AIR QUALITY MONITORING IN INDUSTRIAL ESTATE
(Case Study: Jababeka Industrial Estate, Cikarang)

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Abstract: Ambient Air Quality Monitoring (AAQM) must be conducted by Industrial Estate Management, according to legislation and regulation in EIA (Environmental Impact Assessment) Report. AAQ test parameter are Sulfur Dioxide (SO_2), Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), Ozon (O_3), Hydrocarbon (HC), PM_{10},Total Suspended Solid (TSP), and Lead (Pb). Industrial Estate Management has an extensive role in AAQM, analysing and organizing better environmental policies. The data of Jababeka Industrial Estate (JIE) AAQM was seized from EIA Report each semester from year 2015 to 2018 and analyzed using openair model. In EIA Report year 2015-2018, TSP, NO_2, and H_2S was exceed the NAAQS in a few location and certain time. The limitation of this analysis was on AAQ and meteorological data that gives lack of trend to states the air quality status in this area. A review of AAQM and Management in other industrial estate was done as a lesson-learned and insight to improve the AAQM System in JIE. Openair model can analyze the AAQ data with meteorological data around the sampling point area, and visualize it through the pollution rose function. The limited data of AAQM and weather, will limitate the result and analysis. The future research must aims to make a real-time/continuous AAQM and meteorological data to get more accurate and comprehensive data modeling and analysis.

Keywords: (*Air Quality Monitoring, Industrial Estate, Openair Model, EIA Report).*

Abstrak: Pemantauan kualitas udara ambien (PKUA) wajib dilakukan pengelola kawasan industri sesuai dengan peraturan perundangan dan dalam laporan AMDAL. Parameter uji kualitas udara ambien adalah Sulfur Dioksida (SO_2), Karbon Monoksida (CO), Nitrogen Dioksida (NO_2), Ozon (O_3), Hidrokarbon (HC), PM_{10}, $PM_{2,5}$, Debu (TSP), dan Pb (timbal). Pengelola kawasan industri berperan penting dalam melakukan pemantauan kualitas udara ambien, dalam menganalisa dan menyusun kebijakan lingkungan yang lebih baik. Di kawasan industri Jababeka data pemantauan kualitas udara ambien diambil dari Laporan AMDAL setiap semester tahun 2015-2018 dan dianalisa menggunakan openair model. Berdasarkan Laporan AMDAL Tahun 2015-2018, TSP, NO_2, dan H_2S melebihi baku mutu kualitas udara ambien di beberapa lokasi dan waktu sampling tertentu. Batasan dari analisis ini adalah pada data kualitas udara ambien dan meteorologis yang memberikan tren data yang minim untuk dapat menyatakan status kualitas udara di area tersebut. Kajian pemantauan dan pengelolaan kualitas udara kawasan industri lainnya di Indonesia dan negara lain dilakukan sebagai pembelajaran dan masukan dalam meningkatkan sistem pemantauan kualitas udara di kawasan industri Jababeka. Model openair dapat menganalisa data kualitas udara dengan data meteorologis di sekitar lokasi pengukuran, dan memberikan hasil visual dengan gambar pesebaran polusi sederhana. Keterbatasan data dari pemantauan kualitas udara ambien dan kondisi cuaca/meteorologis, akan membatasi hasil dan analisa dalam penelitian ini. Penelitian di masa depan harus mengarah pada pemantauan kualitas udara ambien dan pengambilan data meteorologis yang otomatis dan berlanjut, untuk pemodelan dan analisa data yang lebih akurat dan komprehensif.

Kata Kunci: *(Pemantauan Kualitas Udara, Kawasan Industri, Model Openair, Laporan AMDAL).*

INTRODUCTION

The industrial sector has an extensive role in economic growth in Indonesia. The increase of industrial growth, especially in industrial estate will supports the sustainable economic growth that deliberate the economic, social, and environmental aspects. The industry that has less concern about to environmental aspects can bring impacts to public health and environment surround. Hence, the industrial estate management needs to conduct the integrated environmental management, especially in environmental monitoring. Jababeka Industrial Estate (JIE), as one of the fast-growth private industrial estate in Cikarang, West Java, has a extensive role to actualize the compliance improvement in environmental standard and integrated environmental

management in industrial area. One of the environmental quality monitoring that obligated by the industrial estate management are Ambient Air Quality Monitoring (AAQM).

