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AIR POLLUTANT EMISSIONS IN BATAM: AN OVERVIEW

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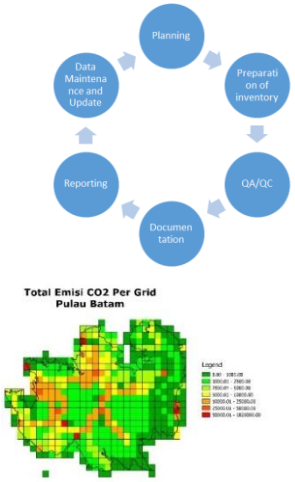
Graphical abstract



Abstract

This paper aims at providing high quality air pollutant emissions analysis, so that policy makers have reliable information in shaping environmental priorities. The study was conducted in Batam, a special economic zone that is packed by industries.Emissions of NO_x, CO, SO_x, PM_{10}, and HC were estimated using the 2013 EMEP/EEA methods and those of CO_x were estimated using the 2006 Intergovernmental Panel on Climate Change (IPCC) guidelines, both were tier 2 methods where applicable. We found that powerplants, large-scale heavy industrymetals and mobile sources were important emission sources, while area sources such ashotels, hospitals, restaurants, universities, banks, malls, vehicle repairs, housings, gas stations, facilities under constructions, landfills, and electronics manufacturing companiescontributed much less significant to the total emissions. By mapping all sources, we found that the air pollution sources densely populated along the main streets. Conclusively, this paper recommends some measures to improve the overall air quality in Batam.

Keywords: Emissions inventory, air pollutant, air quality, batam, geographical information system (gis)

1.0 INTRODUCTION

Emissions Inventory is a comprehensive data recording of the load-source emissions of air pollution sources in some region for a certain period of time. In other words, Emissions Inventory is an action to carry out the management and analysis of emissions data in order to obtain quantitative information on the emission of an area. The end result of the Emissions Inventory is a database that contains all the estimated amount of air pollutant emissions that emitted into the atmosphere. In the application of good air quality management, Emissions Inventory and air quality monitoring data are the minimum information needed by decision makers, such as municipalities of Batam, to assess the air quality status of a city.

Batam city is one of six cities in Indonesia, which was selected by the Ministry of Environment of the Republic of Indonesia to organize Emissions Inventory activities in the year 2013. This activity is needed by Batam Municipaliy and the Government of Indonesia in determining the reference for air quality management policy. The purposes of Batam Emissions Inventory are: Calculating the burden of emissions of air pollutants in the city of Batam, Provide information that can be the starting point for the stakeholder of Batam city in the determination of air ambient quality status of Batam, and helping the decision-makers in determining the direction of Batam pollution control policy for the largest load-source emissions of air pollution sources.

This Paper is organized as follows: in the next section, a brief introduction of research methodology used in preparing the emissions inventory of Batam city will be presented. In section III, the result of estimated calculation of the Batam Emissions

Inventory will be presented and the final section will discuss the conclusions.

2.0 EXPERIMENTAL

2.1 Methodology

In a simple matter, emissions inventory is an activity to determine the sources of air pollutants, what comes out of the air pollutant sources and how much they emitted. The methodology used in this researchis as listed in figure 1 below:

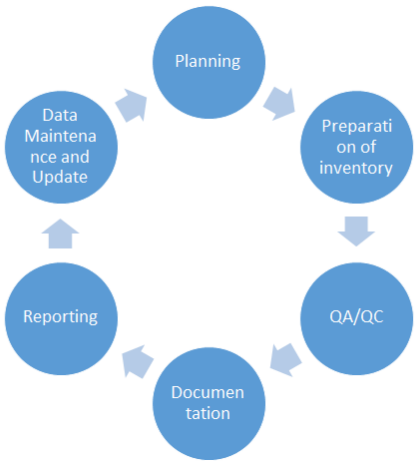


Figure 1 Research methodology for Batam Emissions Inventory

The emissions inventory processconsists of six parts, namely:

