Estimate of Emission Caused by the Operation of Proposed Support Service and Utility Vessels for Chittagong Port

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Abstract

The maritime traffic passing through Chittagong port grows by roughly 10–14% annually. The growth in freight handling and ship calls at Chittagong Port since the 1990s, when open market economics and trade facilitation policies were implemented, has made it necessary for the port to expand and upgrade a number of maritime services. It has been found that various types of support, service, and utility vessels are required for the majority of marine service delivery. Based on the expected handling capability of the Chittagong port with respect to conceptual traffic and other port growth over the next three (three) decades, the need for an adequate number of support, service, and utility vessels has been assessed in light of this. Support, service, and utility vessel operations in a marine port, like those of commercial shipping, are one of the main sources of air pollution since the vessels' powerful diesel engines emit a lot of greenhouse gases. This study estimates the shipping emissions produced by proposed support, service, and utility vessels based on actual vessel operations and engine power data. As a result, it is necessary to investigate the generation of emissions caused by the operations of these support, service, and utility vessels.

Key Words: Ships emission, Service vessels, Utility Vessels, pollution, Chittagong Port.

1. Introduction

The country's primary gateway port for seaborne trade, handling more than 90% of all tonnage, is Chittagong port. The port is organized and operated in a manner that is comparable to that of other ports, although there are obvious differences in terms of traffic volume, operations, performance, and long-term investment and development plans. The infrastructure and facilities of Chittagong Port are located along the

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Karnafuly River's bank, 16 kilometers from the river's point of entry into the Bay of Bengal. The maximum permissible draft is 9.50 m with a length constraint of a vessel of 188 m. Because of this, large ships cannot berth in the port, necessitating the lightering of a sizable amount of import trade from the mooring in the bay. The annual cargo handling growth in Chittagong port is about 10-14%. The expanding freight handling is also increasing the number of ships calling at the port because the harbor lacks the depth to accommodate larger ships. To handle this increased freight handling and to make CPA a contemporary seaport, the port authorities has started a number of infrastructure enhancements. A container terminal is being built in the Patenga area, new port facilities are being established under Bay Terminal, container handling equipment, such as gantry cranes, are being purchased, capital dredging is being done in the Karnafuly River, port operations are being computerized under the Chittagong Port Trade Facilities project, environmental management is being practiced, and local roads are being built under development initiatives taken.

CPA offers a range of marine services, just like other contemporary seaports around the world. Marine services are port-related operations intended to guarantee the safe, fast, and efficient passage of vessel traffic in port approaches and channels as well as a safe stay at berth whether moored or at anchor. The range of the port's marine obligations and jurisdiction heavily influences the specific marine services provided by the Chittagong Port Authority. These include, tugboat service, pilotage service, mooring services, vessel traffic management service, hydrographic survey, dredging and facilitating navigational aids in the channel and harbor, fresh water supply to incoming ships, fuel supply to incoming ships, ambulance service, solid waste and oil spill management at channel, wreck removal from the channel, search and rescue, security and patrol, etc. It has been found that various types of support, service, and utility vessels are required for the majority of marine service delivery. It is, therefore, seen that the tugboat, pilot boat, high speed patrol boat, buoy laying vessel, pollution control vessel, search and rescue helicopter, survey and oceanographic vessel, trailing suction hopper dredger and water supply vessels are necessary to provide necessary support services to different vessels coming to Chittagong port. Based on the anticipated handling capability of the Chittagong port in relation to conceptual traffic and other port growth during the following 3 (three) decades, the required and intended number of crafts has been assessed.

The worldwide maritime industry is very concerned about how shipping operations, specifically in port areas, may affect the environment. Even if maritime operations contribute under a tolerable limit to world emissions, this could increase significantly. From some recent studies OECD (2008) states that the emission of CO_2, NO_x and SO_2

by ship corresponds to about 2-3%, 10-15% and 4-9% of the worldwide anthropogenic emissions respectively. It is well known that more than 95% of the world's shipping fleet is driven by diesel engines. Due to the fact that marine vehicles' powerful primary engines burn heavy fuels, shipping emissions can have a considerable negative impact on the quality of the air around the sea and the shore, which can have regional and global repercussions. Ship emissions from the sea, the beach, and between the continents can readily travel great distances in the atmosphere. Coastal waters, inland waters, small channels, straits, gulfs, and port locations may also experience an increase in the effects of shipping emissions due to heavy marine traffic, delicate ecosystems, and dense populations. Because of this, shipping emissions have a significant negative impact on the environment. As a result, both traditional pollutants and greenhouse gases are regarded to be substantial sources of air pollution from ships and other marine infrastructure.

