Study on the Inventory of Air Pollutants in Ports of Beijing-Tianjin-Hebei Region

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Abstract. According to the 2014 national transportation statistics compilation, the throughput and port machinery classification data of the port-based cargo types in the Beijing-Tianjin-Hebei region in 2014 were obtained. Based on the relevant research results, the calculation methods and related parameters of port heavy trucks, other port machinery, unorganized emissions of particulate matter, and unorganized emissions of VOCs were determined. To calculate the list of atmospheric pollutants in the Beijing-Tianjin-Hebei regional port in 2014, the emissions of SO2, NOx, PM10, PM2.5, VOCs and CO from Tianjin Port, Qinhuangdao Port, Huanghua Port and Tangshan Port were 260.6t, 3784.5t, 2524.1t, 2376.4t, 986.6t and 3068.9t respectively. Combined with the overall planning and layout plan of the Beijing-Tianjin-Hebei Port, the GIS technology was used to grid the inventory data to obtain a spatialized list with a resolution of 3km×3km. To further study the differences in emissions of different pollutants in different ports and the distribution of air pollutant emissions in the port to laid a scientific data foundation.

1. Introduction
China was an important port country in the world. The cargo turnover accounted for eight of the world's top ten ports and has nearly 170,000 water transport vessels. The Beijing-Tianjin-Hebei region, the Yangtze River Delta and the Pearl River Delta region, which were key areas for air pollution prevention and control in China, were also dense areas for port operations. The effects of air pollution caused by ships and ports cannot be ignored.

In August and December 2015, the Ministry of Transport issued the “Special Action Plan for Marine Pollution Prevention and Control (2015-2020)” to implement the Pearl River Delta Ship Emission Control Zone in the Yangtze River Delta and the Bohai Sea (Beijing-Tianjin-Hebei) waters. The plan proposes a series of port and ship control requirements for three key areas of establishing a ship's air pollutant emission control zone in waters such as Beijing, Tianjin and Hebei. In this way, the emission of sulfur oxides, nitrogen oxides and particulate matter from Chinese ships was controlled to improve the ambient air quality in China's coastal areas and riverside areas, especially port cities, laying the foundation for comprehensive control of atmospheric pollution.

Therefore, obtaining detailed, reliable and comprehensive port emission inventories and scientifically analyzing their pollution characteristics were the needs of environmental management and pollution control decision-making in the transportation industry, and provided an important basis for improving port air pollution control technology policies. To defend the country in the next stage, the Ministry of Transport successfully implemented the port air pollution control target.
2. Types of air pollutant emissions and port machinery classification
Port air pollutant emissions mainly included: \( \text{BO}_2, \text{NO}_x, \text{PM10}, \text{PM2.5}, \text{VOCs}, \text{CO} \) emissions from port operations machinery; \( \text{PM10} \) and \( \text{PM2.5} \) generated from unorganized emissions from bulk yards; and \( \text{VOCs} \) from unorganized emissions from oil depots.

According to the statistical caliber compiled by the national transportation statistics, the port machinery could be divided into the following types, as shown in Table 1.

| Mechanical type          | Inclusion category                                                                 |
|--------------------------|-----------------------------------------------------------------------------------|
| Heavy duty truck         | Container transport semi-trailer, container tractor                                |
| Hoisting Machinery       | Wheeled crane                                                                      |
| Conveying machinery      | Belt conveyor                                                                      |
| Loading and unloading    | Dock special tractor, front hoist loader, small forklift                           |
| Non-production machinery | Bus                                                                               |

3. Beijing-Tianjin-Hebei port activity level and pollutant emission factors
According to the 2014 National Traffic Statistics Collection\(^1\), the port throughput and port machinery holdings data of the Beijing-Tianjin-Hebei region in 2014 were shown in Tables 2 and 3.

### Table 2. Port cargo throughput in BTH region in 2014

| Port   | Total throughput (10000 tons) | Coal and products | Oil, natural gas and products | Crude oil | Metal ore | Mining materials | Non-metallic ore |
|--------|-----------------------------|-------------------|-------------------------------|-----------|----------|------------------|-----------------|
| Qinhuangdao | 27403                       | 23964             | 7669                          | 6810      | 6092     | 1986             | 507             |
| Huang Wei    | 17551                       | 140564            | 2219                          | 2209      | 26140    | 852              | 1225            |
| Tangshan         | 50075                       | 178052            | 14978                         | 12383     | 212472   | 18738            | 2123            |
| Tianjin         | 54002                       | 107790            | 52561                         | 44556     | 117700   | 34908            | 2270            |

### Table 3. Port mechanical classification in BTH region in 2014

| Port   | Hoisting Machinery | Conveying machinery | Loading and unloading machinery | Number of non-production machinery |
|--------|--------------------|----------------------|---------------------------------|-----------------------------------|
| Qinhuangdao | 115                | 243                  | 435                             | 445                               |
| Huang Wei    | 46                 | 118                  | 84                              | 0                                 |
| Tangshan         | 258                | 128                  | 232                             | 14                                |
| Tianjin         | 464                | 125                  | 1886                            | 492                               |

