Keynote Address

Air Quality Study and Management in a Coastal Area

by

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Abstract: Air quality of Incheon area has been degraded, especially by the ocean going vessels (OGVs). PAQman© (Portal Air Quality management) system has been developed to estimate the air pollution from OGVs in the port area using field survey data, AIS (Automatic Identification System) data, activity data, etc. Moreover, Atmospheric to Computational Fluid Dynamics (A2Cflow / A2Ct&d) was applied for simulating the coastal air flow and air pollution dispersion. Current version of PAQman© was successful to calculate the emission from OGVs up to 50km far from the port area where air emission is significantly higher at anchorages than the moving mode. Besides, sea and land breeze frequently generates at the coastal area where penetration length and the boundary of the breeze controls the air pollution dispersion in the coastal area.

Keywords: Air pollution, Emission inventories, OGVs, PAQman©, A2Cflow/A2Ct&d.

1. INTRODUCTION

Diesel engines have been widely used for transportation vehicles due to their simple mechanism, excellent performance, easy maintenance, low fuel consumption rate, high thermal efficiency, and durability (Lin and Huang, 2003). It is popular in both on road and off road transportation system, especially those for high power such as ships which supports the overwhelming majority of global trade (Tzannatos, 2010). On the other hand, it is found to be one of the main anthropogenic sources of various atmospheric pollutants around the coastal regions including major ports (Pokhrel and Lee, 2015). The amount of air emission is affected by various factors such as engine type, fuel type, ship operating mode, applications of emission control technologies, etc. More than 50% of ships operating expense is generally the cost of fuel oil, therefore most of the world ship-owners use degraded residue heavy oil in marine power plants for fuel economy (Lin and Chen, 2004). Due to the fact, Ocean going vessels emits significantly huge amount of air pollution as compare with other transportation mode. We have developed and managed the program "Portal Air Quality Management (PAQman©)" by using activity-based methodology for estimating air pollution from sailing ships and tested for Incheon Port of South Korea. The data would be helpful for improving the quality of marine environment of the port area.

Moreover, thermally induced mesoscale wind is likely to develop in the coastal area due to the temperature discontinuity between the land and the sea surfaces which directly influences the air quality of the coastal area. The best example of mesoscale air circulation in coastal area is Sea/Land (S/L) breeze, which is highly significant to transport the air pollution from source to the receptor (Pokhrel and Lee, 2011). Due to its diurnal variation characteristics, it transports the air pollution from the sea to land and vice-versa in the coastal area. The properties of breeze such as breeze depth, speed, penetration length, etc. were different in different locations. It depends on the solar radiation, surface roughness, land use pattern, surface albedo, etc. Here, we used the mesoscale model i.e. A2C flow / A2C t&d model to analyse breeze mechanism of Incheon Port area as a case study.

2. METHODOLOGY

Vessels information, required power, load factor, emission factor, average time for each mode, activity data etc. are important for designing the logic for the emission assessment from marine vessel. Generally, ship propulsion is provided by main engines while on board electricity is generated from auxiliary engines. The emission factors, representative value that attempts to relate the quantity of a
pollutant released to the atmosphere with an activity associated with the release of that pollutant, are dependent on the power of engine and operation. The total air emission from marine vessel was calculated based on Eq. 1.

With the development of tools and techniques, a new concept was developed to estimate the more accurate emission from ocean going vessel where Auto Identification System (AIS) technique played significant role. AIS system cached the real time information (Geographic coordinate, moving or stationary mode) of ocean going vessel. Vessel registration, construction company, construction date, size, main engine / auxiliary engine power, engine types, etc. information are included in Lloyds data.

\[
Emission = \text{Trips} \times \text{Power} \times \text{LF in mode} \times \text{Time (in mode)} \times \text{EF}
\]

(1)

\[
Emission = \text{Energy} \times \text{EF}
\]

(2)

\[
\text{Energy} = \text{MCR} \times \text{LF} \times A
\]

(3)

\[
\text{LF} = (\frac{\text{AS}}{\text{MS}})^{\frac{3}{3}}
\]