Like commercial shipping, activities carried out by support, service and utility vessels of a maritime port are one of the major air pollution sources as the vessels use high-powered diesel engines which emit considerable greenhouse gases. In view of the same, it is necessary to investigate the generation of emission caused by the operations of these support, service and utility vessels and in this study, the shipping emissions generated by proposed support, service and utility vessels are estimated based on the real vessel activities and engine power information.

2. Environmental Concerns of Maritime Shipping

Sustainable development is one of the major concerns now-a-days and there is continuous pressure on the industry and businesses, and different transportation modes, to achieve sustainability in their business operation (Endresen, et. Al, 2008). Global warming, deterioration of air quality, and acidification are the three most significant environmental consequence categories that must be minimized according to the international agenda. Research has concentrated on anthropogenic emissions of chemicals that cause such environmental consequences in light of this. In general, regulations and reasons for regulating pollution aim to lower total maritime emissions, specifically on a source-by-source basis. Emphasis is given either on sources causing the greatest effect or on the most cost-effective methods to control (Corbett and Koehler, 2003) the same. Marine emissions have not previously been delimited, but the International Maritime Organization (IMO) and EU have recently implemented requirements for ships to reduce emissions.

It is well known that marine diesel engines with their exhaust emissions make up the majority of the world fleet's power sources. It largely contains surplus carbon dioxide and water vapor with little amounts of carbon monoxide, oxides of Sulphur and nitrogen, partly reacted and non-combusted hydrocarbons and particulate material (Lloyd’s Register of Shipping (LR), 1995). The exhaust gases spread through interaction with ambient air in the atmosphere after being discharged from the marine engines. The active chemical components are partially altered and thrown onto the ground and onto water surfaces during the mixing and dilution process in the ship cloud. On the other hand, during cargo handling and oil transport, vaporization leads to VOC (Volatile Organic Compounds) releases (Endresen et al., 2003). Shipping the also causes discharge of other compounds (e.g., refrigerants and fire-fighting agents), though these are minor. Precautionary steps can be performed before the combustion process, during the combustion process, or after treatment of exhaust gases to control exhaust emissions. Technical procedures, operational conditions, use of alternative fuels and alternative propulsion systems can be some of the procedures to improve fuel consumption and discharge (Eyring et al., 2005; Tronstad & Endresen, 2005). In order to reduce cargo VOC emissions, various operational and technical measures are also available. However, a trustworthy and up-to-date ship emission account is the first requirement for comprehending the effects of shipping emissions, and for this, it is necessary to measure as many ship emissions as possible in order to develop appropriate policy solutions. Moreover, it is important to understand the spatial distribution of the emission (Buber et al, 2020). On this ground, attempts have been taken in this research to measure the emissions from different service vessels operating under the Chittagong port.

3. Methodology

Emissions caused by the proposed support, service and utility vessels have been computed by the activity-based method (H Saraçoglu, C Deniz, and A Kiliç, 2013), which comprises the application of emission factors for each type of activity (cruising, maneuvering, and hoteling). When defining characteristic emissions values from the engines of support, service, and utility vessels throughout each activity, the emission aspects are crucial. Furthermore, emission issues depend on the speed of the vessels and the fuel type. Therefore, the activity-based method was used to compute the emissions caused by the support, service and utility vessels in Chittagong port. This method is described by flow charts and illustrated in Table 1.

Table 1: The flow chart for the ship activity-based method

Features of the ships	• The features of the support, service and utility vessels of Chittagong Port
The times required in the ship activities	• The times required in cruising, maneuvering and hoteling
Ships power consumption	• The powers of the vessels' main engines and generators (kW)
Load factors	• Load factors of main engines and generators
Emission factors	• Using different emission characteristics for each vessel activity (g/kWh) • Vessel speed and fuel type affect the emission characteristics (g/kWh)
The quantity of emissions	• Vessel emissions for every activity (ton/year) • Over-all emissions (ton/year)

Operational Modes:

Cruising

The speed at which a vessel usually moves when it is traveling at a fast speed for a long distance. The support, service and utility vessels as proposed for Chittagong port has a cruising speed from 18.5 to 74.0 knots. These vessels can be handled well at cruising speed.

