Discussion on the proposed area of an international ship emission control area in China

Cuihong Qin $^{1,3}$, Min Li $^2$, Zheng Wang $^1$, Chunling Liu $^1$ and Wei Zhang $^1$

$^1$China Waterborne Transport Research Institute, Beijing 100088, China; $^2$China Institute of Water Resources and Hydropower Research, Beijing 100038, China

Email: qinch@wti.ac.cn

Abstract. If China intends to designate an international ship air pollutant emission control area (ECA) adopted by the International Maritime Organization (IMO), how to establish the proposed area is a key issue. The paper first analyzes the geographic scope of the four IMO’s ECAs. Comparatively analyzes the actual situation of China’s coastal areas, and then set up four scenarios, namely (1) 12 nautical miles (nm) from the territorial sea baseline, which is the boundary of China’s territorial sea; (2) 24 nm from the territorial sea baseline, which is the boundary for China’s contiguous zone; (3) 50 nm from the territorial sea baseline; and (4) 100 nm from the territorial sea baseline. Using the bottom-up method based on Automatic Identification System (AIS) data of the year 2014 to calculate the proportion of ship emissions in the four scenarios, the results show that the proportion of ship emissions within 12 nm, 24 nm, 50 nm and 100 nm from the territorial sea baseline are 67%, 75%, 82%, and 88%, respectively. It is recommended that the proposed area of an IMO-adopted ECA in China is 100 nm from the territorial sea baseline, which can control the impact of nearly 90% of the ship emissions, and can avoid the ship from rerouting as much as possible. However, in actual operation, the disputed waters should be avoided. This work may provide reference for further research.

1. Introduction

In order to reduce the emission of air pollutants from ships in the port area, the Ministry of Transport of China issued the “Implementation Scheme of the Domestic Emission Control Areas for Vessels in the Pearl River Delta, the Yangtze River Delta and the Bohai-Rim Area (Beijing, Tianjin and Hebei)” at the end of the year 2015 (hereinafter referred to as the 2015 DECA Scheme), which proposed a step-by-step implementation of ship emission control measures in the above three areas [1]. After the implementation of the 2015 DECA Scheme, the emission reduction was significant. According to the environmental monitoring data near the port area [2], the concentration of sulfur dioxide in the atmospheric environment in some port areas in the Yangtze River Delta, the Pearl River Delta, and Bohai-Rim Area (Beijing, Tianjin and Hebei) is more than 20% lower than that before the implementation of the 2015 DECA Scheme. Liu et al. [3] found that the 2015 DECA Scheme could effectively reduce SO$_2$ and PM$_{2.5}$ concentrations in the Pearl River Delta port regions, and the average reduction in the land area were 9.54% and 2.7%. A study by Qin et al. [4] also indicated that a reduction in SO$_2$ emissions by at least 103,998 tons can be achieved for the year 2020 in Shanghai port under the 2015 DECA Scheme. In order to strengthen the effect of the 2015 DECA Scheme and continuously improve the air quality of the port area, in November 2018, the Ministry of Transport
issued the “Implementation Scheme of the Domestic Emission Control Areas for Atmospheric Pollution from Vessels” (hereinafter referred to as the 2018 DECA Scheme), which expanded the domestic emission control areas to cover the country’s entire coastline and the inland river area including the navigable waters of the main stream of the Yangtze River and main stream of the Xijiang River on the basis of the three areas of the 2015 DECA Scheme.

The Domestic Emission Control Areas for Atmospheric Pollution from Vessels in China is different from the four international ship emission control areas in the world. To designate an international Emission Control Area, first a proposal for the designation of Emission Control Area should be formulated and submitted to the IMO by Parties in accordance with the criteria and procedures. And then the IMO shall consider the proposal and finally an Emission Control Area shall be designated by means of an amendment to Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) [5]. The proposed area of the ECA, in addition to the internal waters and territorial waters within the territory of the coastal State, can also be extended to the Exclusive Economic Zone (EEZ). The designation of Emission Control Areas is an international mandatory ship emission control measure. Differently, the designation of China’s Domestic Emission Control Areas is based on Law of the People’s Republic of China on the Prevention and Control of Atmospheric Pollution, which is formulated and issued by the Ministry of Transport. The geographic scope is limited to the internal waters and territorial waters within the territory of China, and is a local mandatory ship emission control measure. Generally, the emission reduction effect of local mandatory policies is not as good as the international mandatory policy [6]. Therefore, if China intends to take further action on the control of marine air pollutants emissions, it is possible to upgrade China’s DECA to an IMO-adopted ECA.