a. Planning
   The planning process is the translation of the objectives and procedures that covering categories of pollutants that will be inventoried, identification of pollution sources, and data reporting. The purpose of the planning process is to ensure that any action should be taken in preparing the emissions inventory.
b. Inventory Process
   This activity is a key part of the emission inventory process, namely the collection of data and calculation of emissions. Estimation methods and approaches used should be the most accurate and representative method that associated with the availabledata.
c. Quality Assurance/Quality Control (QA/QC)
   The QA/QC process is very important in the emissions inventory activity, in order to obtain reliable results. Without QA/QC during the emission inventory process, mistakes can occur and that will disrupt the entire inventory process.
d. Documentation
   The complete and well organized documentation is important so that the emission inventory process can be justified. The purpose of this documentation is to ensure that the compilation of all data indicates that the process is carried out accurately.
e. Reporting
   Reporting on the emission inventory activity includesthe explanations about the data that have been collected, processed, and analyzed.
f. Data Maintenance and Update
   Emission inventory activity is a continuous process. Maintenance and updating data of the inventories that compiled after the first time will ensure its use in the years to come.

2.2 Scope Of Works

The scope of work of this Emission Inventory activity is to identify pollution sources that located in the main administrative area of Batam Island. Emission sources will describe the unique characteristic of Batam Island which is occupied with industrial activity. Batam city has an area of approximately 1647.83 km2, consisting of 1035.30Km2ocean and 612.53 Km2inland. The number of islands that included in the administrative area of municipality of Batam are totaled 186 units, most of which are uninhabited. To simplify the scope of work, the main focus of this research will be Batammainland only, excluding small islands that are around Batam, such as Rempang and Galangislands. To display the location of emission sources that are more accurate, this study will present the results of the inventory in the format of spatial mapsor Geographical Information System (GIS). Spatial presentation will divide the Batam Island into the areaof 1km x 1km grid, with the total amounting to 830 grids.

The data used in this Emission Inventory are the data of the year 2012. In its execution, the absence or inadequacy of existing secondary data will be complemented through a primary survey by a team of emission inventories. Emission inventories provide emission rate data that's based on the assumption of annual emissions in 2012 and not represent the actual emissions that occur in minutes, hours, days, or weekly on each activity.

The inventoried emissions sources are grouped into three main classes based on the emission source: the first is Point source: individual source with large emission; the second is Area source: individual source with smallemissions, but collectively will produce large emission; and the last is Mobile sources: resources that move from one place to another place, e.g. Transportations (Road, Sea and Air). From the early identification of emission sources, the results obtained by grouping the emission sources areas follows:

a. Point source: industries (power plants, heavy industries, electronicmanufacturing, plastic and chemistry, and other industries); hospital; university; bank; hotel; shopping mall;
b. Area source : housing, gas station, landfills, facilities under construction
c. Mobile source : vehicle activity in the streets (road), ship activity in the port and airplane activity in the airport (non road).

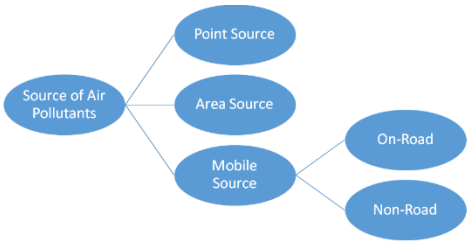


Figure 2 Source of air pollutants that will be inventoried

The parameter of pollutant emissionthat will be inventoried are: nitrogen oxides (NOx), sulfur oxides (SOx), Volatile Organic Compounds (VOC), 10 mm particulates (PM10), Carbon monoxide (CO) and carbon dioxide (CO2). Some of the above parameters have been observed in the ambient by the local environmentagencies (Badan Pengendalian Dampak Lingkungan (Bapedal) of Batam Municipality). The addition of VOC parameters is due to the negative impact on human health and can be a precursor of ozone in the troposphere. While monitoring the emissions of CO2are due to the major impact on global warming [13-15].