Maneuvering

Maneuvering is an action during which a vessel enters or exits the coastal waters of a country, passes over several ships on the way and moves forwards or departs from a berth or jetty of a port. At addition to performing its assigned tasks in a port channel or harbour, a support, service, or utility vessel may need to manoeuvre to assist other vessels in navigating channel and traffic zones.

Hoteling

While they wait for their next voyage to provide the required services, the ships are berthed during the hoteling period.

The total vessel emissions are the sum of the emissions in the above-mentioned activities.

4. Procedure

The activity-based methodology was applied to the proposed support, service and utility vessels of the Chittagong Port to assess the levels of the exhaust pollutants (NOx, SO2, CO2, HC, and PM) while cruising or sailing, maneuvering and hoteling or lodging. Ship power consumption, emission factors, and load factors for the primary engines and generators all affect how much emissions a ship produces. The exhaust gas emissions were calculated for the proposed Support, Service and Utility Vessels for Chittagong Port considering the above parameters and factors.

Table 2: Ship Particulars or the proposed Support, Service and Utility Vessels for Chittagong Port

Ship Particulars					
SL No.		No. of Ships	ME in kw	DG in kw	Berth Time in Hours
1	35 ton Bollard Pull Tugboat	2	2536.0	200.0	12
2	High Speed Pilot Boat	4	1100.0	100.0	12
3	Fast Security Patrol Boat	4	1200.0	100.0	12
4	Buoy Laying Vessel, Crane SWL, 30 ton	2	1500.0	200.0	12
5	Water Supply Vessel, 1000 M T capacity	5	1000.0	150.0	12
6	Pollution Control Vessel, Capacity 100 MT	2	1100.0	100.0	12
7	Search and Rescue Vessel	2	1700.0	220.0	12
8	Trailing Suction Hopper Dredger	2	2850.0	1300.0	12
9	Survey & Research Vessel	2	2200.0	300.0	12
10	300 ton Floating Crane	1	2000.0	300.0	12
11	Hydrographic Survey Boat	3	800.0	100.0	12
12	Mooring Boat	4	370.0	50.0	12
13	Total	33	2536.0		

4.1 Estimation

The following expressions can be used to calculate the emissions produced while the proposed support, service, and utility vessels are cruising, maneuvering and berthing:

(1) E_{Cruising} (g) =2 $\cdot D \cdot (ME \cdot LFME \cdot EF1 + AE \cdot LFAE \cdot EF1)$ / V

(2) $E_{\text{Maneuvering}}$ (g) = $T_{\text{Maneuvering}}$ $(ME \cdot LFME \cdot EF2 + AE \cdot LFAE \cdot EF2) / 2$

(3) E_{Hoteling} (g) = T_{Hoteling} (0.05 · ME · LF ME + AE · LFAE) EF3

Where,

- ME is a main engine power (kW),
- AE is a generator power (kW),
- V is a ship average speed between cruising and maneuvering (km/h),
- D is a distance between cruising and maneuvering (km),
- $LFME$ is a load factor of main engine. at cruising, maneuvering and hoteling (%),
- $LFAE$ is a load factor of generator at cruising, maneuvering and hoteling (%),
- EF 1 is an emission factors for cruising mode (g/kWh),
- T Man is an average time spent during maneuvering (h),
- EF 2 is the emission factors for maneuvering mode (g/kWh),
- T Hoteling is the average time spent at berth (h), and
- EF 3 is an emission factor for hoteling (g/kWh).

4.2 Load Factor

For the proposed support, service and utility vessels, the load factors of the main engines and auxiliary engines for cruising, maneuvering and hoteling modes are illustrated in Table 3.

The cruising distance for the proposed support, service and utility vessels in the Chittagong port area is 39 km. The cruising times of the mentioned vessels were estimated based on the default service speed at 60% MCR. Since the main engine load is assumed as 60%, the half of the service speed of the vessels is used. Vessels' default service speeds are shown in Table 4.

For each vessel, the cruising ship emissions were estimated considering one main engine and two numbers of generators operative. The main engine loads were assumed as 60% at cruising mode. It is also estimated that for the ship's safety, the ships operate with two synchronized generators at cruising mode. Foe each vessel, maneuvering emissions are calculated with one main engine and two parallel generators operative. The maneuvering distance has been assumed as 26 km for both arrival and departure conditions, as obtained from Chittagong Port Authority. It is also assumed that during hoteling, main engine load decreases to 20%.