The Ambient Air Quality (AAQ) test parameters are sulphur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), ozon (O_3), hydrocarbon (HC), total suspended particulate (TSP, including PM_{10}), and Lead (Pb), according to Government Regulation of Republic of Indonesia Num. 41 Year 1999 about Air Pollution Control – Appendix of National Ambient Air Quality Standards (NAAQS). The good air quality can effect on how people sustain their health and productivity. But, all human activities (antropogenic source) emits gases and air pollution substances that will changes the air quality and cause health problems. The crucial concern is from industrial and transportation activities that highly effect the ambient air quality around some areas.

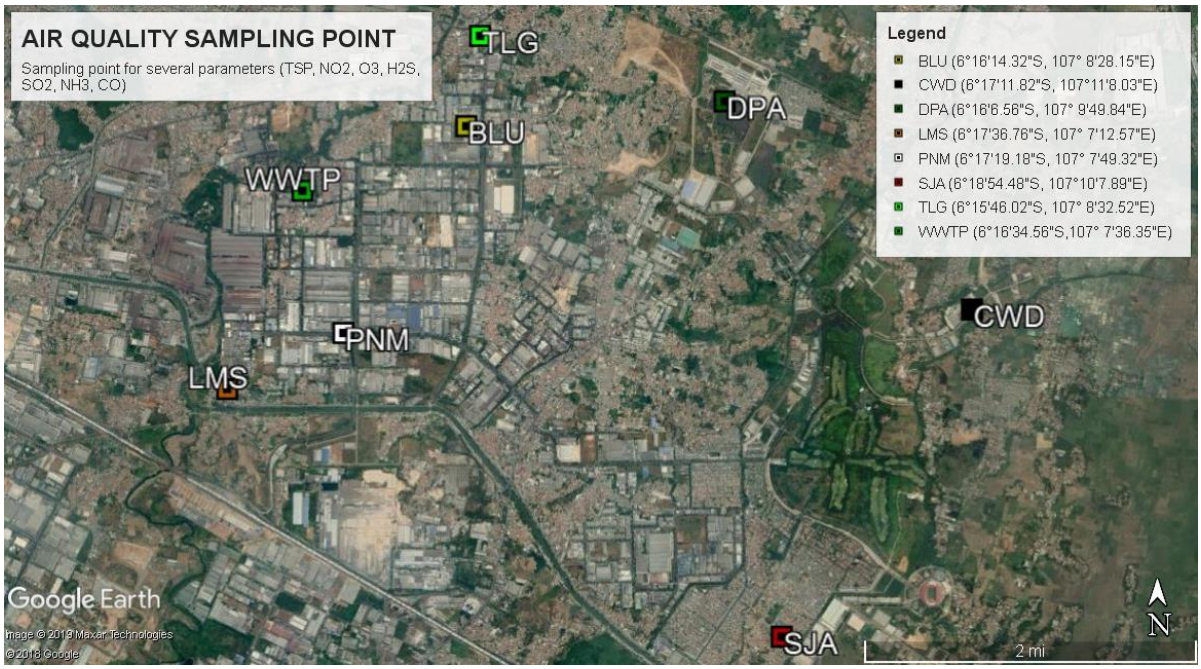

Figure 1 Air Quality Sampling Point in JIE

In 2016, 91% of world population was stated to live in places that cannot meets the World Health Organization (WHO) air quality level standards. Ambient air in urban and rural area are predicted caused 4.2 million of premature death (WHO, 2016; Neira and Prüss-Üstün, 2016). Thus, the air quality management (AQM) plays a crucial role in monitoring and mitigating air pollution that will give the better air quality for people in certain area.

Industrial Estate Management has an extensive role in AAQM, analysing and organizing better environmental policies. AAQM Data is very important and must be analyzed for better environmental policies in industrial area. Thus, the research on air quality monitoring in Industrial Estate is very influential for better environmental management, especially in air quality. The specific purpose of this research are: (1) to review and elaborate the best practice of air quality management in industrial estate in Indonesia and other countries; (2) to analyze the available data of AAQM in certain time in JIE by using openair model; (3) to give the result and evaluation from AAQM analysis as an insight for better air quality management in industrial estate.