Establishing the appropriate area of an IMO-adopted ECA in China is a complex task, which not only maximizing the environmental benefits as much as possible, but also considering factors such as cost-effectiveness, politics and ship rerouting. Due to the large amount of content involved, but limited time and energy, this paper will focus on the study of impact area of ship emissions by calculating the air emissions inventory in the coastal areas of China, and integrating politics, ship rerouting and other factors to discuss the four scenarios for establishing the proposed area of an IMO-adopted ECA in China. This work may provide reference for further research.

At present, there are mainly two methods calculating ship emission inventory: the first is the top-down method based on the amount of fuel consumed by ships; the second is the bottom-up method based on AIS data. Since it is difficult to obtain the actual fuel consumption of ships, the estimated fuel consumption will lead to deviation, so the accuracy of the top-down method is poor. The advantage of the AIS-based method is that it can obtain real-time ship navigation data, so the calculated ship emissions are more accurate. Compared with the earlier foreign concern about the impact of ship emissions, China’s research on ship emissions inventory started late. Due to the limitations of data availability and research methods, China’s calculation of ship emissions inventory starts from local area using top-down method, including Shanghai Port [7, 8], Tianjin Port [9], Qingdao [10], Shenzhen [11], Guangdong Province [12]. With the increasing availability of AIS data of coastal ships and the research level in China, some scholars began to use the AIS-based method to calculate China’s ship emissions inventory, and the research scope has gradually expanded from local to national and even East Asian regions. Such as Dalian Port [13], Shenzhen Port [14], Hong Kong [15], the Yangtze River Delta [16], the Greater Pearl River Delta [17], the coastal area of China [18], East Asia [19].

2. Material and methods

2.1. Study area and object

China’s coastal areas (within 105°~125° east longitude and 16°~41° north latitude), with 2014 as the base year, the types of ships studied are merchant ships (excluding military vessels and fishing boats), and the types of air pollutants include sulfur oxides, nitrogen oxides and particulate matter.
2.2. Calculation method
The bottom-up method based on AIS data was taken to calculate the ship emissions inventory, using the following Equation (1):

\[ E_i = \text{Load} \times LF \times \text{Act} \times EF_i \]  

(1)

Where \( E_i \) is emissions of certain types of pollutants; \( \text{Load} \) is the load power of the ship’s main engine (ME), auxiliary engine (AE) or boiler under certain operating conditions; \( LF \) is low load adjustment factor; \( \text{Act} \) is operation time; \( EF_i \) is the emission factor of the pollutant.

\[ LF = \left( \frac{\text{Speed Actual}}{\text{Speed Maximum}} \right)^3 \]  

(2)

Where \( LF \) is low load adjustment factor of ME; \( \text{Speed Actual} \) is actual speed of the ship’s navigation; \( \text{Speed Maximum} \) is the maximum design speed.

Emission factors and load adjustment factor of ME and AE used by the U.S. EPA [20] was used in this study. Operation time was extracted based on AIS data.

3. Results and discussion

3.1. Geographic scope of the four IMO’s ship emission control areas
At present, the four ship emission control areas adopted by the IMO in the world are the Baltic Sea Emission Control Area, the North Sea Emission Control Area, the North American Emission Control Area, and the United States Caribbean Sea Emission Control Area. Geographic Scope of the four IMO’s ECA is shown in Table 1.

| IMO’s ECA | Geographic Scope |
|-----------|-----------------|
| The Baltic Sea ECA[21] | The area of the Baltic Sea ECA comprises the Baltic Proper with the Gulf of Bothnia, the Gulf of Finland and the entrance to the Baltic Sea bounded by the parallel of the Skaw in the Skagerrak at 57°44.8’ N (Figure 1). The Baltic Sea ECA is in the inter-continental sea area. |
| The North Sea ECA[22] | The North Sea ECA is in the sea area between the island and the mainland. Figure 2 presents a map of the North Sea. |
| The North American ECA[23] | The area of the North American ECA includes waters adjacent to the Pacific coast, the Atlantic/Gulf coast and the Hawaiian Islands. The area of the North American ECA is illustrated in Figure 3. The outer boundary of the North American ECA extends 200 nautical miles from the baseline of the U.S. and Canadian territorial waters, covering its EEZ. |
| The United States Caribbean Sea ECA[24] | The area of the United States Caribbean Sea ECA is illustrated in Figure 4. This area is located in the Caribbean Sea and consists of waters surrounding the islands of the Commonwealth of Puerto Rico and the United States Virgin Islands. The U.S. Caribbean ECA is in the archipelago sea area, which is different from the coastal situation in China. |