Table 3: Load factors of main engines and generators according to operational modes.

Load Factor		
Cruising	0.60	0.50
Maneuvering	0.60	0.50
Hoteling	0.20	0.50

Table 4: Average speed of the Support, Service and Utility Vessels of Chittagong Port.

Average Vessel Speed (km/h)	
35 Ton Bollard Pull Tugboat	22.22
High Speed Pilot Boat	46.30
Fast Security Patrol Boat	74.08
Buoy Laying Vessel, Crane SWL, 20 ton	22.22
Water Supply Vessel, 1000 M T Capacity	18.52
Pollution Control Vessel, Capacity 100 MT	18.52
Search and Rescue Vessel	46.30
Trailing Suction Hopper Dredger	21.30
Survey & Research Vessel	22.22
300 ton Floating Crane	22.22
Hydrographic Survey Boat	19.45
Mooring Boat	18.52

It is assumed that the main engine is stopped and one generator is running while at berthing. There is one generator running at a load factor is 50% at hoteling phase. The berthing time for each vessel call was obtained from Chittagong Port Authority. The data used to estimate vessel exhaust emissions are main engine powers, generator powers and vessel duration in the berth and these are the actual values for the proposed support, service and utility vessels of the Chittagong Port. Since the engine power, engine load and engine running hours are the key inputs to estimate the emissions, using the exact values of these data gives more accurate results.

5. Result and Discussions

The most significant seaport in Bangladesh, Chittagong, has proposed support, service, and utility vessels. In this work, the exhaust emissions of these proposed vessels are calculated using an activity-based emission model. It is seen that the emission from the support, service and utility vessels are noteworthy. However, support service and utility vessels will emit significantly less emissions than incoming commercial ships that call at Chittagong Port, which is a significant contributor to air pollution in the city of Chittagong. The distribution of the emissions of various types of pollutants by different types of support, service and utility vessels have been furnished in Figure 1 to Figure 6.

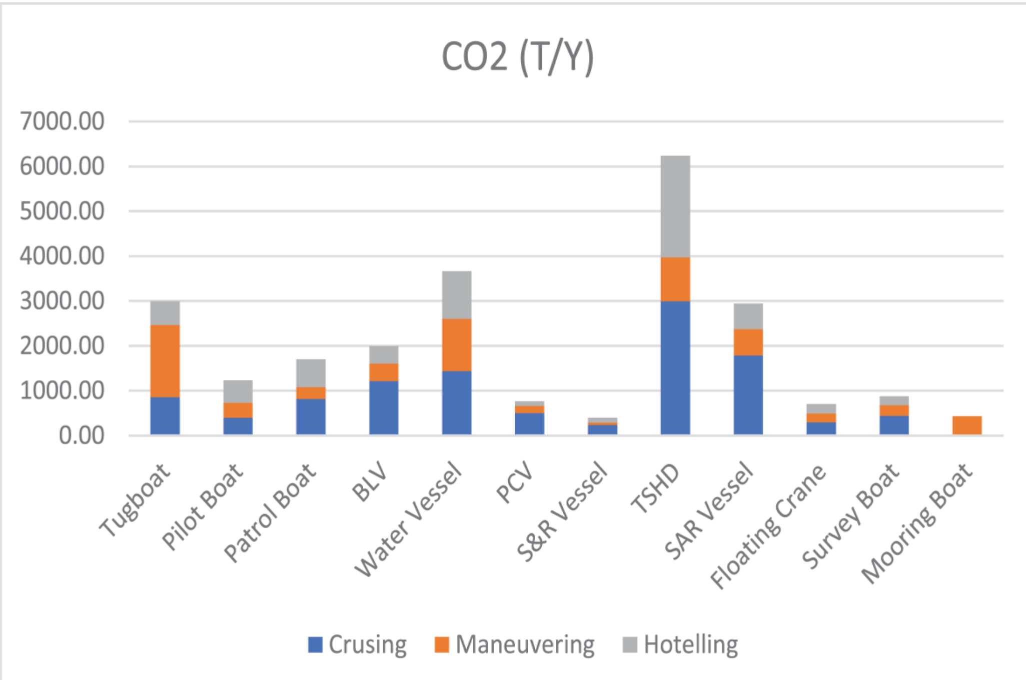

Figure 1: Emissions of CO_2 by different types of support service and utility vessels

From Figure 1 we can see that Trailing Suction Hopper Dredger generates maximum CO_2 emission and also CO_2 emission from water barge and tugboats are higher than the same by others. Obviously, the emission quantity depends not only of the fuel burnt but also on the number of vessels of the same type, which is clear from Figure 1.

