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Regional Case Study

Determination of Air Quality Protection and Management Strategic Area : Case Study of Tangerang City

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Abstract

Metropolitan cities are often associated with anthropogenic activities that affect air quality. Tangerang, as a buffer city in the Greater Jakarta area, needs control strategies to tackle severe air pollution problem. Government Regulation No. 22/2021 requires the establishment of Air Quality Protection and Management Areas (AQPMA) in every city, including Tangerang. The determination of AQPMA involve emissions inventories, air quality, population density, land use, and meteorological conditions, using secondary data and air quality modeling with AERMOD. The results of the emission inventory show that the largest contribution comes from the manufacturing and road transportation industries, with NOx 19,747, CO 556,341, PM_{10} 27,001, $PM_{2.5}$ 22,080, SO_2 2,233, and NMVOC 295,482 (in Gigagrams/year). The result of the air model then accordance with measurements at AQMS Pasir Jaya in 2022. The average annual concentration results at this station are NOx 35, CO 1,200, PM_{10} 38, $PM_{2.5}$ 39, and SO_2 7.5 (in $\mu g/m^3$). Ciledug is the sub-district with the highest population density, which is 19,233 people/km^2. Based on AQPMA scores, eight very high-risk sub-districts must be a priority in mitigating clean air in Tangerang. A similar approach can be used in other cities to map vulnerability to air pollution as mandated by AQPMA.

Keywords: Air Quality; air quality model; aqpma; emission inventory; risk level

1. Introduction

Tangerang City is one of the cities in Banten Province that is categorized as a metropolitan city and is part of the greater Jakarta Metropolitan Area (JMA). Based on the regional spatial plan, Tangerang City is directed as a buffer zone for JMA as well as for the development of industrial, service, trade, and residential activities including satellite cities. The increase in industry is directly proportional to the growth in population due to urbanization while the development of new satellite cities is also increasing which is accompanied by the increase in residential and commercial areas. The largest international airport in Indonesia (Soekarno Hatta International Airport, SHIA) is also located in the administrative area of Tangerang City. These anthropogenic activities have impacted the intensified air pollutant emissions which in turn deteriorating air quality in Tangerang City.

Air pollution is the entry or inclusion of substances, energy, and/or other components into the ambient air by human activities so that it exceeds the ambient air quality standards that have been determined (Government Regulation, 2021). According to Lestari et al. (2020), the main contribution of pollutants comes from the land transportation sector, where NOx contributes 57% and CO 93%. Based on ambient air quality monitoring data from the Ambient Air Quality Monitoring Station (AQMS) the Air Quality Index (AQI) of Tangerang City in 2022 is 69.43, which is categorized as moderate (Directorate of Air Pollution Control, 2022). Poor air quality can affect public health, especially children, in the city and one of the mostly reported disease related to air pollution is ARI (Abdul Rahman et al., 2017). Based on data from the Tangerang City Health Office, in 2022 there was an increase in the number of patients with acute respiratory infection (ARI) by 45,469 people or 41.28% of patients from 2021.

In an effort to overcome air problems, a collective commitment has been coordinated by the Ministry of Environment and Forestry (MoEF) to improve air quality in the JMA region. One form of this commitment is the cross-regional Air Quality Protection and Management Plan (Directorate of Air Pollution Control, 2023). In forming the Air Quality Protection and Management Plan, it is necessary to determine the AQPMA as mandated in the Governmental Regulation No. 22 year 2021. The determination of AQPMA is carried out to determine priority areas for air pollution control, based on several criteria such as emission inventory results, ambient air concentration values, population density, similarity of landscape characteristics, and climatic and meteorological conditions. This research aim to develop the AQPMA methodology and provide example of its application in a city. The main purpose of this study is to provide input in determining priority areas for emission reduction measures, as well as to support the action plan in Tangerang city.

2. Methods

2.1. Domain and Grid Creation

To determine the areas that will become AQPMA in Tangerang City, it is necessary to divide the area into small grids to make it easier to determine the areas that will become the priority for formulating air pollution mitigation plan in the City. Based on its designation, AQPMA can be classified into 3 classes, namely Class I (clean air conservation and reserve area), II (residential and comersil), and III (industry). The grid contains AQPMA criteria such as emission inventory, air quality, population density, land use characteristics , and meteorological conditions. The data were obtained from various Tangerang municipalities through Internet and field visit data collection.

2.2. Emission Inventory

The emission inventory (EI) in this study will focus on several sectors such as the manufacturing industry, construction, residential, on-road transport, off-road transport represented by airports, and municipal solid waste open burning (MSW OB). For emissions from manufacturing and residential industries, the Atmospheric Brown Clouds Emission Inventory Manual (ABC EIM) software is used to calculate the inventory. ABC EIM is designed in the form of an Excel spreadsheet by applying the emission estimation method. ABC EIM was published by the United Nation for Environment Programme (UNEP) to provide guidance on the air pollutant emission inventory, especially in developing countries. The most common emission estimation method is to multiply the emission factor (FE) by the activity level (AR) which can be seen in **Equation 1** (Shrestha et al., 2013). The parameters to be inventoried are NOx, CO, PM10, PM2.5, SO_2, and NMVOC (Non-Methane Volatile Organic Compounds).

$$EM = AR \ x \ FE \tag{1}$$

In this study, the emission factors used are the default emission factors provided by the ABC-EIM worksheet. However, for some sectors such as construction and off-road transport, emission factors issued by EMEP/EEA 2023 were used and the activity data of those sources were provided by the relevant agencies as presented in **Table 1**.