MATERIAL AND METHODS

Best Practice Review. A review of AAQM and Management in other

industrial estate (in Indonesia and other countries) was conducted by using desk evaluation method from various research reference.

AAQM Data Analysis. In Jababeka Industrial Estate (JIE), the AAQM data was seized from EIA Report each semester from year 2015 to 2018 and analyzed using openair model. The data had been carried out according to the standards method and government regulation. Meteorological data collection was taken from the local weather monitoring at the sampling point, and adapted to the data availability (See **Figure 1** and **Table 1**). Air pollution and meteorological data was processed and imported to openair model (software R) in *comma separated value (csv)* format. The input data should consist of *date-time*, air pollution, and meteorological data. Field data can be inputted by coding. Analysis data was conduct by choosing various function in openair model. Every function has analytical method or background alone, such as *linear regression, decision making* with *p-value* and *coefficient of determination* (Carslaw and Ropkins, 2012).

Result and Evaluation. The evaluation of AAQM will be discussed after analyzing the data and the openair model. The result of this study can be a lesson-learned and insight to improve the AAQM System in JIE.

Table 1 Air Quality Sampling Point in JIE and the coordinate

Code	*Location*	*Lat*	*Long*
cwd	Depan PT. Conwood (area KIJ VI)	6°17'11.82"S	107°11'8.03"E
sja	Desa Serta Jaya	6°18'54.48"S	107°10'7.89"E
dpa	Dry Port Area	6°16'6.56"S	107° 9'49.84"E
lms	Kampung Limus Blok P	6°17'36.76"S	107° 7'12.57"E
wwtp	Depan WWTP-1x	6°16'34.56"S	107° 7'36.35"E
blu	Perempatan Blok U	6°16'14.32"S	107° 8'28.15"E
tlg	Kampung Teleng	6°15'46.02"S	107° 8'32.52"E
pnm	Perempatan Nissin Mas	6°17'19.18"S	107° 7'49.32"E

RESULT AND DISCUSSION

Best Practices of AQM in Industrial Estate/Region (National/International)

In the current research and its development, the AAQM can be connected to the internet based technology and remote sensed image technique and geographic information system (GIS). In Italy, the network plan of air pollution monitoring in industrial estate was being done by using Remote Sensed Images technique and GIS (Rotatori et al, 2011). In Thailand, Rayong Industrial Estate is designing the action plan to reduce and mitigate air pollution in its area. They use the Balanced Scorecard (BSC) modification technique to increase its air quality management. This techique is showing 80-90% effectiveness of various industry that now have a better emission control of VOCs, SO2, and NOx (one of four main perspective in air quality management improvement) (Poboon et al, 2012). In Rawalpindi and Islamabad, Pakistan, the research was conducted on AAQM from heavy-transportation and industrial sector, by using GIS to analize its impact on environment and health of nearest civilians in the study area. This research is done as a mitigation action plan from PM and NO_2 measurement data (Hassan et al, 2013). The research trend relates with AAQM data analysis and

disaster mitigation are increasing, along with the escalation of critical concern to pollution/waste management in industrial sector.

In Nigeria, some research are conducted with the same topic of AAQM (Njoku et al, 2016; Yusuf et al, 2013; and ETIM, 2012). Conventional research was conducted in AAQM in metropolitan city (Njoku et al, 2016) and emission load estimation (ETIM, 2012). Spatial pattern of air pollution in Lagos Industrial Estate, Nigeria, was conducted with *Principal Components Analysis (PCA)* statistical analysis to predict the quantitative and qualitative contribution of SO_2, NO_2, PM_{10} , CO, H_2S, CH_4 dispersion, and the noise data in ambient air. *Correspondence Analysis* (CA - Reciprocal Averaging) was used to analyze air pollution characteristic based on the similarity of pollutants and the relation between AAQM component (Yusuf et al, 2013). This research indicated one approach to statistical data analysis of air quality as a basis for better air quality management. Another research founds in China that study the *willingness to pay* policy to increase air quality among workers and manufacture association, as a lesson-learned on the implementation of AAQ data analysis result that changed the air quality management policies in certain area (Liu et al, 2018).