2.3 Emission Estimation Approach

There are several methods that can be used to calculate emissions of pollutant sources. However, because most of the emissions and activity data is not available and is not sufficiently detailed for each complicated methodology, then for the calculationswe used the general equation for estimating emissions using this formula:

$$E = A \times EF \quad (1)$$

Where:
E = emissions
A = activity rate: e.g. amount of fuel burnt, the amount of raw material processed or number of product units produced
EF = emission factor unit, e.g. kg particles per kg fuel burnt or g NOX per km driven

Emissions of NOx, CO, SOx, PM10, and HC were estimated using the 2013 EMEP/EEA methods and those of CO2 were estimated using the 2006 Intergovernmental Panel on Climate Change (IPCC) guidelines, both were tier 2 methods where applicable.

3.0 RESULTS AND DISCUSSION

Emissions inventory has identified potential emission sources in Batam, calculate the amount of air pollutant emissions (CO, NOx, SO2, PM10, HC) and Greenhouse Gas (CO2) emissions from these sources and their contribution to total emissions, and produce spatial distribution emission maps (GIS).

3.1 Emission Rates

A point source is divided into six categories, namely industrial and power plants, hospitals, universities, banks, hotels, and malls. Data were collected from primary data in the form of surveys and questionnaires and secondary data obtained from the data Proper, UKL / UPL, and data APDL (BAPEDAL Batam). Table 1 below shows the resume of emission rate from a point source successfully estimated the emissions based on data capacity, fuel consumption, type of fuel, type of emission sources, etc:

Table 1 Emission rates for point source in Batam, 2012 (ton/year)

Point Source	NOx	CO	PM10	SOx	HC	CO2
Industries and Power Plants	6.598,58	984,27	203,21	4.354,70	2.505,89	3.450.047,02
Hospital	0,27	0,08	0,00	0,01	0,01	24,52
University	0,65	0,19	0,01	0,23	0,02	52,23
Bank	0,82	0,22	0,01	0,21	0,02	41,75
Hotel	20,30	6,71	0,34	21,29	0,62	3.142,02
Shopping Mall	2,42	0,83	0,04	0,07	0,07	380,89
Total	6.623,03	992,28	203,62	4.376,51	2.506,63	3.453.688,43

Power plants and large-scale industries from the metal and the heavy industrial sector arethe important emission source. Other point sources of emissions, such as: hotels, hospitals, food industries, colleges, banks, shopping malls, packing cement industries, electronics assembly industries, contributing much smaller (not significant)to the total emission compared to the metal and heavy industry as well as power plants.

The area source is divided into 5 categories: Gas Station, Household (using LPG), vehicle repair, landfills (TPA Punggur) and construction project. Table 2 below shows some of the source areas are successfully estimated:

Table 2 Emission rates for area source in Batam, 2012 (ton/year)

Area Source	NOx	CO	SO2	HC	PM10	CO2
Gas Station	0.00	0.00	0.00	444.38	0.00	0.00
Housing (LPG)	0.35	0.18	0.00	0.01	0.01	368.39
Vehicle repairs	0.00	0.00	0.00	10.52	0.00	0.00
Landfills	0.00	0.00	0.00	22.60	0.00	0.0
Facilities Under construction	0.00	0.00	0.00	0.00	1.98	0.0
TOTAL	0.35	0.18	0.00	477.52	1.99	368.

Overall the area source emissions do not contribute significantly to the total emissions in the city of Batam. Vehicle repair, housing, gas stations, facilities under construction and landfills (TPA Punggur) emissions impact is very small (less than 2%) compared with the mobile emission sources and emissions from industrial point. Domestic waste is an important source of Greenhouse Gas (GHG) emissions, but the emissions inventory of air pollutants, the parameters considered were the HC and the amount is not significant.