Table 1. Activity data

Activity Data	Source	Output
Industry fuel consumption	Environmental Service	Manufacturing industry sector EI
Residential fuels consumption	National Socio-Economic Survey (SUSENAS)	Residential sector EI
Construction area	Public Works and Spatial Planning Office (PUPR)	Construction sector EI

Activity Data	Source	Output
Number of Vehicles	One-Stop Integrated Administration System (SAMSAT)	On-road transport sector EI
Vehicle Travel Kilometers (VKT)	Department of Transport	On-road transport sector EI
Landing and Take-off of aircraft	Airport Authority (PT. Angkasa Pura II)	Off-road transport sector EI
Waste generation and composition	Waste Management Information System (SISPN)	Municipals solid waste open burning (MSW OB) EI

2.3. Air Quality Data

The air quality continuous monitoring data were taken from Pasir Jaya air quality monitoring station (AQMS) measurements in 2022 of the parameters such as NO2, Carbon Monoxide (CO), Particulate Matter (PM10 and PM2.5), and sulfur dioxide (SO2). Furthermore, the results of AQMS monitoring will be compared with ambient air quality standards according to Government Regulation No. 22 of 2021.

In this study to determine the concentration of pollutants in each grid using the results of AERMOD software by using input data from the emission inventory in the previous stage. The AERMOD model (the United States Environmental Protection Agency's preferred air quality model) has the ability to model the distribution of emissions from various sources such as point, line, volumetric, and area sources in one run (Demirarslan et al., 2017) and predict pollutant concentration over different time scales, such as hourly, daily, monthly and yearly (Rouhi et al., 2013).

The results of the model were validated using 4 statistical tests: MNBE, MNGE for gas, and MFE and MFB for particulates. Validation was carried out by comparing the model results and measurements from AQMS Pasir Jaya on the grid where the monitoring station is located. To validate all AERMOD grids, more stations are needed, but there is currently only one air quality monitoring station in the city

2.4. Population Density Analysis

The population density analysis in this study uses data from the Central Bureau of Statistics of Tangerang City to determine the population in each sub-district and in each AQPMA grid based on the data for each sub-district. The data are important to determine the number of populations exposed to air pollution in the city. The higher number of populations exposed to the higher concentration would be associated with higher risk levels.

2.5. Landscape Characteristic Analysis

The analysis of landscape characteristics in this study is represented by land cover (land use) from the City Development and Planning Agency (Bappeda). Higher risk level would be assigned for the built areas in which the dense population is concentrated inside.

2.6. Meteorological Condition Analysis

The analysis of meteorological conditions in this study was represented by the parameters of temperature (°C), air humidity (%), rainfall (mm), solar radiation (in W/m2), wind speed (m/s), and direction (degree). Meteorological data in this study used an online database provided by ERA5 and Power-NASA. ERA5 dataset is the fifth generation ECMWF atmospheric reanalysis of the global climate. Reanalysis combines model data with observations across the world into a globally complete and consistent dataset (Hersbach et al., 2020). The Prediction of Worldwide Energy Resource project developed by the American National Aeronautics and Space Administration (POWER-NASA) provides meteorological observations and surface energy fluxes on 1° latitude by 1° longitude grid, with a continuous daily coverage and for the entire globe (Negm et al., 2017).

These data were also used for AERMET simulation to provide city-specific meteorological parameters for the air quality modelling application of AERMOD. Meteorological data in the AERMOD model plays a crucial role in determining the direction, dispersion, and concentration of pollutants in Tangerang City. AERMOD uses the Gaussian equation to describe the dispersion of airborne particles based on distance and time. Pollutants continuously released from chimneys at a constant emission rate (Q) are carried by wind at an average horizontal speed (u), with the mass velocity of the pollutant determined by the Q/u ratio (Nauli, 2002). The Gaussian equation used in AERMOD is shown in **Equation 2**.

$$C= \frac{Q}{2\pi\mu s\sigma y\sigma z} exp\left(-\frac{1y^2}{2\sigma y^2}\right) x \left\{exp\left(-\frac{1}{2} * \frac{(z-He^2)}{\sigma z^2}\right) + exp\left(-\frac{1}{2} * \frac{(z+He)^2}{\sigma z^2}\right)\right\} \quad (2)$$

2.7. Scoring

To determine Tangerang City AQPMA, each criterion (includes inventory results, air quality, population density, land use, and meteorological conditions) is scored and averaged. Score interval are calculated by subtracting the minimum from maximum value and dividing by the number of class (Marwasta and Nurhidayat, 2019), as shown in Equation 2. The emissions inventory score is based on spatial distribution, population density is determined by the grid's population, air quality is assessed according to AQPMA standard, and land use and meteorological condition data are sourced from literature.

$$Interval\ Score = \frac{Max\ Value - Min\ Value}{Number\ of\ Class} \quad (3)$$

This study will use a score range of 1-5 according to the AQPMA risk level classification which can be seen in **Table 2.**

Table 2. Risk level classification

Score	Color	Description*
1		Very low risk
2		Low risk
3		Moderate risk
4		High risk
5		Very high risk

Source: (Directorate of Air Pollution Control, 2020)

3. Result and Discussion

3.1. Grid Creation

Tangerang City, located in Banten Province, cover an area of 164,55 Km² and consist of 13 sub-districts: Batuceper, Benda, Cibodas, Cipondoh, Jatiuwung, Karang Tengah, Karawaci, Neglasari, Periuk, Pinang, Tangerang, Ciledug and Larangan. To assess AQPMA, a grid is created to facilitate scoring and prioritizing of area. Although there is no standard formula for grid size, this study follows the Ministry of Environment guidelines in 2013, which specify a 1 Km x 1 Km grid for area large than 100 Km². Thus, the grid of Tangerang City illustrated in **Figure 1.**