In Indonesia, previous research are focusing on AAQ data in Bandar Lampung Industrial Estate (Febrina, 2013), Cilegon (Ruhiat et al, 2008), and SIE Surabaya (Herdriyono, 2017). In Cilegon, the study use gaussian dispersion model using *Screen3* to predict the dispersion and pollutant maximum ground level concentration from the stack in several company. In Surabaya, the study count on emission load total of SO_2 and NO_x from industrial activities (main source of pollutant from the coal-based energy consumption). In Bandar Lampung, SO_2, NO_2, CO, H_2S, NH_3 parameter was measured using spectrophotometry and TSP using gravimentry method. In Indonesia, the AAQM was conducted according to government regulation and been evaluated periodically. General and conventional research in AAQ analysis, pollution dispersion, and emission load study, are need to be improved for its data analysis.

Jababeka Industrial Estate Profile

Jababeka Industrial Estate is the largest industrial estate in south-east Asia with its master plan of around 5,600 hectares' area. It was founded in 1989 by private local company that followed President Decree No 53/1989 that local and foreign private sectors are able to develop the industrial estate. Before the decree, only state-owned company allowed to develop the industrial estate. At present, JIE has been spanned as a new city with industrial development more than 2,000 hectares and it been occupied with more than 1,650 local and multinational corporations from 30 countries, such as Japan, USA, Korea, France, Netherlands, Australia, United Kingdom, Singapore, Taiwan, Malaysia, and other numerous countries. The type of industries in JIE are otomotives, electronic, food, cosmetics, pharmacy, textiles and miscellaneous.

Beside the industrial activities, Jababeka city also allocated area for power plant, waste water treatment plant, dry port to support the industrial logistic, education park, commercial area, hospital, and about 800 ha of residential area. This various activities have also contributed to the ambient air quality in Jababeka, especially from industrial and transportation (traffic) activities. In the other hand, the residential area relatively closed to industrial area and heavy traffic roads. The residential area need a good air quality to sustain their health and wellness. By consider the area size, amount of air pollutants and its dynamics behaviour, many stakeholders, and roles taker, it is a great challenge to study the air quality management and control in industrial estate.

Air Quality Management (Policy and Regulation) in Jababeka

JIE management had issued the Industrial Estate Regulation since the beginning of its operation. According to the government regulation revision, the regulations has been many times revised since the first issued in 1991. The environmental item such us water, waste water, air quality, hazardous waste, and solid waste are the subjects that mentioned and regulated in the estate regulation. To control the ambient air quality in industrialarean, it has stated in the estate regulation that each industrial companies should comply the air emission quality standard which issued by both province (West Java Governor Decree No.660.31/SK/694-BKPMD/82) and national government standards (Government Regulation No 41/1999) by following stricter standard and threshold limit. The JIE regulation document should be signed by industries before purchasing the industrial land. In operational phase, the AAQM is conducted by JIE management to control the emission quality of industries and make sure that it will comply to the government requirement.

Air Quality Monitoring in Jababeka

The organization who manages and monitors all operations activities in Jababeka is done by a subsidiary company who focus in the estate management, include the environmental management. Jababeka have the program to monitor the air ambient quality weekly that cover about 2,000 hectares of all industrial area in 41 air monitoring stations. The stations plotting was considered by the type of industries, traffic intensity and also the distance to the other station.

The parameter of ambient air quality that monitored are noise, dust (suspended particulate matter), SO_2, H_2S, NH_3, NO_2, O_3, CO refer to applied government regulation. The ambient air quality analysis report is one of the data requirement that should be obtained periodically for AMDAL (known as EIA – Environmental Impact Assessment) implementation report to the government. The activities of air monitoring, sampling and analysis were done by officers and laboratory analysts of Environmental Laboratory of Jababeka. The Laboratory already has been certified by *Komite Akreditasi Nasional Indonesia* that similar with **ISO 17025 certification**. Analysis report from certified Laboratory means the analysis is processed by standardized methodology with the thrusted result.