Mobile source is a source that is associated with the movement of people with the potential of causing air pollution or emissions. In general,mobile source is divided into two, namely on-road and non-road. Source of on-road emissions associated with highway traffic while non road can also be defined as a non-highway emission source (ports and airports). Table 3 below shows the emission rate of the mobile source emissionthat successfully estimated:

Table 3 Emission rates for mobile source in Batam, 2012 (ton/year)

Mobile Source	NOx	SOx	HC	PM10	CO	CO2
Road	1.466,71	66,19	13.252,53	156,07	25.177,23	466.775,56
Airport	116,24	1,82	10,32	1,06	163,79	35.433,77
Port	680,81	10,90	33,80	44,47	112,06	1.069.335,44
Total	2.263,76	78,92	13.296,65	201,60	25.453,09	1.571.544,77

A significant contributor to mobile source emissions is road transportation and marine transportation, where land transport is the largest contributor to emissions to 5 parameters (NOx, CO, PM10, SOx and HC), while the largest contributor of CO2 emissions is the transportation by sea. These are the resume of the road transport emissions (3rd largest):

1. NOx: cars (30.38%), bus (27.72%), HDV (20.12%)
2. SOx: motorcycle (41.04%), car (36.9%), bus (10.87%)
3. HC: motorcycle (96.99%), cars (2.44%), LDV (0.27%))
4. PM10: cars (58.33%), motorcycles (22.95%), bus (8,04%)
5. CO: motor (89.33%), cars (8.54%), LDV (1.54%)
6. CO2: motor (47.15%), car (36.3%), bus (7.9%)

If the three emission sources are combined, the obtained emission profile of Batam city, as seen in Table 4 below:

Table 4 Total Emission Rate in Batam, 2012 (ton/year)

Source	NOx	CO	PM10	SOx	HC	CO2
Point	6.623,03	992,28	203,62	4.376,51	2.506,63	3.453.688,43
Area	0,35	0,18	1,99	0,00	477,52	368,39
Mobile	2.263,76	25.453,09	201,60	78,92	13.296,65	1.571.544,77
Total	8.887,14	26.445,54	407,21	4.455,43	16.280,79	5.025.601,58

From the aforementioned tables we can conclude the following:

- Source emissions that contribute significantly are point source (power plants and large-scale industries from heavy industrial sector and metals) as well as mobile sources.
- Area source and other point source (hotels, hospitals, food industry, colleges, banks, malls, and electronics assembly) contribute much smaller (not significant) to the total emission.
- A significant contributor to emissions in Batam Island at a mobile source is land transportation (road) and marine transportation (port).

3.2 Geographical Information System (Gis)

In addition, in this research, a spatial map of each pollutant also produced in grid cells (1 km x 1 km) that covers all Batam island. This spatial distribution map of different pollutants is created by linking the Emission Inventory data in Excel format to GIS software. Contribution of point sources, area sources and mobile sources in each grid cell are summed and the total emissions of each grid will be obtained. Figure 3 displays total emission of NOx, figure 4 displays total emission ofSOx, figure 5 displays total emission for HC, figure 6 displays total emission for PM10, figure 7 displays total emission of CO and figure 8 displays total emission of CO2 respectively.