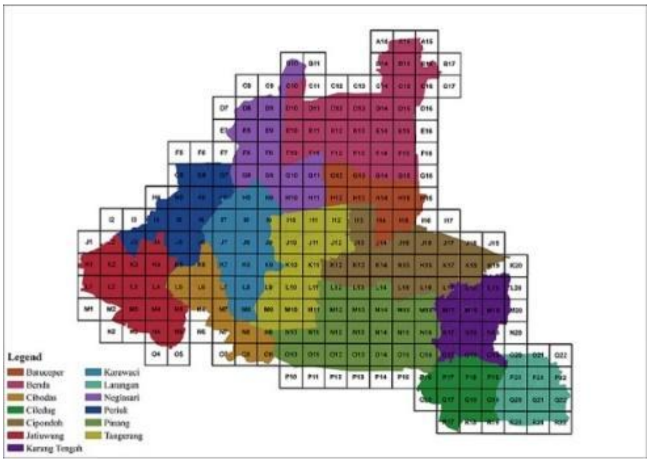


Figure 1. Grid of air quality protection and management areas of Tangerang City

Each grid will include values for various criteria such as emission load, air quality, population density, land use, and meteorological conditions, which will be scale and average. The emission load for each grid is calculated by distributing the total emission load according to the emission sources within the grid. Furthermore, a grid of these emission loads will be used as data inputs for air quality modeling with AERMOD. Before using this grid's in AERMOD, the emission load must be converted from ton/year to gr/s.m^2.

3.2. Emission Inventory

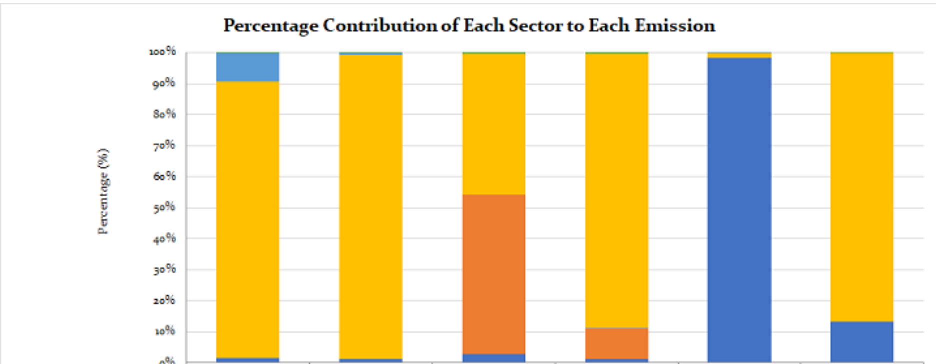
In determining the AQPMA, an emission inventory must be conducted. Emission inventory is an action to manage and analyze emissions, to obtain quantitative information on the amount of emissions (Minister of Environment, 2010). The emission inventory is also a stage to identify dominant sources of emissions so that appropriate air quality management strategies can be carried out. In this study, the emission inventory is focused on 6 sectors there are manufacturing industry, residential, construction, On-Road transport, Off-Road transport, and municipal solid waste open burning with the activity data from each sector can be seen in **Table 3.**

Table 3. Activity data for each sector

Activity Data	
Manufacturing Industry	
Fuel	Consumption
Coal (Ton)	48,781.52
Natural Gas (m^3)	61,899,123.66
LPG (Kg)	187,096.00
Gasoline (liter)	362,034.60
Diesel (Liter)	4,637,426.36
Wood (Kg)	5,360,496.00
Residential	
Fuel	Consumption
LPG (Kg)	43,530,350.61
Kerosene (Liter)	4,706,074.94
Construction	
Activity	Area (m^2)
Road construction	6,662.10
Road reconstruction	71,892.36
Road rehabilitation	12,301,752.80

Bridge construction	533.70
Bridge replacement	831.94
Total	12,381,672.90
On-Road Transport	
Vehicle Type	Quantity (Unit)
Motorcycle	856,597
Jeep	13,610
Sedan	12,598
Light Truck	11,998
Minibus	142,699
Bus	544
Microbus	1,053
Pick Up	18,506
Truck	2,651
Total	1,060,256
Vehicle Category	VKT (Km/Year)
Motorcycle (MC)	36,374.155
Light Vehicle (LV)	73,619.036
Heavy Vehicle (HV)	95,954.380
Off-Road Transport	
Flight	Landing and Take Off
Domestic (LTO)	257,063
International (LTO)	48,624
Total	305,687
Municipals Solid Waste Open Burning (MSW OB)	
Amount of waste burnt (Kg)	5,322,943.452

An emission inventory needs to be conducted to determine the amount of emissions generated from the activities of each sector in Tangerang City. In addition, through the inventory we can find out which sectors contribute the most to the production of pollutants in Tangerang City. Based on the results of emission inventories produced from 6 sectors in Tangerang City, the most emitted emissions are CO 566,341 Tons (60.71%), NMVOC 295,481 Tons (31.67%), PM_{10} 27,001 Tons (2.89%), PM2.5 22,080 Tons (2.37%), NOx 19,747 Tons (2.12%) and SO2 2,233 Tons (0.24%).