From Figure 2, it is seen that Trailing Suction Hopper Dredger generates maximum NOx emission and also NOx emission from water barge and tugboats as well as survey and research vessels are higher.

From Figure 3, it is seen that Trailing Suction Hopper Dredger generates maximum SO_2 emission and also SO_2 emission from water barge and tugboats as well as survey and search vessels are higher.

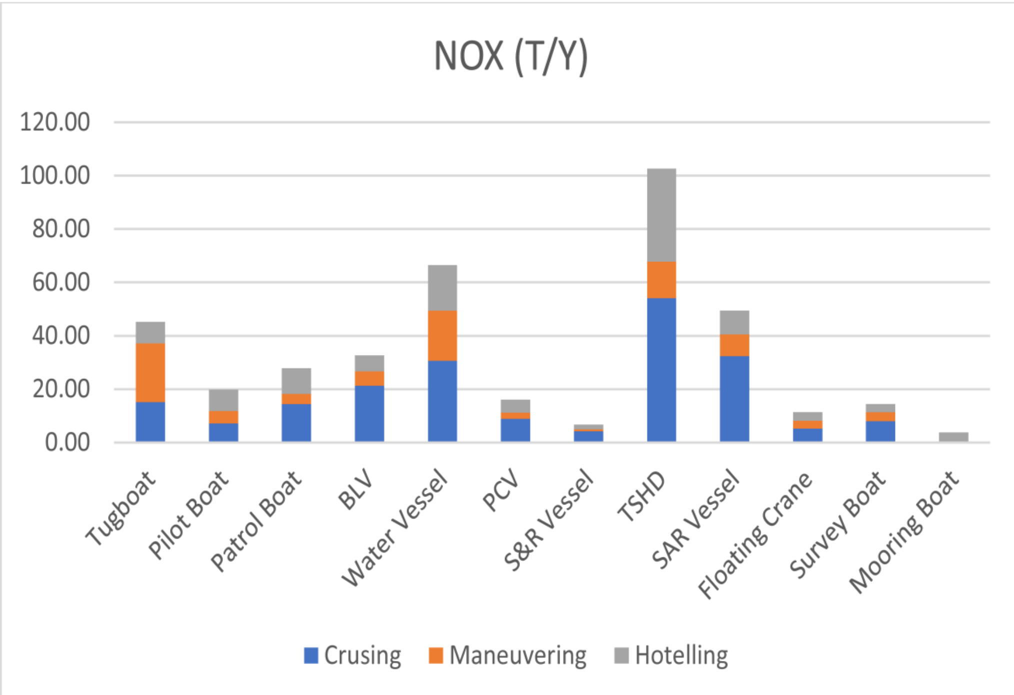

Figure 2: Emissions of NOx by different types of support service and utility vessels

From Figure 4, it is seen that Trailing Suction Hopper Dredger generates maximum SFC emission and also SFC emission from water barge and tugboats as well as survey and research vessels are higher.

From Figure 5, it is seen that Trailing Suction Hopper Dredger generates maximum HC emission and also HC emission from water barge and tugboats as well as survey and research vessels are higher.

From Figure 6, it is seen that Trailing Suction Hopper Dredger generates maximum PM emission and also PM emission from water barge and tugboats as well as survey and research vessels are higher.

From Figure 7, it is seen that 75% to 80% emissions are CO2 and about 20% are SFC. Other pollutants are negligible.