There are 42 sampling location from year 2015 until 2017, and around 21 sampling point in 2018. During this period in all sampling location, there are only 8 location that has detected (measured with value) from year 2015 to 2018. (See **Table 2**). From Table 2, we can see all range (min – max value) of each parameter in the 8 location. Only Pb that has no value (ND = Not Detected) during all sampling time. The possible reason are the value is below the minimum measurable value from the standard sampling method, which far below the threshold limit. From this table, we can see there are 3 (three) important parameter that exceed the NAAQS, which are TSP, NO_2, and H_2S. But instead there is not enough trend to states the air quality status in this area. There are two things to be considered in analyzing the data: (1) the very limited data availability and trend, and (2) the limited meteorological data. First, there are only 2 days sampling time in a year, with 1-day average data in a month that gives us no trend to analyze it more comprehently. As the pollutants can disperse over time and spaces, during the AAQM measurement, there might be some accumulation and delusion process at the sampling point. Second, the meteorological data was taken only show the current local weather during the sampling point time. The lack of meteological data will limitate our dispersion model in justifying where will the pollutants may disperse by the dominant wind direction and speed. TSP

highly contributed from construction work and transportation activities surround the sampling point. It means that, in that area we need to have a mitigation plan in short and long-term to reduce the TSP concentration in this area. One mitigation plan that are being done by the industrial estate management are marking more *green belt*, plants more trees surround the area, and make non-permanent wall around the construction area. In the industrial estate environmental management, the green supplier criteria selection can be considered as a part of mitigation plan to reduce air pollutions (Sidjabat and Runtuk, 2019).

NO_2 parameter highly contributes from transportation activities. The traffic management can be improved by evaluating the current traffic and predict it in the nearly future. The JIE management was managing the traffic with some scenarios during a different time in a day. This effort will reduce the contribution of NO_2 from traffic activities. The baseline of emission load from transportation sector can be conducted as the first stage to evaluate the reduction of air pollution from this traffic activities (Sidjabat et al, 2016). The second stage is to develop a spatial model from transportation sector (Sidjabat and Driejana, 2017).

H_2S could be contributed from petroleum industries or oil and gas industry near the area.

Table 2 Jababeka Industrial Estate Ambient Air Quality Monitoring Data Recap Year 2015 - 2018

Id Code	Parameter	TSP	Pb	SO_2	NO_2	H_2S	NH_3	O_3	CO
	NAAQS of Indonesia PP RI Num 41 Year 1999	260 ug/m^3	1,5 ug/m^3	265 ug/m^3	100 ug/m^3	24 ug/m^3	1360 ug/m^3	160 ug/m^3	10000 ug/m^3
	Range	min - max	min - max	min - max	min - max	min - max	min - max	min - max	min - max
cwd	Depan PT. Conwood (area KIJ VI)	6,46 - 226	ND	0,2 - 1,53	0,564 - 18	16,6 - 16,6	5 - 200	1 - 9,57	222 - 1347
sja	Desa Serta Jaya	75,3 - **1093**		0,99 - 1	2,48 - 23	0,187 - 0,187	1 - 17,6	1 - 20,4	222 - 896
dpa	Dry Port Area	12,9 - **1261**		0,24 - 1,3	0,8 - 50	0,187 - 0,189	1 - 47,4	1 - 11	112 - 1343
lms	Kampung Limus Blok P	53,1 - **729**		0,3 - 1	1 - 76,8	0,187 - **81,6**	0,92 - 17	1 - 10	222 - 2024
wwtp	Depan WWTP-1	14 - **408**		0,7 - 1,47	0,01 - 53,2	0,2 - 11	4 - 30	1 - 9,04	222 - 2233
blu	Perempatan Blok U	31,2 - **390**		0,8 - 2,63	9 - 60,1	0,1 - **32,8**	6 - 154	1 - 49	113 - 2235
tlg	Kampung Teleng	13 - **964**		1 - 1	5,08 - 56,4	5,61 - 16,4	3 - 33	1 - 17	223 - 2244
pnm	Perempatan Nissin Mas	21 - **349**		0,4 - 2,45	3 - **111**	0,05 - 11	0,2 - 96,2	2 - 34,3	223 - 2222
All Data range		6,46 - 1261	ND	0,2 - 2,63	0,01 - 111	0,05 - 81,6	0,2 - 200	1 - 49	112 - 2244

Meteorological Data from nearest station are about 86 km from Curug Meteorological Station and about 51 km from Meteorological Climatological and Geophysics Agency Region II. Because there is no close weather station near JIE, the meteorological data was taken from the current local weather condition during the sampling point. It will limitate the result because the available meteorological data are in a small number.