	Nox	CO	PM10	PM2.5	SO2	NMVOC
MSW OB	15,969	223,563	159,688	52,165	2,661	79,844
Off-Road Transportation	4.551,053	3.070,828			260,609	
On-Road Transportation	43.545,036	462.207,529	12.185,872	12.185,872	8.844,868	256.360,970
Residential	83,531	201,064	15,777	15,777	0,060	11,288
Construction			13.892,251	1.389,225		
Manufacturing Industry	739,097	5.742,445	747,751	157,121	498.360,075	39.029,770

Figure 2. Percentage contribution of each sector to emissions

According to **Figure 2,** Each sector has a different contribution to the amount of emissions produced, for NOx the largest contributors are the On-Road Transportation (88.20%), Off-Road Transportation (10.10%), Manufacturing Industry (1.50%), Residential (0.17%), and MSW OB (0.03%). For CO parameters, the largest contributors are from the On-Road Transportation sector (97.94%), Manufacturing industry (1.22%), Off-Road Transportation (0.76%), MSW OB (0.05%), and residential (0.04%). For PM_{10} parameters, the largest contribution was from the construction sector (51.45%), On-Road Transportation (45.13%), manufacturing industry (2.77%), MSW OB (0.59%) and Residential (0.04%). For $PM_{2.5}$ parameters, the largest contribution was from the On-Road Transportation sector (88.30%), construction (10.07%), manufacturing industry (1.14%), MSW OB (0.38%), and residential (0.11%). For SO_2, the largest contribution was from the manufacturing industry sector (98.20%), On-Road Transportation (1.74%), Off-Road Transportation (0.05%), MSW OB (0.001%) and residential (0.00001%). For NMVOCs, the largest contribution is from the On-Road Transportation sector (86.70%), manufacturing industry (13.21%), MSW OB (0.03%), and residential (0.004%). Emissions generated from fuel use are highly dependent on the type of fuel used (Soenarno, 1999). Thus, of the contribution of each sector, the on-road sector 87%-98% and the manufacturing industry 98% are the sectors that have the largest contribution in producing emissions.

Each sector's activities impact emission levels. For example, coal-based manufacturing produces high SO2 emissions, while gasoline and diesel in transportation contribute significantly to NOx and CO emissions from engine combustions. Based on research conducted by Namara et al. (2020), one of the main problems faced by Tangerang City is the increase in pollution caused by emissions from the industrial and transportation sectors.

Research conducted by Agustian Permadi et al.(2020) for a case study in Bogor City, the land transport sector contributes $PM_{2.5}$, SO_2, and NMVOC emissions of at least 60% - 80% of overall emissions. In addition to the transport sector, one sector that also contributes to NOx and CO emissions is industry with a contribution of 90% and 92%.

In general, NOx, CO, PM_{10}, $PM_{2.5}$ and SO_2 emissions come from incomplete combustion processes. In addition, one parameter that needs to be considered in the emission inventory is NMVOC (Non-Methane Volatile Organic Compounds) because NMVOC has a very important role as an ozone (O_3) precursor in the air. High levels of ozone (O_3) can affect human, plant, and material health (Dave et al., 2020).

After the emissions inventory is carried out, the next step is to map the distribution of emissions through spatial distribution in Tangerang City. The results of the spatial distribution of the emissions inventory, which includes several parameters from six sectors, can be seen in **Figure 3**.

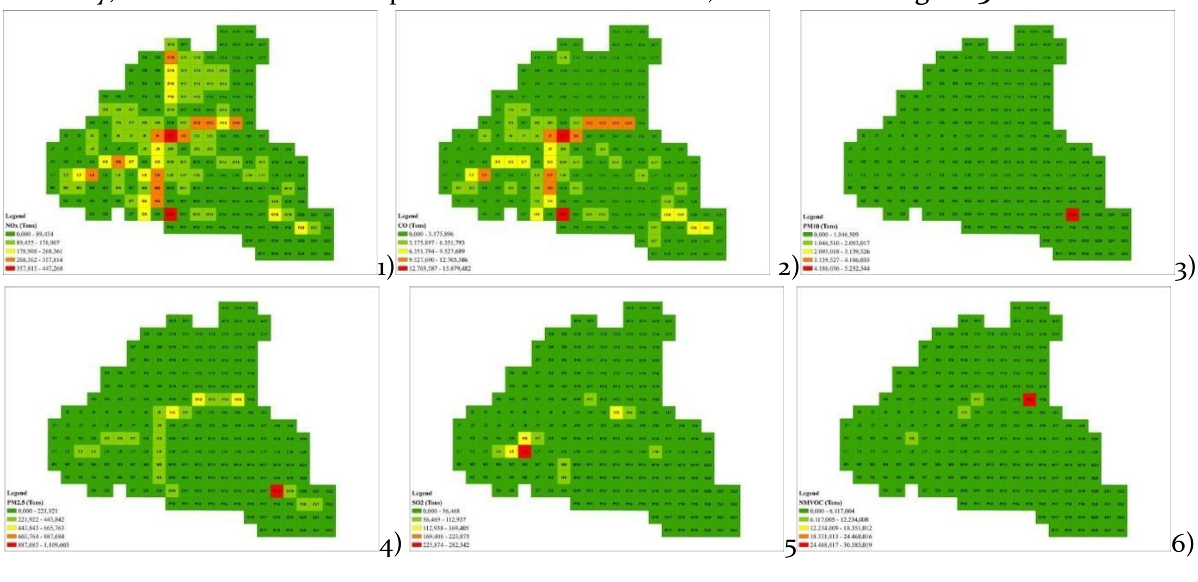


Figure 3. Spatial distribution of emission (1) NOx, (2) CO, (3) PM_{10}, (4) $PM_{2.5}$, (5) SO_2 (6) NMVOC

According to **Figure 3**, each emission is produced at different girds, for example, for the NOx and CO parameters, the largest emissions are generated from the I10 (Neglasari) and O10 (Pinang) grids, for the PM10 and PM2.5 parameters are predominantly generated on the O18 grid (Karang Tengah), the dominant SO2 parameters are generated on the L6 grid (Cibodas) and the dominant NMVOC parameters are generated on the H15 (Batuceper) grid. The resulting emissions are highly dependent on the level of activity data on the grid.