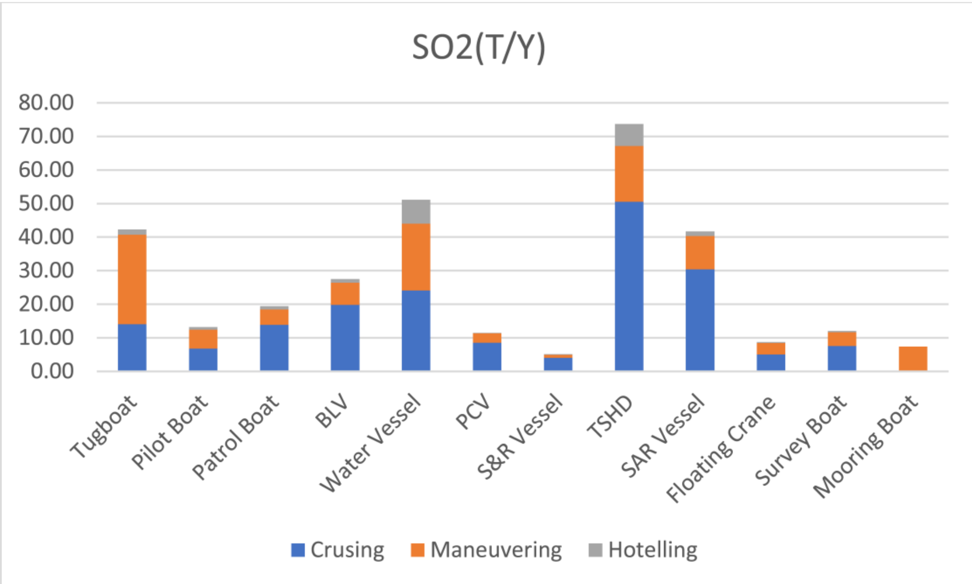

Figure 3: Emissions of SO2 by different types of support service and utility vessels

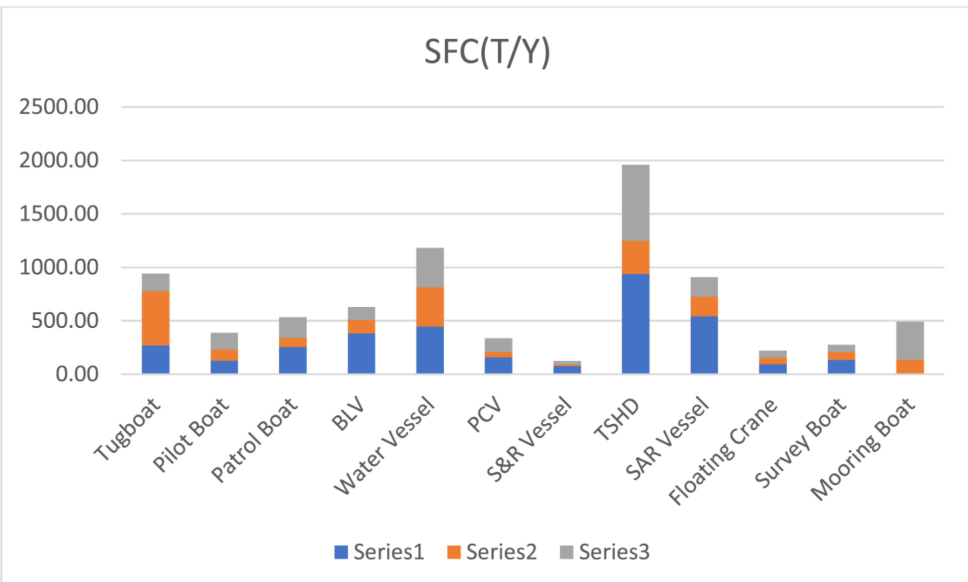

Figure 4: Emissions of SFC by different types of support service and utility vessels

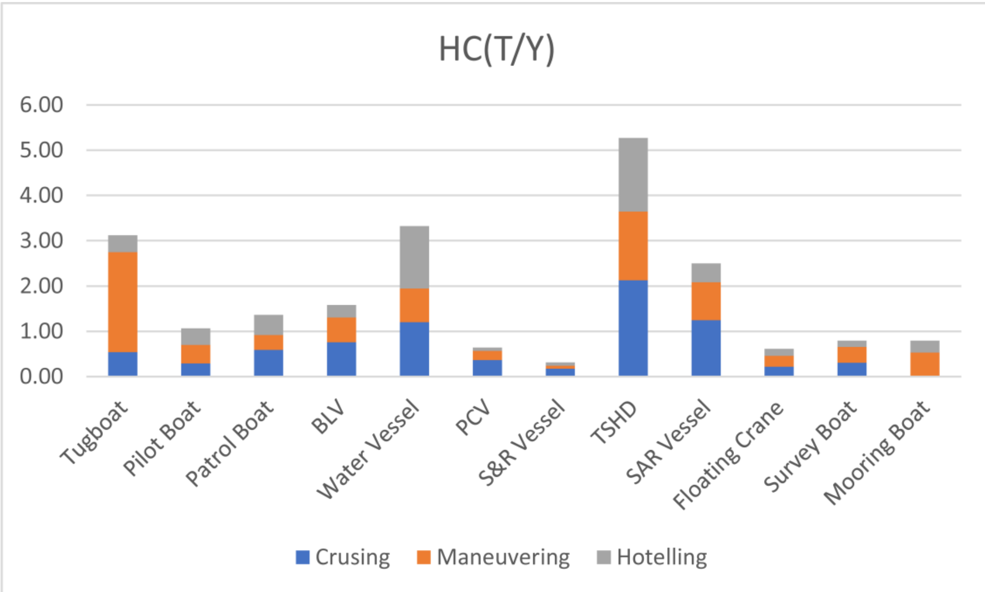

Figure 5: Emissions of HC by different types of support service and utility vessels