3.1. Port heavy truck
The port method for the discharge of pollutants from heavy trucks in the port used the flow method. The specific idea was to estimate the number of heavy-duty trucks entering and leaving the port based on the port cargo throughput. The estimation method was based on the “Study on Air Pollution Emission Characteristics and Control Countermeasures in Shenzhen Seaport Area”\(^2\). The estimated formula for the entry and exit of heavy trucks were as follows:

\[
T = \frac{G \times A \times P \times 2}{2}
\]

\( G \) - the annual cargo throughput; \( A \) - the weight of each heavy-duty truck, which is 30 tons; \( P \) - the proportion of road transportation, which is 25%. The formula for estimating atmospheric pollutant emissions is as follow:

\[
E_p = T \times M \times EF_p
\]

\( P \) - type of pollutants; \( EP \) - pollutant emissions from heavy truck pollutant types; \( T \) - heavy trucks entering and leaving the port; \( M \) - average distance traveled by each heavy truck in the port area (3km for this study); \( EE_p \) - the emission factor of the type of pollutant.
Table 4. Emission factors of heavy trucks [2]

| Type of pollutant | Emission factor (g/km) |
|-------------------|------------------------|
| SO\(_2\)          | 0.08                   |
| NO\(_x\)          | 13.52                  |
| CO\(_2\)          | 7.29                   |
| PM\(_{10}\)       | 0.263                  |
| PM\(_{2.5}\)      | 0.25                   |
| VOC\(_s\)         | 1.6                    |

According to Table 2 and Equation 1, calculate the inflow and outflow of heavy trucks in the port in Beijing-Tianjin-Hebei region in 2014, as shown in Table 5.

Table 5. Inbound and outbound traffic of heavy trucks in BTH port in 2014

| Port            | Heavy truck inbound and outbound traffic (times) |
|-----------------|-----------------------------------------------|
| Qinhuangdao     | 4567199                                       |
| Huang Wei       | 2925187                                       |
| Tangshan        | 8345894                                       |
| Tianjin         | 9000398                                       |

3.2. Other port operations machinery

Emissions from port machinery other than heavy trucks were studied in this section. The SO\(_2\) emissions of other port operations machinery were calculated according to the fuel consumption method, and the calculation method was as follows:

\[
E = \sum P_i \times A_i \times CF_i \times EF_i \times 10^{-6}
\]

among them, \(CF_i = 0.12 \times G_i \times LF_i\).

E-port machinery SO\(_2\) annual emissions (tons/year), \(P_i\)-i-type machinery holdings, \(A_i\)-year activity levels (h), \(CF_i\)-class i mechanical average hourly fuel consumption (kg/h), \(EF_i\)-i-type i port operating machinery emission factor (g / kg), \(i\) is the port operating machinery type. The average hourly fuel consumption per unit of rated power \(CF_i\) considers the power and load factor of the port operation machinery. According to Li Dongling's related research [3], the coefficient is 0.12kg/h/kw, and \(G_i\) is the i-type port. The average rated power (kw) of the machine and the average load factor of \(LF_i\) are shown in Table 6.

Table 6. Average hourly fuel consumption of other port machinery (kg/h)

| Mechanical type          | Average hourly fuel consumption rate |
|--------------------------|--------------------------------------|
| Hoisting Machinery      | 10.608                               |
| Conveying machinery     | 0.9945                               |
| Loading and unloading    | 12.3981                              |
| Non-production machinery | 5.8344                               |

Table 7. Activity level of other port machinery in BTH port in 2014 (h/a)

| Port         | Annual activity level |
|--------------|-----------------------|
| Qinhuangdao  | 770                   |
| Huang Wei    | 493                   |
The NOx, PM10, PM2.5, VOCs, and CO emissions of other port machinery were calculated using the power method. Based on the NONROAD model developed by the US Environmental Protection Agency, the power method comprehensively considered the comprehensive factors such as engine power and annual activity level, and obtains the pollutant emissions of non-road machinery. The calculation formula was as follows:

$$E_j = \sum (P_i \times G_i \times A \times LF \times EF_{ij}) \times 10^{-6}$$

\(E_j\) pollutant emissions (t/year), \(P_i\) - i-type port machinery holdings (vehicles), \(G_i\) is the i-th port machinery rated power (kw), \(LF\) - port machinery Engine load factor, which is the ratio of the average practical power of the engine to the rated power, \(A\) - year activity level (h), \(EF_{ij}\) pollutant type i mechanical type emission factor (g/kw•h). Emission factors, load factors, and annual activity levels are also referenced in the recommended values in the Technical Guidelines for the Preparation of Non-Road Mobile Source Air Pollutant Emission Inventory (Trial) [5]. The annual activity level correction method is the same as the calculation method of SO2 emissions from port operations machinery. The emission factor refers to the national three-stage emission limit of Tier 3 in the technical guide.