3.3. Air Quality Analysis

In this study, air quality analysis uses 2 data sources, namely the results of Pasir Jaya AQMS measurements and the results of AERMOD concentration modelling.

3.3.1. Pasir Jaya AQMS Measurement Results

The concentration of pollutants in the air affects the level of air quality in an area, so that as much as possible the concentration of pollutants in the air is below a predetermined threshold value. In this study, pollutant concentration data was obtained from the results of AQMS Pasir Jaya measurements in 2022 and for parameters to be analysed such as NOx as NO_2, CO, PM_{10}, $PM_{2.5}$, and SO_2. The average measurement results of each parameter obtained from AQMS Pasir Jaya can be seen in **Table 4.**

Table 4. AQMS concentration results with ambient air quality standard

No.	Parameters	Pasir Jaya AQMS Concentration (μg/m³)	Ambient Air Quality Standard[a] (μg/m³)	Duration
1	NOx	35.70	50	1 year
2	CO	1,092.46	4,000	8 hours
3	PM_{10}	47.42	40	1 year
4	$PM_{2.5}$	40.68	15	1 year
5	SO_2	8.79	45	1 year

Source: [a](Government Regulation, 2021)

Based on of AQMS Pasir Jaya monitoring results in 2022, the average of NOx, CO and SO2 concentration are below the ambient air quality standard set by government regulation No. 22 of 2021. However annual average of particulate matter (PM_{10} and $PM_{2.5}$) concentration exceed the standard, with concentration of PM10 47.42 μg/m³ and PM2.5 40.68 μg/m³ respectively. As shown in **Table 4**, this particulate matter level can negatively effects the human respiratory system, potentially contributing to increase case of respiratory disease such as Acute Respiration Infection (ARI) and cough in Tangerang City. Based on data from the Tangerang City Health Office indicate a 41.38% increase in ARI and a 21.66% increase in cough in cases from the previous year. Particulates in the air (especially $PM_{2.5}$), contribute to mortality (87.27%) and to ARI (87.95%). This is due to Particulate matter contains inorganic compounds like Na, K, Mg, Mn, Zn, Cd, Cr, Cu, Co and As, which are linked to respiratory disorders (ARI) (Leinawati et al., 2013).

3.3.2. Air Quality Modelling

In this study, air quality analysis also uses AERMOD software due to the limited availability of AQMS data, with only one monitoring station in Pasir Jaya. To Estimate the pollutant concentration in other areas can obtain result from AERMOD software. Also in this study, the AERMOD data input use the result of the gridded emission inventory that was conducted in the previous stage. The results of the modeled annual average concentrations generated by the AERMOD model are presented in **Figure 4**.

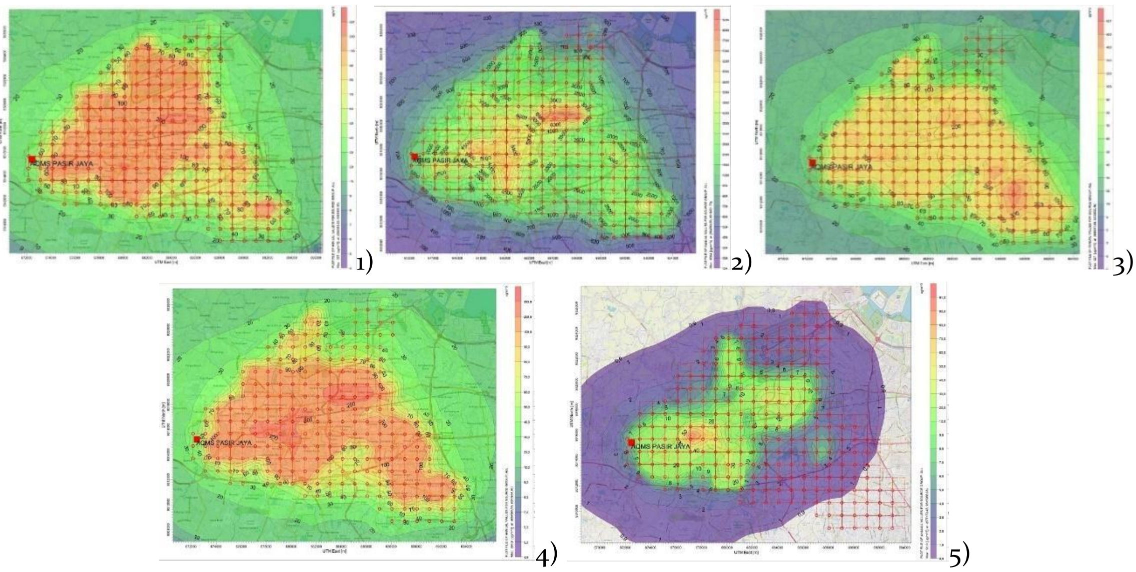


Figure 4. Distribution concentration of (1) NOx, (2) CO, (3) PM_{10}, (4) $PM_{2.5}$, (5) SO_2 in µg/m³

The distribution of pollutant concentrations in Tangerang City obtained through the AERMOD model results can be seen in Figure 3, where almost most concentrations (NOx, CO, PM_{10}, $PM_{2.5}$) are evenly distributed throughout Tangerang City and SO2 emissions are dominantly distributed only around the centre of Tangerang City. From the AERMOD model results, it is known that the highest concentrations of NOx 227 µg/m³, CO 8,204 µg/m³, PM_{10} 527 µg/m³, $PM_{2.5}$ 203.9 µg/m³, SO_2 91 µg/m³.