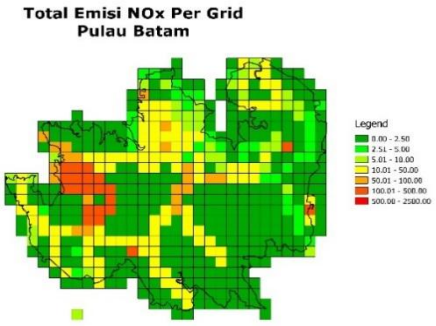


Figure 3 Total Emission Rates for Nox per grid in Batam, 2012

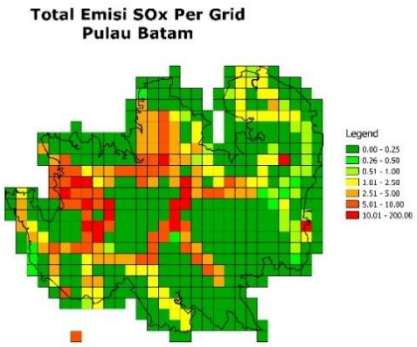


Figure 4 Total Emission Rates for SOx per grid in Batam, 2012

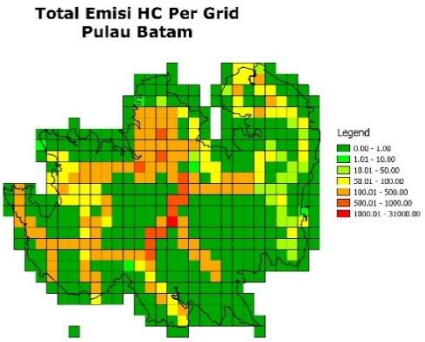


Figure 5 Total Emission Rates for HC per grid in Batam, 2012

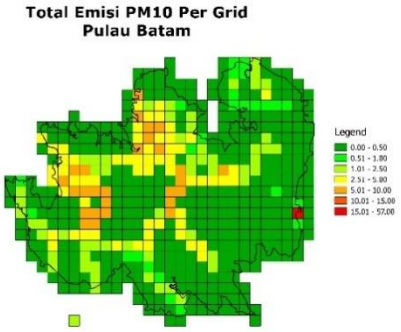


Figure 6 Total Emission Rates for PM10 per grid in Batam, 2012

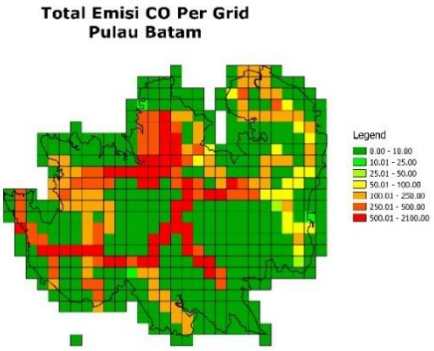


Figure 7 Total Emission Rates for CO per grid in Batam, 2012

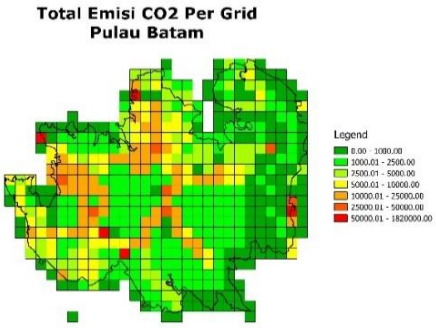


Figure 8 Total emission rates for CO2 per grid in Batam, 2012

Emissions inventory has succesfully identified the potential emission sources in Batam, and then determines the amount of air pollutant emissions (CO, NOx, SO2, PM10, HC) and GHG (CO2) emissions from these sources and their contribution to total emissions, and also creating the spatial distribution of emissions maps (GIS). Emission inventory of air pollutants in the city of Batam can be compared to other cities in Indonesia if they use the same methodology.

The activity data of air pollutant emissionssources is equal to the GHG emissions activity data, so in the future, it can be used to compile an inventory of GHG emissions. For an inventory of GHG emissions, should be added to other emission sources that are not included in the emission sources of air pollutants, namely liquid waste and the changing of the land use (open green space).

Emission inventory and air quality monitoring are complementary. Air quality monitoring can determine what contaminants have exceeded the ambient air quality standards, while through an emissions inventory of emission sources can be known what contributes greatly to the critical pollutant emissions.