Openair model in JIE Year 2015 – 2018.

Openair is the *R-packed software to analyze the air quality data.* This software already used extensively by academician, government and private sector. Its development project was initiated and funded by UK Natural Environment Research Council (NERC), and Defra. The latest data information about *openair* can be found from the software package and the guidelines. **Openair** is being developed to analize the atmospheric composition data for many years, before its first focus in air quality data (Carslaw and Ropkins, 2012). The utilization of *openair* function for *air pollution assessment and modeling* was conducted in Krakow (Polandia). The function in *openair* can identify the relation between air pollution concentration and meteorological condition. It can also help to find the resposible emission sources that effects on air quality changes in certain location (Szulecka et al, 2017). In Indonesia, research in AAQ data analysis in Jakarta also using openair model. This openair model is able to anaylize long periode of air quality data, and can be

implemented in many countries in Indonesia that have not conduct the AAQ data analysis (Agustine et al, 2017). From the input of openair model to the pollution rose result, we can see the sampling point as the center of pollution rose, and the dispersion model is based on the input from meteorological data (see **Figure 2** and **Figure 3** below).

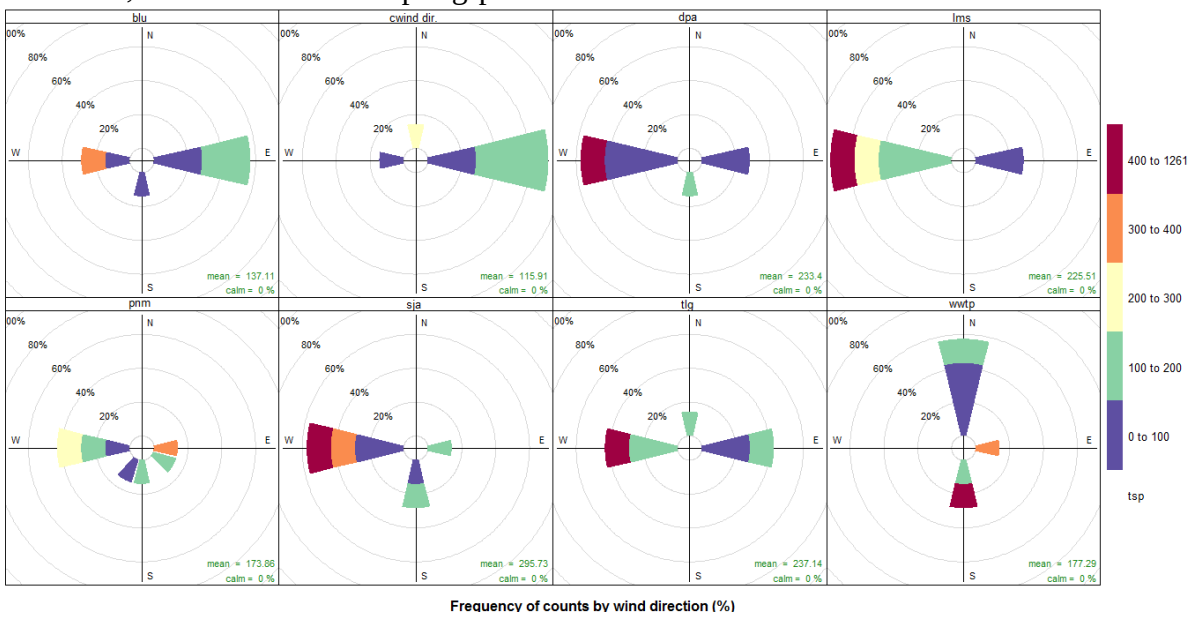

Figure 2 Pollution Rose of Total Suspended Particulates (TSP) (Unit: µg/m^3)