The pollutant concentrations obtained from the AERMOD model results must be validated to determine the accuracy of the model. In this study, the validation of concentration obtained from the AERMOD model will be conducted using four statistical test MNBE, MNGE, MFB, and MFE. The results of the statistical test of the AERMOD model results with the measurement results can be seen in **Table 5.**

Table 5. Calculation of statistical measure used for model performance evaluation

No.	Parameters	Concentration (µg/m³)		Statistical Test			
		AQMS Pasir Jaya	AERMOD	MNBE (%)	MNGE (%)	MFB (%)	MFE (%)
1	NOx	35.70	35	-1.96	1.96		
2	CO	1,092.46	1,200	9.39	9.39		
3	PM_{10}	47.42	38			-22.05	22.05
4	$PM_{2.5}$	40.68	39			-4.22	4.22
5	SO_2	8.79	7.5	-14.70	14.70		

Based on the statistical test results presented in Table 5, the values obtained meet the criteria for MNBE ≤ ±15% and MNGE ≤ 35% (EPA, 1991) and goal for MFB ≤ ±30%, and MFE ≤ 50% (Boylan and Russell, 2006). Thus, the concentrations obtained from the AERMOD model are acceptable as they meet the criteria of all the statistical tests.

3.4. Population Density Analysis

In determining AQPMA, it is necessary to consider the level of population density in an area. The population density in each subdistrict in Kota Tangerang in 2022 can be seen in Figure 5.

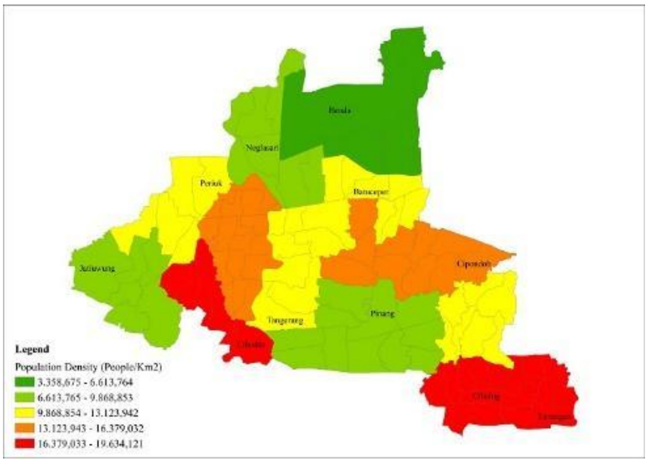


Figure 5. Population density map of Tangerang City

Based on **Figure 5**, Cibodas, Ciledug, and Larangan are the three sub-districts with the highest levels of population density. Population density can significantly affect air quality, as a higher population density typically leads to increased energy consumption for domestic activities. Additionally, higher population density often results in a reduction of green open spaces, which can contribute to higher concentrations of pollutants in the air, particularly in urban areas (Borck and Schrauth, 2021).

3.5. Analysis of Land Cover Characteristics

Landuse have an influence on air quality in an area. Metropolitan cities are centers of community activity that are densely populated by human activities, resulting in changes in land use and land cover. Land use and land cover changes can alter the spatial and temporal distribution of airborne pollutant levels close to the surface through a complex set of physical and chemical processes (Heald and Spracklen, 2015). The land use map of Tangerang City can be seen in **Figure 6**.

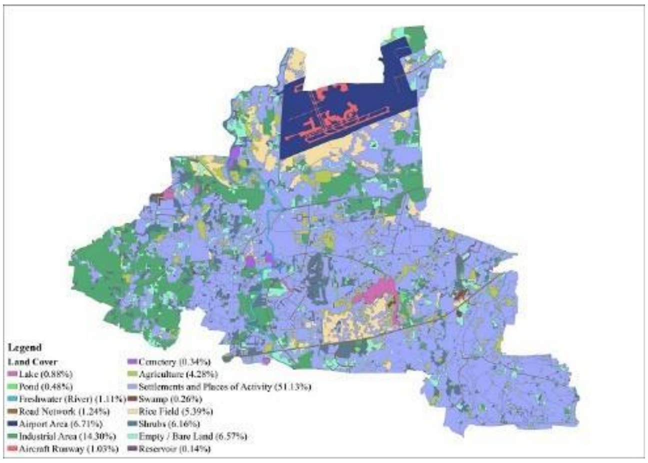


Figure 6. Land use of Tangerang City

Land use is a key factor in determine AQPMA Classification in Tangerang City. based on **Figure 6,** land in Tangerang City is predominantly use for residential purpose (51.13%), industrial estate (14.30%), green open spaces (16.09%), and other use (34.57). Consequently, Tangerang City falls into AQPMA for Class II (residential/commercial) and Class III (industrial) categories. According to Directorate of Air Pollution Control (2021), ambient air quality standard for Class II are stricter than those for Class III.

Green open space plays an important role in circulation and air quality, even in small areas, as it affect urban air quality. According to research conducted by Zhu et al. (2019), show that some variations of air pollutants in an area have a positive correlation with built-up land and a negative correlation with forest or green open space areas. This indicate that land use, such as the limited green open space which only 16.09% of the area of Tangerang City, which includes plantations, rice fields, swamps, and shrubs.

3.6. Meteorological Condition

Meteorological conditions greatly affect the concentration level of pollutants in urban areas. Therefore, in determining the area of air quality protection and management, it is also necessary to pay attention to the meteorological conditions in the area. In this research, the meteorological conditions that will be studied in general are temperature, rainfall, relative humidity, solar radiation, wind speed, and direction. The meteorological conditions of the city of Tengarang in 2022 can be seen in **Table 6.**

Table 6. Average meteorological condition in Tangerang City on 2022

No.	Parameters	Value	Units
1.	Temperature[a]	27.17	°C
2.	Rainfall[a]	2,347.89	mm/years
3.	Relative humidity[a]	83.10	%
4.	Solar radiation[b]	414.73	Wh/m^2
5.	Wind speed[a]	2.79	m/s

Source: a)(Power Nasa, 2024); b)(ERA5, 2024)

Meteorological conditions influence pollutant levels in the air by affecting their dispersion and mixing, which can cause pollutant concentration to vary (Unal et al., 2011). The meteorological factor that impacting to pollutant distribution such as temperature, air humidity, rainfall, solar radiation, wind speed, and direction (Karppinen et al., 2000). While in this study does not conduct an in-depth analysis of meteorological conditions, it provides a general overview of how this factor related to pollutant concentration based on literature.

