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# AIR POLLUTION DISPERSION MODELING IN PORT AREAS

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## Abstract

For the last couple of decades, environmental protection awareness within port areas is gaining ever more importance. Ports can have a tremendous impact on the environment, especially in terms of air pollution. The main pollution sources are various port activities such as road and rail traffic, cargo handling and marine vessel operations. Air quality models can be of great help in estimating the effect on the ambient air quality from one or more sources emitting pollutants to the atmosphere. One of those models is the widely used Gaussian Plume dispersion approach. Based on existing measurements and port activity data, models can simulate the dispersion of air pollutants caused by activities and operations taking place within the port. By using historical data, they can simulate the current state of the air quality in the port and with the help of weather predictions simulate possible future situation. Simulations can assist the port manager/operator in the decision-making process in order to optimize various activities within the port and minimize their impact on the environment. One of the main objectives of the Horizon 2020 Project PIXEL (Port IoT for environmental leverage) is the deployment of environmental pollution models which can aid in the decision-making processes within the port domain. This paper reviews the current advances in the field of air pollution modelling with a special emphasis on port scenarios.


## 1. Introduction

Due to the growth of the international trade, economic activity and transport of goods through ports have been steadily increasing and are likely to continue to do so in the future [1]. Such development also has some negative side effects like: vehicle emissions, air pollution from port and ship operations, noise and light pollution., contamination of water and soil, hazardous waste generation and traffic congestion. Being close to urban areas ports as well have an impact on the inhabitants in the area. Some of the health risks include respiratory diseases, cancer, cardiovascular disease, bronchitis and premature mortality [1]. Therefore, environmental protection is of great importance in port areas. Several initiatives like EcoPorts and Green Marine were established to make ports more environmentally sustainable and to raise awareness on environmental protection. In the EcoPorts 2018 report, (*Table 1*) a trend of increasing priority of clean air and energy consumption can be observed [2].

Table 1 Ports' environmental priorities [2]

| Top 10 environmental priorities in participating ports | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **1996** | **2004** | **2009** | **2013** | **2016** | **2017** | **2018** |
| **1.** | Port development (water) | Garbage/ Port waste | Noise | Air quality | Air quality | Air quality | Air quality |
| **2.** | Water quality | Dredging operations | Air quality | Garbage/ Port waste | Energy consumption | Energy consumption | Energy consumption |
| **3.** | Dredging disposal | Dredging disposal | Garbage/ Port waste | Energy consumption | Noise | Noise | Noise |
| **4.** | Dredging operations | Dust | Dredging operations | Noise | Relationship with the community | Water quality | Relationship with the community |
| **5.** | Dust | Noise | Dredging disposal | Ship waste | Garbage/ Port waste | Dredging operations | Ship waste |
| **6.** | Port development (land) | Air quality | Relationship with the community | Relationship with the community | Ship waste | Garbage/ Port waste | Port development (land) |
| **7.** | Contaminated land | Hazardous cargo | Energy consumption | Dredging operations | Port development (land) | Port development (land) | Climate change |
| **8.** | Habitat loss/ degradation | Bunkering | Dust | Dust | Water quality | | Water quality |
| **9.** | Traffic volume | Port development (land) | Port development (water) | Port development (land) | Dust | Ship waste | Dredging operations |
| **10.** | Industrial effluent | Ship discharge (bilge) | Port development (land) | Water quality | Dredging operations | Climate change | Garbage/ Port waste |

## 2. Air pollution sources in seaports

Port operations such as on-site fuel combustion, ship emissions, logistic activities of dredging and bunkering result in air emissions. The main air pollutants related to port activities include Particulate matter (PM), diesel exhaust, Carbon monoxide (CO), Carbon dioxide ($CO_2$), Sulphur dioxide ($SO_2$), Nitrogen oxides ($NO_X$) and volatile organic compounds (VOCs). Other air pollutants hazardous to the environment and health are heavy metals, dioxins and formaldehyde, (*Table 2*)[3,4].

Table 2 Air pollution sources in seaports and their negative environmental effects [3,4]

| Source | Pollutants | Effects | |
|---|---|---|---|
| Dry bulk | Sulphur dioxide ($SO_2$), Hydro carbons (HCs), Particulate matters ($PM_{10}$, $PM_{2.5}$), Lead (Pb), Nitrogen oxides ($NO_x$), volatile organic compounds (VOCs) Ozone ($O_3$), Hydrogen fluoride (HF), Carbon monoxide (CO), Hydrogen fluoride (HF), Heavy metals (e.g. Hg, Pb, Cd etc.) | Human Health (acute and chronic) | Local, Regional and Global |
| Liquid bulk | | | |
| General cargo | | | |
| Cargo handling storage | | Ecosystem (acute and chronic) | Local, Regional and Global |
| Vehicle and equipment maintenance | | | |
| Users Handling and storage of chemicals (non-bulk) | | Greenhouse gas emission | Global |
| Fueling and bunkering | | Acid rain | Global |
| Building and open area maintenance | | | |
| Transshipment (Ro-Ro, Passenger, Container, …) | | Stratospheric ozone depletion | Global |
| Ship movement | | Long-range transport | Global |
| Maintenance dredging & disposal | | | |
| Towing | | | |
| Mooring | | | |

## 3. Air dispersion modeling

Air pollution modeling is used to predict the way pollutants behave in the ambient atmosphere. They are mathematical simulations of the chemistry and physics governing the transformation, transport and dispersion of pollutants in the atmosphere. These simulations show the environmental impact under different weather conditions, emission rates and development scenarios. There are two main groups of air dispersion models available today: Gaussian-plume models (AERMOD, AUSPLUME, ISCST3 ) and advanced models (CALPUFF) which is a non- steady state air quality and meteorological modeling system.