(4)

\[\text{Figure 1 Calculation protocol for real time air pollutants emission (Port of LA, 2004).}\]

Where, emission from the ship is in (g); Trips is the number of vessels calls by vessel and engine type (no.), Power is the rated power of propulsion engine by vessel and engine type (hp), Time is the average time for each mode by vessel and engine type (hr), Energy is the energy demand (kW-hr), EF is the emission factor (g/kW-hr), MCR is the maximum continuous rated engine power (kW), LF is the load factor, A is the activity (hr), AS is the actual speed (knots) and MS is the maximum speed of the vessel (knots). The calculation protocol for real time air pollutants emission is expressed in detail as in Figure 1 where the power of engine, maximum speed, cruising speed, etc. were taken from Lloyds database and they were validated with survey data (actual manoeuvring and cruising speeds, trip segment durations). Moreover the mesoscale modelling technique such as Atmospheric to Computational fluid dynamics (A2Cflow / A2Ct&d; t&d stands for transport & diffusion), an updated version of HOTMAC / RAPTAD was introduced in this study to investigate the air pollution dispersion mechanism in the coastal area.
3. RESULTS AND DISCUSSION

Thousands of national and international flagged vessels arrive or depart from the Incheon port and the air quality of this area is influenced by the emissions generated from those ocean going vessels in different level in different locations. PAQman covers the emission data for 4 km to 50 km with 2 km interval buffer zone from Incheon port according to its setting. Figure 2 demonstrates the yearly emission of particulate matter (PM10) and carbon monoxide (CO) by sailing ships at different geographic location covering 4 km to 50 km range. Vessels were anchored at distances of 8 km, 14 km, and 24 km for loading and unloading when they are on idling stage. When the vessels are in starting or heating stage or idling stage, they emit more pollution than medium or high speed mode. There are three peaks at distances of 8 km, 14 km, and 24 km in the Figure 2, where the amount of emissions are nearly double than other locations. Similarly, Figure 3 demonstrates the total amount of NOx and SO2 emission around the Incheon port at different distance from 4 km to 50 km. Similar to PM10, and CO, the amount of NOx and SO2 were also significantly higher at the anchorage points as shown in Figures 2 and 3. The amount of emissions at the anchorage points are approximately double than other points.

![Figure 2 Total emission of particulate matter (PM10) and carbon monoxide (CO) by marine vessel at different distance from the Incheon port in 2005.](image1)

![Figure 3 Total emission of nitrogen oxides (NOx) and sulfur dioxide (SO2) by marine vessel at different distance from the Incheon port in 2005.](image2)

Diurnal variation of sea and land breeze was found in the Incheon coastal area where the land breeze flows from late night to early morning and the sea breeze flows during the day time. The penetration length of the sea and the land breezes are approximately 25~30 km, and 15~20 km, respectively while the suction lengths are approximately 15~20 km. By considering penetration and suction length of the breezes, it is understood that the pollutants generated inside 25 km from the port at the coastline penetrate to inland area and pollutants far from 25 km may not reach to inland area by the diurnal variation of the breeze. Therefore the vessels emission generated around 25 km far from the port area i.e. coastal area has nominal impact on coastal air quality.

4. CONCLUSION

PAQman© was successfully introduced to calculate the amount of air emission from the Ocean Going Vessels (OGVs) / sailing ships in the Incheon portal area where the mesoscale air dispersion modeling (A2Cflow / A2Ct&d) produced the breeze boundary and the air pollution dispersion mechanism in the coastal area. PAQman© estimated the air emission from the OGVs in the Incheon Harbor area where air emission at the anchorages is 2~3 times higher than the sailing status. The system and the produced data are helpful for managing the air emission from the sailing vessels and for controlling the air emission from the vessels. Moreover, air dispersion modeling at the coastal area produced the breeze boundary area and the pollution dispersion mechanism in the coastal area. Therefore, the information produced will be helpful for managing the coastal air quality in further.
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REFERENCES