3.7. Scoring

To determine the areas that will become the AQPMA in Tangerang City, it is necessary to score each criterion. In this study, the scoring will be done on each grid that has been made previously. The scoring for each criterion is not regulated in any regulation, so the scoring in this study for the criteria of emission inventory results and population density level using the results from distribution value on each grid, for air quality the scoring is based on quality standards based on each AQPMA class, for landscape characteristics and meteorological conditions using an approach based on the results of literature studies. Where the greater the value of each criterion, the greater the score will be given. However, for meteorological conditions using the scoring given is inversely proportional to the scoring of other criteria. This is because based on the results of the references, it is known that meteorological conditions tend to have a negative or inverse relationship with air quality, where if meteorological conditions are greater, it will reduce the concentration of pollutants in the air, and vice versa.

Table 7. Air Quality protection and management area criteria score

Emission Inventory		
Parameters	Value Interval	Score
NO_x	x ≤ 89.454	1
	89.454 ≤ x ≤ 178.907	2
	178.907 ≤ x ≤ 268.361	3
	268.361 ≤ x ≤ 357.814	4
	x ≥357.814	5
CO	x ≤ 3,175.986	1
	3,175.896 ≤ x ≤ 6,351.793	2
	6,351.793 ≤ x ≤ 9,527.698	3
	9,527.698 ≤ x ≤ 12,703.586	4
	x ≥ 12,703.586	5
PM_{10}	x ≤ 1,046.509	1
	1,046.509 ≤ x ≤ 2,093.017	2
	2,093.017 ≤ x ≤ 3,139.526	3

	3,139.526 ≤ x ≤ 4,186.035	4
	x ≥ 4,186.035	5
$PM_{2.5}$	x ≤ 221.921	1
	221.921 ≤ x ≤ 443.842	2
	443.842≤ x ≤ 665.763	3
	665.763 ≤ x ≤ 887.684	4
	x ≥ 887.684	5
SO_2	x ≤ 56.468	1
	56.468 ≤ x ≤ 112.937	2
	112.937 ≤ x ≤ 169.405	3
	169.405 ≤ x ≤ 224.873	4
	x ≥ 225.873	5
NMVOC	x ≤ 6,117.004	1
	6,117.004 ≤ x ≤ 12,234.008	2
	12,234.008 ≤ x ≤ 18,351.012	3
	18,351.012 ≤ x ≤ 24,468.016	4
	x ≥ 24,468.016	5

Air Quality[a]

Parameters	Value Interval		Score
	Class II	Class III	
NOx	≤ 9	≤ 10	1
	9 ≤ x ≤ 18	10 ≤ x ≤ 20	2
	18 ≤ x ≤ 27	20 ≤ x ≤ 30	3
	27 ≤ x ≤ 36	30 ≤ x ≤ 40	4
	> 36	> 40	5
CO	≤ 780	≤ 800	1
	780 ≤ x ≤ 1,560	800 ≤ x ≤ 1,600	2
	1,560 ≤ x ≤ 2,340	1,600 ≤ x ≤ 2,400	3
	2,340 ≤ x ≤ 3,120	2,400 ≤ x ≤ 3,200	4
	> 3,120	> 3,200	5
PM_{10}	≤ 7.6	≤ 8	1
	7.6 ≤ x ≤ 15.2	8 ≤ x ≤ 16	2
	15.2 ≤ x ≤ 22.8	16 ≤ x ≤ 24	3
	22.8 ≤ x ≤ 30.4	24 ≤ x ≤ 32	4
	> 30.4	> 32	5
$PM_{2.5}$	≤ 2.8	≤ 3	1
	2.8 ≤ x ≤ 5.6	3 ≤ x ≤ 6	2
	5.6 ≤ x ≤ 8.4	6 ≤ x ≤ 9	3
	8.4 ≤ x ≤ 11.2	9 ≤ x ≤ 12	4
	> 11.2	> 12	5
SO_2	≤ 8	≤ 9	1
	8 ≤ x ≤ 16	9 ≤ x ≤ 18	2
	16 ≤ x ≤ 24	18 ≤ x ≤ 27	3
	24 ≤ x ≤ 32	27 ≤ x ≤ 36	4
	> 32	> 36	5

Population Density

Value Interval	Score
0.015 ≤ x ≤ 457.305	1
457.305 ≤ x ≤ 914.596	2
914.596 ≤ x ≤ 1,371.886	3
1,371.886 ≤ x ≤ 1,829.176	4
1,829.176 ≤ x ≤ 2,286.467	5

Land Cover[b]

Land Cover Classification	Score
Built-up Area	5
Open Area/Bare Land/scrub/sparse vegetation	4
Farm/Field/Garden/Mixed crops	3
Rice Fields/Vegetation	2
Water body/Mine/Sand/Land	1