3.2. Discussion on the possibilities for establishing the proposed area of an IMO-adopted ECA in China
According to Appendix III-Criteria and procedures for designation of SOx emission control areas of MARPOL 73/78 Annex VI, a proposal for designation of an ECA for NOx or SOx and particulate matter or all three types of emissions shall include 1) a clear delineation of the proposed area of application, along with a reference chart on which the area is marked. There is no specific delineation requirement for the scope of the ECA. It can be seen from the geographic scope of the four IMO’s ECA, the Parties have delineated different water areas according to the actual conditions of the applicable areas. The biggest one of them is the North American ECA which extends 200 nm from the United States and Canada’s territorial sea baselines. Undoubtedly, the greater the area of the ECA, the
better the environmental benefits, but it is impossible to extend indefinitely. When designating an IMO-adopted ECA in China, the proposed area of 200 nm (EEZ) from the territorial sea baseline with reference to the North American ECA is not feasible. The reason is as follows.

![Figure 1. Map of the Baltic Sea ECA.](image1)

![Figure 2. Map of the North Sea ECA.](image2)

![Figure 3. Map of the North American ECA.](image3)

![Figure 4. Map of the U.S. Caribbean Sea ECA.](image4)

The EEZ and continental shelf area of China is about 3 million km\(^2\) [25], but there are a lot of maritime disputes between China and neighboring countries, including Japan, North Korea, South Korea, Vietnam, the Philippines, Brunei, Indonesia, and Malaysia. The disputed sea area is 1.2 million km\(^2\), including 7km\(^2\) in the Yellow Sea, 300,000km\(^2\) in the East China Sea, and 800,000km\(^2\) in the South China Sea [26]. According to the United Nations Convention on the Law of the Sea, the “Exclusive Economic Zone” refers to the sea area of the territorial sea and should not exceed 200 nautical miles. Because the width of the continental shelf in the Yellow Sea and the East China Sea is less than 400 nautical miles, it has objectively caused partial overlap of EEZ between China and South Korea and between China and Japan. There are different claims of EEZ in the Yellow Sea and the East China Sea between China and South Korea, and in the East China Sea between China and Japan. China advocates that under the guidance of the principle of fairness, the boundary is determined according to natural extension, while South Korea and Japan advocate the division of equidistance rules [27]. In the South China Sea, Vietnam, the Philippines, Brunei, Indonesia, Malaysia have different claims with China, so the 200 nautical miles from the baseline of China's territorial waters will involve disputed waters with Vietnam and the Philippines. Because the 200-nm extension area
from the territorial sea baseline will involve territories of neighboring countries and regions or disputed areas, this situation was not considered in this paper. The four scenarios that we studied are (Figure 5):

(1) 12 nm from the territorial sea baseline, which is the boundary of China’s territorial sea.
(2) 24 nm from the territorial sea baseline, which is the boundary for China’s contiguous zone.
(3) 50 nm from the territorial sea baseline.
(4) 100 nm from the territorial sea baseline.

3.3. Ship emissions in the four scenarios
In the year 2014, the discharges of ships in China's coastal areas were 871,800 tons of sulfur oxides, 1,378,400 tons of nitrogen oxides, and 117,300 tons of PM$_{10}$. Ship emissions in the four scenarios are shown in Table 2.

|           | sulfur oxides |             | nitrogen oxides |             | PM$_{10}$ |             |
|-----------|---------------|-------------|-----------------|-------------|-----------|-------------|
|           | Emissions/    | Percent     | Emissions/      | Percent     | Emissions/ | Percent     |
|           | 1,000 tons    | %           | 1,000 tons      | %           | 1,000 tons| %           |
| 12 nm     | 595.7         | 67.71       | 929.6           | 67.44       | 81.0       | 69.05       |
| 24 nm     | 663.7         | 75.44       | 1,043.9         | 75.73       | 90.4       | 77.07       |
| 50 nm     | 717.5         | 81.55       | 1,134.6         | 82.31       | 97.8       | 83.38       |
| 100 nm    | 772.5         | 87.80       | 1,226.2         | 88.96       | 105.3      | 89.77       |