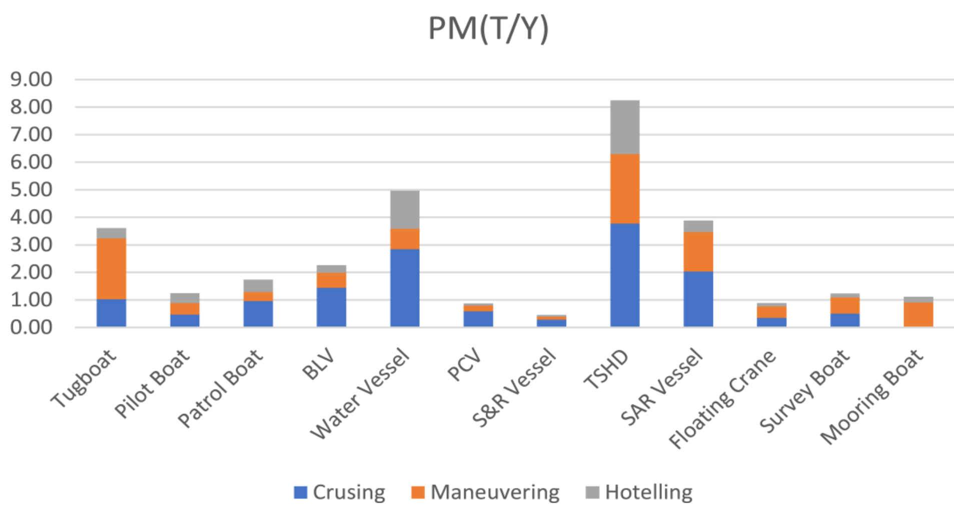

Figure 6: Emissions of PM by different types of support service and utility vessels

In this study, the exhaust emissions have been estimated using the activity-based emission model for the operation of the proposed support, service and utility vessels of Chittagong Port, which is the most important container and cargo port in Bangladesh, as mentioned before. It is found that ships calling into Chittagong Port are a major source of air pollutions in the city of Chittagong. It is also stated that ship emissions may cause critical health effects to human body because Chittagong port is adjacent to the city of Chittagong, which contains the third highest population of Bangladesh.