For any model to work and produce reliable results it is crucial to acquire the needed data sets. Information needed to calculate pollutants concertation downwind of a source are [5]:

1. **Meteorological data** - ground-level concentrations caused by the constant discharge of pollutants change depending on the current weather conditions.
2. **Emission inventory** - a comprehensive list of pollutants emitted from all sources in a geographic area over a specified period.
3. **Local topography** - upwind terrain can influence turbulence characteristics and wind flow can have a considerable impact on the transport of pollutants in the ambient air.
4. **Building and obstacle locations** – the building downwash effect which occurs when the wind flows around and over buildings affects plume rise and the dispersion of pollutants in the atmosphere.

## 4. Quantifying air emissions and air dispersion modeling in seaports

Air emissions in seaports are generated at different locations of the terminal as a product of different operations, i.e. energy consumption from cargo handling machinery. To successfully model air pollution a comprehensive emission inventory is needed and its necessary to determine which type of emission source the polluting port operations and activity include. One way of classifying types of emission sources is shown in *Table 3* [6].

Table 3 Air emission source categorization in seaports [6]

| **Emission source** | **Source Type** |
|---|---|
| Ships (Harbor Transit) | Volume |
| Ships (At Berth - Auxiliary Engines) | Volume |
| Ships (Turning and Docking Near Berth) | Volume |
| Ships (At Berth - Auxiliary Engines) | Point |
| Ships (At Berth – Boilers) | Point |
| Ships (At Anchorage) | Area |
| Tugboats | Volume |
| Locomotives | Point |
| Cargo Handling Equipment | Area |
| Trucks | Point |
| Worker Vehicles | Point |

Such emission inventory requires detailed information on the characteristics and activities of vessels and land equipment, as well as detailed information on the geography of the port and the ship routes within the port. The main three air pollution sources are: vessels, cargo handling equipment and vehicles.

**Ocean going vessels (OGVs)**

Air emissions from ships in a seaport depend on the size and type of the ship and the specificity of the energy system. A method for calculating total emissions from seagoing ships uses energy-based emission factors is shown in Eq. 1 [7].

$$TE = P \times LF \times A \times EF \qquad (1)$$

TE = total emission [g]; P = maximum continuous power rating [kW]; LF = load factor [%]; A = activity [h]; EF = emission factor [g/kWh].

$$LF = \left(\frac{AS}{MS}\right)^3 \qquad (2)$$

LF = load factor [%]; AS = actual speed [m/s]; MS = maximum speed [m/s]

**Cargo-handling equipment (CHE)**

Cargo handling equipment can be considered as numerous point sources in container handling areas. When modeling such activities, they are classified as area pollution sources. Besides determining the type of pollution source, it is also necessary to quantify emissions from them. Total emission can be calculated with the following equation: [7].

$$TE = N \times P \times LF \times A \times EF \qquad (3)$$

TE = emissions [g]; N = number of items; P = maximum continuous power rating [kW]; LF = load factor [%]; A = activity [h]; EF = emission factor [g/kWh]

## Conclusion

Ports are rapidly developing information and economical hubs with adverse side effect on the environment and human health. Those negative side effects are consequences of exhausts of particles, $SO_2$, $NO_X$ and $CO_2$ emissions from cargo handling equipment, ships' main and auxiliary engine noise, dust from handling cargo and pollutant emissions from ship engines and machinery used in port areas, making air dispersion of pollutants in ports is one of the biggest concerns both on the local and global scale. air pollution modelling methods and resulting simulations can assist in optimizing various activities within the port and minimize their impact on the environment. For successful model runs it is important to have reliable meteorological and terrain data, a comprehensive emission inventory which includes source type and location and data on buildings and their locations.

## Literature

[1] Bailey, Diane, and Gina Solomon. "Pollution prevention at ports: clearing the air." *Environmental impact assessment review* 24.7-8 (2004): 749-774.

[2] ESPO (European Sea Ports Organisation), ESPO/EcoPorts Port Environmental Report 2018, 2018.

[3] Srivastava, Anjali, and B. Padma S. Rao. "Urban air pollution modeling." *Air Quality-Models and Applications* (2011): 364.

[4] Darbra, R. M., et al. "A procedure for identifying significant environmental aspects in sea ports." *Marine pollution bulletin* 50.8 (2005): 866-874.

[5] National Institute of Water and Atmospheric Research, Aurora Pacific Limited and Earth Tech Incorporated. "Good Practice Guide for Atmospheric Dispersion Modelling" (2004)

[6] Port of Los Angeles "Appendix B2- Criteria Pollutant Modeling", 2017

[7] Ho Quoc Bang and Vu Hoang Ngoc Khue." Air Emission Inventory" *Air Pollution - Monitoring, Quantification and Removal of Gases and Particles* (2018)

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