It can be seen from Table 2 that the proportion of ship emissions within 12 nm, 24 nm, 50 nm and 100 nm from the territorial sea baseline are 67%, 75%, 82% and 88% respectively. Fan et al. [16] researched spatial and seasonal dynamics of ship emissions over the Yangtze River Delta and East China Sea and found that more than 60% and 85% of ship emissions occurred within 54 nautical miles (100 km) and 108 nautical miles (200km) of the coast. In the study of distribution of air pollution from oceangoing vessels in the Greater Pearl River Delta, Mao et al. [17] found that the 12-nm boundary and the 96-nm boundary captured about 63% and 82% of total emissions. The results of this study are close to those of Mao et al. [17], but compared with Fan et al. [16], the results within 50 nautical miles are quite different. The emissions inventory calculation involves many factors such as fuel quality, engine power, activity levels and emission factors, and the choice of each value will affect the accuracy of the emissions inventory.

At present, the outer boundary of the 2018 DECA is 12 nautical miles from the territorial sea baseline, which is the boundary of China’s territorial sea. China can unilaterally regulate ships in this area according to the United Nations Convention on the Law of the Sea. 24 nautical miles from the territorial sea baseline is the boundary for China’s contiguous zone. According to the calculation results of this study, when designating an IMO-adopted ECA in China, all four scenarios can control the impact of most ship emissions. Control effects increase as the proposed area expands. The area of Scenario 4 is twice the area of Scenario 3, the cost of emission control will increase a lot, but the proportion of ship emissions only increase by 6%. It can be seen that it is not cost-effective to blindly expand the proposed area of an IMO-adopted ECA in China.

According to the experience of the California ECA and the North American ECA, if an ECA is narrow, belt-shaped along the coast, ships may choose to detour to the non-control area because of cost savings. As a result, the effectiveness of ECA is reduced. According to research by Mao et al [28], the closer the ECA boundary is to the coast, the more ships will reroute, an ECA needs to be at least 100 nm from the coast to be most effective.

Therefore, according to the calculation results of the ship emission inventory in this study, combined with the research results of the ship rerouting, it is recommended that designate an IMO-
adopted ECA in China with the boundary to be 100 nm from the territorial sea baseline, which can control nearly 90% the impact of ship emissions, and can also avoid ship rerouting as much as possible. In order to avoid international disputes, the proposed area should avoid the disputed waters between China and neighboring countries when designating an IMO-adopted ECA in China.

![Image of the four scenarios discussed in this paper.](image_url)

**Figure 5.** The four scenarios discussed in this paper.

4. Conclusions

Ship emissions inventory was calculated using the bottom-up method based on AIS data of the year 2014, and the types of air pollutants include sulfur oxides, nitrogen oxides and particulate matter. When discussing on the possibilities for establishing the proposed area of an IMO-adopted ECA in China, this paper first analyzes the geographic scope of the four IMO’s ECA. Comparatively analyzes the actual situation of China’s coastal areas, and then set up four scenarios. The results show that in the year 2014, the discharges of ships in China's coastal areas were 871,800 tons of sulfur oxides, 1,378,400 tons of nitrogen oxides, and 117,300 tons of PM$_{10}$, and the proportion of ship emissions within 12 nautical miles and within 100 nautical miles range, but the results within 50 nautical miles are quite different. The calculation results of this study are similar to the previous research results within 12 nautical miles and within 100 nautical miles range, but the results within 50 nautical miles are quite different. The calculation of the emission inventory has large uncertainties due to deviations in parameter selection, AIS data matching, and detail processing. It is recommended that designate an IMO-adopted ECA in China with the boundary to be 100 nm from the territorial sea baseline, which can control nearly 90% the impact of ship emissions, and can also avoid ship rerouting as much as possible. However, in actual operation, the disputed waters should be avoided.

This work may provide reference for further research. However, due to limitations in time and objective factors, there are some limitations in this study. For instance, the uncertainty in ship emissions inventory due to the lack of localized data on ship emission factors and the lack of partial content of AIS data; lack of research on the environmental impact of ship emissions, the cost and ecological health benefits of the ECA, etc. All these subjects might be studied in the future work.

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