Meteorology Condition

Meteorology Condition	Value Interval	Score
Temperature (°*C*)	24,98 ≤ x ≤ 25,89	5
	25,89 ≤ x ≤ 26,79	4
	26,79 ≤ x ≤ 27,70	3
	27,70 ≤ x ≤ 28,61	2
	28,61 ≤ x ≤ 29,51	1
Rainfall (mm/year)[c]	< 1.500	5
	1.500 - < 2.000	4
	2.000 - < 2.500	3
	2.500 - < 3.000	2
	>= 3.000	1
Humidity (%)[d]	RH < 50	5
	50 ≤ RH ≤80	3
	RH > 80	1
Solar radiation (Wh/m^2)[e]	> 700	5
	350 ≤ x ≥ 700	3
	< 350	1
Wind speed (m/s)[f]	< 2	5
	2 – 3	4
	3 – 5	3
	5 – 6	2
	> 6	1

Source: [a)]Directorate of Air Pollution Control (2021); [b)]Hadi et al.(2023); [c)]Ministry of forestry (2013); [d)]Ku-Mahamud and Khor (2009); [e)]Seinfeld (1986); [f)]Pasquill (1961)

3.8. Air Quality Protection and Management Area (AQPMA)

AQPMA is an area divided into several areas for air quality protection and management planning (Government Regulation, 2021). After the scoring process is carried out on each AQPMA criterion, the area that will become an AQPMA will be determined by averaging all the scores on each grid. The map of the final score of AQPMA in Tangerang City in 2022 can be seen in **Figure 7.**

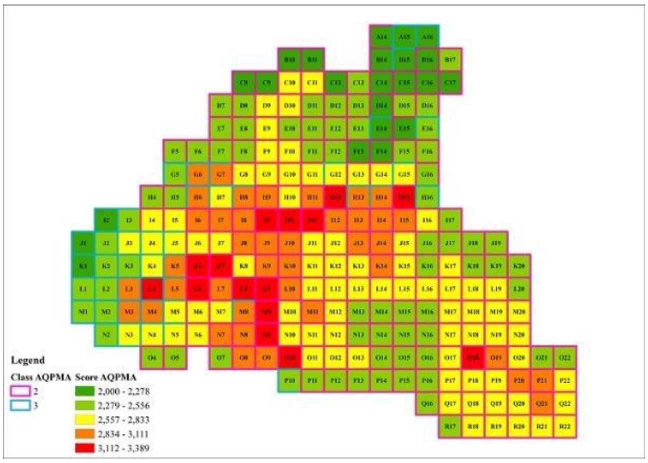


Figure 7. Air Quality Protection and Management Area of Tangerang City

Based on **Figure 7**, there are 15 red-coloured grids with a score range of 3.112 – 3.389 which are categorized as areas with a very high-risk level. These 15 grids are the priority areas for AQPMA in Tangerang City which are located in Batuceper Subdistrict (H15,H12), Cibodas Subdistrict (K6,K7,L6,N9), Jatiuwung Subdistrict (L4), Karang Tengah Subdistrict (O18), Karawaci Subdistrict (I9, L8), Neglasari Subdistrict (I10), Pinang Subdistrict (O10) and Tangerang Subdistrict (I11,L9, M9). Thus, some sub-districts that will become the protection and management areas for air quality quality in Tangerang City. The same research was also conducted by Afifah (2022) for a case study in Metro City, Lampung. The results of the study were that most of the areas had the same characteristics, the areas with very high and high-risk levels in three sub-districts, namely Central Metro District, West Metro District, and East Metro District with the lowest score of 1.6 and the highest score of 4.4.

Based on **Figure 7**, it is known that grids with high-risk levels are included in WPPMU Class II (Residential/Service Areas) and Class III (Industrial Areas). Therefore, the scenario that can be carried out focuses on reducing emissions resulting from these sectors. Some scenario strategies to solve problems in each class can be seen in **Table 8.**

Table 8. Possible scenario strategies

Possible Scenario	
AQPMA Class II	**AQPMA Class III**
1. Using clean fuels such as LPG gas and electric stoves (Majumdar et al., 2020). 2. Improve waste collection services to reduce the behavior of burning waste and throwing waste into the environment (Ramadan et al., 2022). 3. Tightening of vehicle emission standards (Beck, 1984). 4. Conducting socialization to the public to carry out engine maintenance and vehicle emission tests periodically (Nurdjanah, 2014). 5. Encouraging the use of environmentally friendly vehicles (Nurdjanah, 2014).	1. Installation of air pollutant control devices, especially in boilers (Hardie et al., 1995). 2. Restrictions on the use of coal as an energy material (Norco and Cohen, 1973). 3. The use of sustainable raw materials can reduce environmental impacts and emissions in the industrial supply chain (Frianto et al., 2023) 4. Tightening exhaust emission standards from the industrial sector (Kuo et al., 2009).

4. Conclusions

To prioritized area under the AQPMA, it is essential to consider pollutant concentration, emission inventory result, population density, land use, and meteorological conditions. These factors help assess population exposure to air pollution and understand how land use and meteorological condition affect emission levels and air quality. In Tangerang City, the primary emission from various sectors are SO_2, CO and NMVOC, with the manufacturing and on-road transportation being the major contributions. This study identifies eight sub-districts as priority areas for AQPMA base on a high-risk score range of 3.112 – 3.389 such as Batuceper, Cibodas, Jatiuwung, Karang Tengah, Karawaci, Neglasari, Pinang and Tangerang. It is hoped that this research will assist the local government of Tangerang City in targeting air quality management efforts and developing effective strategies to address air quality issue in the city.

This study has limitations in analyzing gridded meteorological conditions which were not available and their relationship with air quality parameters in Tangerang City. This study contributes to putting the policy into practice by conducting a case study in Tangerang City. This can be a good showcase for other cities in Indonesia in implementing the AQPMA concept when the air quality monitoring information is very limited in the city. By combining emission inventory and air quality modelling applications, they can be economic option to avoid the high cost of air quality monitoring to cover all parts of the city.

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