Carrying capacity of air quality analysis as part of air pollution control strategy in Kendal Industrial Estate, Kendal Regency, Central Java

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Abstract. The development of the industrial sector in Indonesia produces benefits and carries risks, one of which is air pollution. Industrial estates play an important role as economic growth sources with their emissions should have cared about carrying air quality capacity in their area. The projected carrying capacity of air quality is predicted using a simple box model with the emission factor using IPPS. Historical ambient air quality measurements in this area were also collected. Based on the calculation, results show the constructed industries emission load of SO2, NO2, CO, VOC, and TSP 109 tons/year, 128 tons/year, 42 tons/year, 1263 tons/year, and 2008 tons/year. To comply with the ambient air quality standard, the maximum number of industries that can be accommodated in those areas is 190 industries. The critical parameter for violating ambient air quality standard is TSP. Thus, air pollution control strategy should be focused on reducing TSP emission load.

1. Introduction

Through technological advances, humans can create various advances to increase a sector that continues to develop, namely the industrial sector. As the leading sector, industry plays a role in pursuing and stimulating other sectors in Indonesia. However, it is also at risk of causing pollution to the surroundings and disrupting people's health and life. As a result, good air quality has become challenging to obtain, especially in industrial areas. Coupled with other factors such as meteorological factors, they naturally play a vital role in regulating and controlling air pollution to regulate and control every pollutant's entry. Meteorological factors that affect air pollution are wind direction and speed, temperature, air pressure, and atmospheric stability [1].

The need for clean air and the increasing population in the world need to be anticipated so that a healthy air crisis does not occur. Therefore, the air needs to be maintained and considered for its health [2]. The government has imposed quality standards based on existing [3] with regulated parameters including Sulfur Dioxide (SO2), Carbon Monoxide (CO), Nitrogen Dioxide (NO2), Oxidants (O3), Hydro Carbon (HC), PM10, PM2, PM5, TSP (dust), Pb (Lead), Dust fall (dust falling). Kendal Industrial Estate is an industrial area located in Kendal Regency and is the location for this planning.

Kendal Industrial Estate has carried out technical controls regarding air pollution, but no specific rules limit how much control effort is needed. Meanwhile, air pollution that occurs is not only the responsibility of the developer but also related industries, government, and academia. Formulating a strategy and policy pattern for controlling air pollution in industrial areas is needed to create an environmentally sound and sustainable industrial area. It is hoped that industrial actors in an industrial area can improve environmental, economic, and social performance through efforts to minimize environmental impacts and produce products that have competitive advantages in the market. Using the IPPS and Box model, this study analyses emission inventory and designs a proposed strategy for parties located in the Kendal Industrial Estate. IPPS is a method to calculate the emission load inventory using
the number of workers and type of industry; meanwhile, the Box Model Method was developed to calculate air quality capacity to regulate the number of industries in Kendal Industrial Estate.

2. Methodology
This research was conducted to determine the source of pollutants, the distribution of pollutants in the Kendal Industrial Area, and the largest party contributing to air pollutants in the Kendal Industrial Area. Secondly, to choose an effective strategy in reducing air pollution in the Kendal industrial area through calculating an inventory of emissions loads. Thirdly, to calculate the load capacity of air pollutants in the Kendal industrial area so that the number of industries that can be built in phases 2 and 3 is obtained. The coordinates location of Kendal Industrial Area is 1090 40' – 1100 18' ”E, and 60 32’ – 70 24’ ”S.

The air quality calculation in the Kendal Industrial Estate was carried out using secondary data, namely the Kendal Industrial Estate RKL RPL Document Report data. Meanwhile, the use of primary data in the form of sampling was not obtained due to the Covid-19 pandemic constraints. In September 2019, the Kendal Industrial Estate conducted ambient air sampling based on SNI 19-7119.6.2005. It was found that all measured air parameters had not passed the air quality standard threshold value. Strategy development covers industrial activities (stack emissions) and emissions from ongoing construction activities.

The emission load inventory calculation is carried out by calculating the IPPS based on [4] factors like the type of industry that has been built and will be built. It is continued with calculating the industrial area's capacity using the Box Model to compare the recommended air quality based on ambient air regulations with the emission load generated by the operational activities and development of 3 phases of the Kendal Industrial Area. Box Model is a model of air quality that uses a mathematical formulation of parameters that affect pollutants' concentration in the air, namely wind direction and speed, and altitude, to calculate the air pollutants' load capacity allowed into the air.

![Box model illustration](image)

**Figure 1.** Box model illustration

In addition to planning the number of industries, planning for air pollution control strategies is also carried out by looking at policies at both national and regional levels and the impact of air quality on workers and communities around industrial estates.