3.3. Unorganized emissions of particulate matter

3.3.1. Working dust. The amount of dust in the port terminal was highly correlated with human factors, and it was difficult to determine a fixed calculation mode. Referring to He Xiaoyun's research [6], different calculation formulas were used for the calculation of the amount of dust generated during the loading and unloading process and the amount of dust generated at the road.

Loading and unloading of cargo:

$$Q = 0.033 u^{1.6} H^{1.28} e^{-0.28}$$

\(Q\) - dust removal capacity (t/a), \(u\) - unloading average wind speed (m/s), take 4m/s, \(H\) - unloading drop height (m), take 2m.

The amount of dust on the road:

$$Q_i = 0.123 \times (v/5) \times (m/6.8)^{0.65} \times (p/0.05)^{0.72}$$

\(Q_i\) - Dust amount per vehicle (kg/ (km)), \(v\) - vehicle speed (km/h), \(m\) - car weight (T), \(P\) - road surface dust amount (kg/m2). After the watering measures are taken, \(P=0.2\)kg/m2; the transportation speed of the port is about 10km/h and the carrying capacity is 45T.

3.3.2. Non-working dust. In the process of bulk bulk storage, the amount of dust generated by the natural wind force in the yard is based on the wind tunnel model test conducted by Wuhan Water Transport College and the Ministry of Communications, and He Xiaoyun's research [6], through simulation in the wind tunnel. The amount of dust generated was used to estimate the amount of unorganized dust from the actual pile. The calculation formula was as follows:

$$Q_p = 2.1 k \times (u-u_0)^3 \times e^{-1.033 w} \times p$$

\(Q_p\) - dust pile dusting amount (kg/a); \(k\) - experience coefficient is a function of material moisture content, taking \(k=0.96\); \(u\) - stack average wind speed (m/s); \(u_0\) - material dusting start speed (m/s), take 3.0; \(w\) - surface moisture content (%), taking into account the difference between coal yard and ore wharf, taking an average of 7%; \(p\) - bulk yard annual stockpile (t/a) According to the total throughput of coal and ore goods.

3.4. VOCs unorganized emissions
The VOCs emissions of the tanks in the oil terminal were calculated by the following formula:

$$E = M \times p \times C \times (1-q) \times 10^{-6}$$
E-VOCs emissions (t), M-petroleum throughput (t), p-oil/natural gas/crude oil average density (t/m³), C-emission concentration (g/m³), and q-oil and gas treatment effectiveness.

4. Port air pollutant emission inventory calculation

Calculate the air pollutant emissions of Qinhuangdao Port, Huanghua Port, Tangshan Port and Tianjin Port in 2014 according to the method and related formula in Section 3. A summary of the 2014 Beijing-Tianjin-Hebei port air pollutant discharge list was presented, as shown in Table 8.

| Port     | SO₂  | NO₃  | PM₁₀ | PM₂.₅ | VOCs | CO   |
|----------|------|------|------|-------|------|------|
| Qinhuangdao | 30.6 | 576.1 | 1077.8 | 991.6 | 126.3 | 446.9 |
| Huang Wei     | 4.6  | 261.4 | 272.2 | 250.6 | 42.1  | 153.0 |
| Tangshan     | 36.0 | 907.5 | 372.1 | 342.3 | 192.0 | 611.2 |
| Tianjin     | 189.5 | 2039.4 | 801.9 | 791.9 | 626.2 | 1857.9 |
| Total     | 260.6 | 3784.5 | 2524.1 | 2376.4 | 986.6 | 3068.9 |

According to the obtained port air pollutant inventory data, combined with the Beijing-Tianjin-Hebei port overall planning layout plan, the ARCGIS software is used to grid the inventory data.

![Figure 1](image1.png)  ![Figure 2](image2.png)

![Figure 3](image3.png)  ![Figure 4](image4.png)
5. Conclusion

This study obtained the throughput and port machinery classification data of the port-type cargo types in the Beijing-Tianjin-Hebei region in 2014; the calculation methods for port heavy trucks, other port machinery, unorganized emissions of particulate matter, and unorganized emissions of VOCs were determined. Relevant parameters were calculated and the list of atmospheric pollutants in the Beijing-Tianjin-Hebei regional port was calculated in 2014. The results of the list showed that in 2014, Tianjin Port, Qinhuangdao Port, Huanghua Port and Tangshan Port emitted SO2, NOx, PM10, PM2.5, VOCs and CO totaling 260.6t, 3784.5t, 2524.1t, 2376.4t, 986.6t and 3068.9t. According to the obtained port air pollutant inventory data grid, a spatialized list with a resolution of 3km×3km was obtained, which provided scientific data support for further analysis of port air pollutant emission characteristics and formulation of air pollution optimization control plan for ports in Beijing-Tianjin-Hebei region.

Acknowledgments

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