4.0 CONCLUSION

Based on the results obtained from emission inventory, these are some recommendations that can be given :

- The policymakers in Batam should focus on controlling the biggest emission sources of pollution, namely industry and land or marine transportation.
- The high activity of the industry as a major driver of the economy in Batam, needs to be balanced with the increased awareness of the environmental burden caused by, including the impact of the emission load.
- Consideration should be given to the power plants that provide the greatest emissions

impact, to switch to a fuel that is more environmentally friendly.

- The high number of ownership and the use of private vehicles in Batam, would be linear with a high burden of emissions generated. So it is urgent to provide reliable and convenient public transport for residents of Batam city to reduce the activity by private vehicle. So that the load of emissions can be lowered.
- Keep an emission inventory continued to closely monitor the changes of the emissions in Batam and also building a database and statictical system so that a more accurate emission inventories can be created. and also, air pollutant emissions inventoryintegrated with GHG emissions can be created, because they use the same activity data.
- Continuing of air quality monitoring by the method of passive and/or continuous will complement an emissions inventory process, and using that data, the decissionmaker of Batam can make a good policy on the environment.

Acknowledgement

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References

[1] Erupean Environment Agency. 2013. *EMEP/EEA Air Pollutant Emission Inventory Guide Book*. Luxembourg : Publication Office of the European Union.

[2] Erupean Environment Agency. 2009. *EMEP/EEA Air Pollutant Emission Inventory Guide Book*. Luxembourg : Publication Office of the European Union.

[3] IPCC .2006. *IPCC Guidelines for National Greenhouse Gas Inventories*. Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

[4] P. Krittayakasem, S. Patumsawad, and S. Garivait. 2011. Emission Inventory of Electricity Generation in Thailand. *Journal of Sustainable Energy & Environment*. 2: 65-69.

[5] A. K. Varma, and M. Srimurali. 2014. Emission Inventory for Criteria Pollutants of a Thermal Power Plant. *J Civil Environ Eng*. 4:135.

[6] B. Zhao, P. Wang, J. Z. Ma, S. Zhu, A. Pozzer, and W. Li. 2012. A high-resolution emission inventory of primary pollutants for the Huabei region, China. *Atmos. Chem. Phys*. 12: 481-501.

[7] T. Oda and S. Maksyutov. 2011. A very high-resolution (1 km×1 km) global fossil fuel CO2 emission inventory derived using a point source database and satellite observations of nighttime lights. *Atmos. Chem. Phys*. 11: 543-556.

[8] M. A. Fagbeja, H. Jennifer, C. Tim, L. James, and A. Joseph. 2013. Residential-Source Emission Inventory for the Niger Delta - A Methodological Approach. *Journal of Sustainable Development*. ISSN 1913-9071.

[9] Y. SHI, Y. XIA, Bi-hong LU, Nan LIU, Lei ZHANG, Su-jing LI, and Wei LI. 2014. Emission inventory and trends of NOx for China, 2000–2020. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*. ISSN 1862-1775.

[10] H. Huo, Qiang Zhang, Kebin He, Zhiliang Yao, Xintong Wang, Bo Zheng, David G.Streets, Qidong Wang, and Yan Ding. 2011. Modeling vehicle emissions in different types of Chinese cities: Importance of vehicle fleet and local features. *Environmental Pollution* 159: 2954-2960.

[11] P. Gargava, C. Judith. Chow, G. John. Watson, Douglas and H. Lowenthal. 2014. Speciated PM10Emission Inventory for Delhi, India. *Aerosol and Air Quality Research*, 14: 1515–1526.

[12] M. I. Qureshi, N. U. Khan, , A. M. Rasli, and K. Zaman. 2015. The battle of health with environmental evils of Asian countries: promises to keep.Environmental Science and Pollution Research. 1-8.

[13] M. I., Qureshi, A. M. Rasli, U. Awan, J. Ma. G. Ali, A. Alam. and K. Zaman. 2014. Environment and air pollution: health services bequeath to grotesque Menace. Environmental Science And Pollution Research. 22(5): 3467-3476