3. Results and discussion
The calculation of air pollutants' load capacity that is still allowed to enter the air in the Kendal Industrial Estate is carried out using the Box Model approach. By considering the emission load issued, wind speed, area expansion, and ambient air quality standards, the results of the capacity of phase 2 and 3 development of the Kendal industrial area are obtained, as shown in the table below.
Table 1. Load capacity calculation.

| Parameter | Load Capacity phase 2 | Load Capacity phase 3 |
|-----------|-----------------------|-----------------------|
| SO₂       | 10523,6954            | 12245,23              |
| NO₂       | 37089,1108            | 43114,49              |
| CO        | 3153224,995           | 3663727               |
| VOC       | 64174,0596            | 74768,13              |
| PM        | 59645,2385            | 69577,19              |
| TSP       | 34799,76675           | 40758,94              |

Considering the percentage of industrial development schemes that will be built, calculations are carried out based on a factor of 10 and 100 companies to be divided into each type of company contained in the scheme below. The increase in the number of industries also coincides with the expansion of the area for each phase. Development is expected to occur based on the type of industrial cluster area and not exceed the optimal number that can be built for each phase. Industry classification is based on issued by the Ministry of Industry and Trade [6].

Table 2. Total industry calculation.

| Industry                                      | total |
|-----------------------------------------------|-------|
| Automotive                                    | 1     |
| Educational                                   | 2     |
| Cement, Lime & Plaster                       | 16    |
| Office, Computing & Accounting Machinery      | 2     |
| Plastics Products, NEC                        | 5     |
| Plastics Products, NEC                        | 21    |
| Special Industrial Machinery & Equipment      | 3     |
| Manufacturing Industries, NEC                 | 15    |
| Furniture & Fixtures, Nonmetal                | 13    |
| Food Products, NEC                            | 19    |
| Textile, NEC                                  | 60    |
| Electrical Industrial Machinery               | 33    |
| Total                                         | 190   |

Figure 2. Industry planning Kendal Industrial Estate.
The public health impact analysis is carried out by calculating the Environmental Health Risk Analysis or commonly abbreviated as ARKL. According to WHO (2014), ARKL is a risk analysis as a process intended to calculate or predict the risk to a target organism, system, or sub-population, including identifying the uncertainties that accompany it [7]. After being exposed to a specific agent, with due observance of the characteristics attached to the cause (agent) of concern and the specific target system's characteristics, ARKL can be calculated using the risk quotient method [8]. The calculation of the Risk Quotient is used to calculate the impact of pollutants on industrial workers by considering the cancer influence factor according to the contaminant content. The calculation results can be seen in the following table:

| Parameter | Condition | RQ   | Parameter | Condition | RQ   |
|-----------|-----------|------|-----------|-----------|------|
| SO₂       | Build (phase 1) | 0.224967 | VOC       | Build (phase 1) | 0.001437 |
|           | Phase 1   | 0.249162 |           | Phase 1   | 0.696865 |
|           | Phase 2   | 0.257611 |           | Phase 2   | 0.939714 |
|           | Phase 3   | 0.256834 |           | Phase 3   | 0.917377 |
| NO₂       | Build (phase 1) | 0.037247 | PM        | Build (phase 1) | 0.000219 |
|           | Phase 1   | 0.054922 |           | Phase 1   | 0.106221 |
|           | Phase 2   | 0.061094 |           | Phase 2   | 0.143238 |
|           | Phase 3   | 0.060526 |           | Phase 3   | 0.139833 |
| CO        | Build (phase 1) | 4.284166 | TSP       | Build (phase 1) | 0.000381 |
|           | Phase 1   | 4.286796 |           | Phase 1   | 0.184669 |
|           | Phase 2   | 4.287714 |           | Phase 2   | 0.249024 |
|           | Phase 3   | 4.287630 |           | Phase 3   | 0.243105 |

After two analyses were carried out, through the calculation of the projected capacity for the planning of the number and type of industry as well as the analysis of environmental health risks, it was found that the hypothesis was proven, as evidenced by the value of the emission load that exceeds the carrying capacity and the Risk Quotient value, there are parameters that exceed RQ = 1, so a pollution control strategy is needed air because industrial activities and activities that support it have an impact on
surrounding pollution. Although, the weather condition uncertainty in Indonesia has become a challenge because the increased of carbon emissions are alleged as one of the causes of accelerating climate change [9,10].

4. Conclusion

Based on the results of the study and discussion in this study, several conclusions were obtained, namely: planning for the number of industries built in phases 1, 2, and 3 can only amount to 118, 70, and 100 industries with TSP and PM parameters almost exceeding their capacity. Industrial chimney emission control technology such as filter fabric is needed, with filtering considerations focusing on large particles, using energy that is not too large and not causing other pollution impacts. An industrial cluster based on type is needed so that air pollution control can be focused based on the largest emission of a type of industry.

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