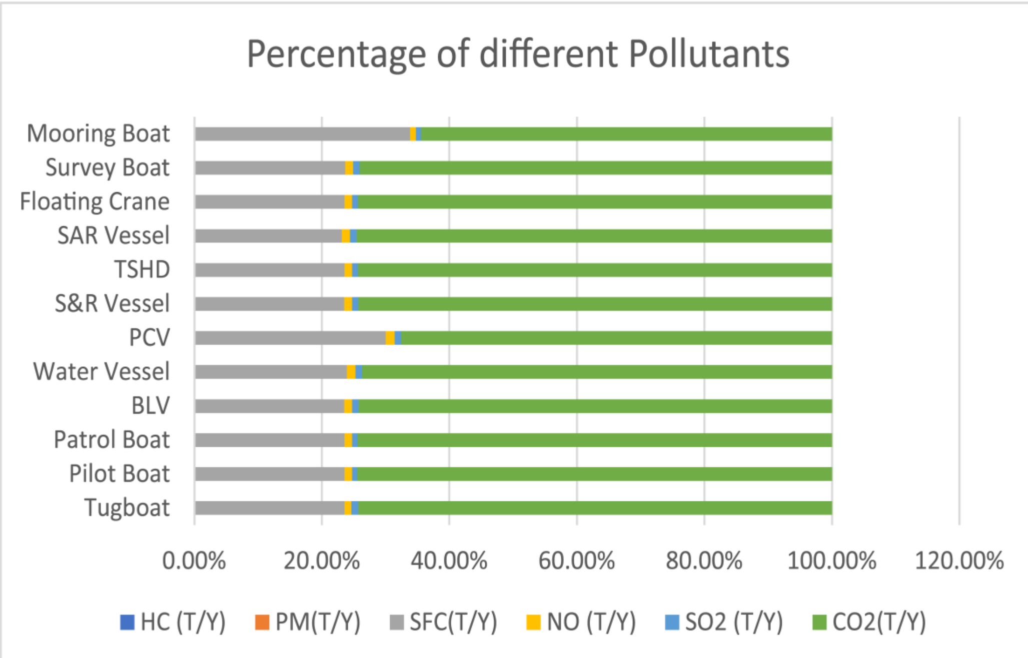

Figure 7: Emissions of different vessels in different modes of operations

It is seen from the estimate that the quantities of emissions during operations of proposed support, service and utility vessels at Chittagong port will be 409.18 tons of NOx, 320.74 tons of SO2, 24,685.09 tons of CO2, 21.66 tons of HC and 30.96 tons of PM in 2019. It is also seen that approximately 11,724 tons of fuel will be consumed annually by the proposed 33 (thirty-three) nos. of support, service and utility vessels in the port area.

The emissions during cruising mode were higher than the same at maneuvering and hoteling due to traveling of longer distances, also the main engine and one generator were operated at the maximum load. The exhaust gas pollutants released during hoteling, maneuvering and cruising modes by different types of service vessels are illustrated in Table 5. It is seen that the exhaust gas pollutants produced from the vessels during cruising were 46.0% of the total quantities in operational modes, while emissions were 26.0% in maneuvering and during 29.0% in hoteling. It is seen that though for all types of vessels emission is maximum in case of cruising but for tugboat emission is maximum during maneuvering and for mooring boat also the scenario is similar. It is also seen from Table 5 that the maximum exhaust gas emissions were from Trailing Suction Hopper Dredger, Self-propelled Water Barge, Tugboat and Search & Rescue Vessel as compared to the same of other types of support, service and utility vessels.

Table 5: Total Emission of different vessels in different mode of operations

Sl	Ships	Total	Cursing	Maneuvering	Hoteling
1	Tugboat	4029.09	29%	54%	17%
2	Pilot Boat	1657.90	33%	27%	41%
3	Patrol Boat	2280.84	48%	16%	36%
4	BLV	2685.83	61%	20%	19%
5	Water Sup. Vessel	4976.00	39%	32%	29%
6	PCV	1132.04	60%	20%	21%
7	S&R Vessel	533.16	60%	13%	26%
8	TSHD	8387.08	48%	16%	36%
9	SAR Vessel	3946.34	61%	20%	19%
10	Crane Barge	946.67	42%	28%	30%
11	Survey Boat	1180.89	50%	27%	22%
12	Mooring Boat	1827.32	29%	32%	39%
13	All Ships	33583.17	46%	26%	29%

6. Conclusion

In the present world scenario, environmental contamination is a major worry. The reduction of emission of greenhouse gases has now also taken on a significant role in the effort to lessen environmental pollution. Ship emissions are significant contributors to port city air pollution and directly impact both people and the environment. In this study, the estimation of exhaust gas emissions (NOx, SO2, CO2, HC, and PM) from proposed support, service and utility vessels of Chittagong Port has been carried out on the activity-based approach. The changes in the current environmental conditions that are a direct or indirect result of the acquisition of the vessels have been characterized as the environmental impact and greenhouse gas emission generated by the operation of the support, service, and utility vessels. As far as possible, the source of the effects have been identified, the risks have been examined and the emissions have been estimated. A qualitative assessment has been made, which is based on the experience, professional judgement and assessment of public values. However, following observations can be made from this research:

- NOx, SOx and CO_2 emissions are maximum for TSHD since the power as well as fuel consumption is maximum for the same. The emissions from water barge, tugboat and survey and research vessels are also significant as compared to the same of other types of support, service and utility vessels, since these depends on the number vessels too resulting in total power as well as fuel consumption.
- For all types of support, service and utility vessels emission of CO_2 are the maximum and emissions of HC are minimum for all types of vessels.

On the above ground, it is recommended that, Chittagong port authority can take some precautionary measures for examples;

- It is to be mentioned that the engine, generator and other accessories should be overhauled as per maintenance schedule to reduce the probability of air pollution.
- Implement the best standardized operational and technical practices accepted or implemented around the world.
- Vessels crews can be provided with sufficient training to follow the efficient operation and technical manual to reduce the emission.

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