (block 2 and block 5) although the correlation value is relatively low. Time lag in every pollutant and block is varied. These are means that pollutants that emitted from human activity, industrial activity, and transportation could not be captured directly from the NIES monitoring system or it needs several times. This condition is possibly influenced by the wind speed. However, CO₂ does not have time lag in blocks 1 and 2 and NOx does not have time lag in blocks 1, 2, and 4, which means time lag is onward. Therefore, this research result using sampling from June 6th 2020, shows that spatial coverage sensitivity of NIES monitoring in capturing the effect of nearest traffic to air pollutant concentration is relatively high.

Acknowledgments

We would like to thanks Maria Venita Dominica Lero, Alfina Damayanti, Mastura Hairunnisa, Aviandy Viratama, Sarah Chelsabiela R, Eryana Nurwenda, Ikhas Taufiqul H, and CCROM-SEAP IPB for helps author to create this paper until done.

References

[1] Nur RPR, Purnomo H 2015 Model simulation of CO₂ emission and absorption in Bogor City Jurnal Ilmu Pertanian Indonesia 20 pp 47-52
[2] M Nishihashi et al 2019 IOP Conf. Ser.: Earth Environ. Sci. 303 012038
[3] G S Immanuel et al 2019 IOP Conf. Ser.: Earth Environ. Sci. 303 012055
[4] Sukmawati T, Fitrihidajati H, Indah NK 2015 The carbon dioxide absorption of plants of the urban forest in Surabaya LenteraBio 4 pp 108-111
[5] Hervani A, Wiharjaka A 2014 Effectiveness of sampling time and measurement of greenhouse gas on water management in rice field Widyariset 17 pp 227-232
[6] Sadullah AFM, Latif SRSA, Yahaya NZ 2003 Air pollution from motor vehicles a mathematical model analysis: case study in Ipoh City, Perak, Malaysia Journal of the Eastern Asia Society for Transportation Studies 5 pp 2367-2381
[7] Ira S et al 2019 A preliminary result of air quality identification and analysis of PM₁₀ and PM₂.₅ in Steel Industrial Area, Cilegon, Banten Jurnal Riset Teknologi Pencegahan Pencemaran Industri 10 pp 22-28