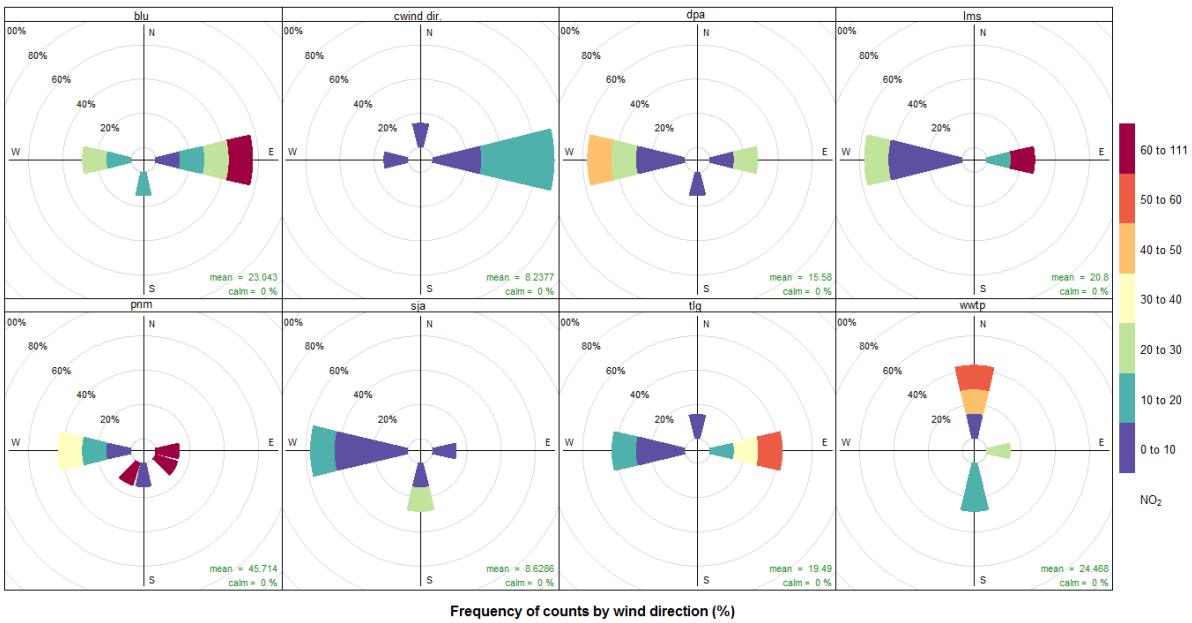

Figure 3 Pollution Rose of NO_2 (Unit: µg/m^3)

From **Figure 2** and **3** we can see various dispersion of pollutants in each sampling point, but the dispersion of all AAQ parameter in certain point are all the same. It is because the same meteorological data that been inputed to openair model. The differences is only based on the pollutant concentration range. By having more detail and sustain meteorological data, the pollution rose of pollutants made by openair will be more accurate and comprehensive. In other hand, the openair model can help all stakeholders to analyze the AAQM data and made it as a basis data

to plan better air quality management, especially in industrial area.

The gap that was found in this research are the lack of available data in AAQM and meteorological data. The meteorological data was taken from local weather condition sampling, during the AAQM been done in certain location. The research also shown that only 2 (two) AAQM data in a year for each location The AAQM data in the 8 (eight) location shown that are consistent taken between year 2015 to 2018. The future research must aims to make a real-time/continuous AAQM and meteorological data for better data modeling and analysis. If the AAQM and meteorological data that will gained are more sustain in certain periode of time and places, the basis data will be more accurate. It will give more benefits for all stakeholders that relates to better air quality management.

CONCLUSION

Air quality monitoring in industrial estate is an very important as a regular basis data in air quality management. The review of AAQM system shows recent research on data analysis, such as remote sensed image technique and GIS, BSC modification technique. AAQ data also been analyzed through emission load estimation, spatial model on air pollution, conduct PCA statistical analysis, CA – Reciprocal Averaging, and openair model.

For AAQM data analysis, openair model creates pollution rose, and the dispersion model that based on the input from meteorological data. The limited data of AAQM and meteorology can still be analyzed using openair model, and visualized through pollution rose function. Pollution rose will give a simple model of pollutants dispersion in each sampling point. By having more detail and sustain meteorological data, the pollution rose of pollutants will be more accurate and comprehensive. This model can help all stakeholders to analyze the AAQM data and made it as a basis data to plan better air quality management, especially in industrial area.

Data analysis and modeling can be improved by using real-time/continuous AAQM and meteorological data. The basis data will be more accurate and comprehensive if AAQM and meteorological data gained continuously in certain periode of time and places It will give more benefits for all stakeholders that relates to better air quality management.

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