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AN ASSESSMENT OF IMPACTS OF MARINE POLLUTION BY THE OPERATION OF INLAND VESSELS IN BANGLADESH

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ABSTRACT

Being a riverine country, the Inland Shipping of Bangladesh has been providing the cheapest, safest and reachable means for carrying passengers, cargoes and petroleum products all the year round. But, the amount of marine pollution caused by the operation of these vessels is not known. In this paper, an attempt has been taken to estimate the amount of pollutants due to operation of vessels in inland and coastal routes in Bangladesh. Quantity of fuel burnt as well as well as discharge of bilges, oily water and ballast water by different types of inland shipping operation has been assessed. An environmental modeling for these different types of vessels has been done to find out the impacts of pollutants. It is found from the study, among the vessels, oil tankers operating in inland and coastal routes contribute the highest total environmental impact and sand carriers emit the highest quantity of GHG in terms of equivalent CO_2 gas in Bangladesh. Some remedial measures to combat different types of pollution have also been discussed.

Keywords : *Inland vessels, marine pollution, oil tanker, sand carrier, passenger vessel.*

1.0 INTRODUCTION

Nowadays the reduction of ship related pollution and emissions, energy efficiency and operational expenditure are key priorities to shipping communities around the world. Even IMO (International Maritime Organization) adopted the mandatory application of the EEDI (Energy Efficiency Design Index) and EEOI (Energy Efficiency Operating index) for ship design and ship operation stage respectively in order to reduce the emissions of CO_2 by shipping operation [1]. As a result, it is important to know the exact status of environmental pollution by operating ocean going vessels as well as inland vessels. On the other hand, Inland vessels are usually navigate through much nearer to the populated areas than ocean-going vessels and so their carbon footprint, energy efficiency and environmental attributes are now getting more and more importance than ever before.

Bangladesh is a riverine country. It is criss-crossed with a network of three big renowned rivers namely the Padma, the Meghna and the Jamuna and their innumerable tributaries like the Surma, the Rupsha, the Dhaleswar, the Passur, the Kushiyar etc. and which occupies about 11 per cent of the total area of the country. The river network of Bangladesh is shown in Figure 1. Since long, this river network has been regarded as the safest and the most cost-effective route in Bangladesh. The inland waterways comprise a

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total length of nearly 6000 km of navigable waterways. More than half of the country's total land area is within a distance of 10 km from navigable waterway. A huge number of different types of vessels is plying in inland and coastal routes. The IWT (Inland Water Transportation) sector carries over 50% of all arterial freight traffic and one quarter of all passenger traffic each year. Moreover, more than 80% of petroleum products is transported all the year round through the inland tankers [2] & [3].

To cater the increase demand for the cargo and passenger transport, IWT sector increases its capacity by adding the number of different types of vessels each year. It is anticipated that this upward trend is likely to continue in the coming years due to poor condition and huge traffic on roads and also due to expected increase in personal mobility. On the other hand, the significant no of vessels plying in inland routes has made vulnerable to marine pollution. The inland water ways are getting polluted not only by discharging bilges, solid waste, oily water, and ballast water, but while in operation, it is making air pollution through burning fuels for running engines or machineries. Unfortunately, the current status of pollutions made by inland shipping operation is yet to be known as there was no report or work found so far.

Considering the above circumstances, this paper at first aims at estimating operational pollutants such as amount of discharge of bilges, oily water and ballast water as well as the amount of fuel consumption made by different types of inland shipping operation in Bangladesh. Then these specific pollutants have been used for environmental modelling with the help of well-known Life Cycle Assessment (LCA) Software Sima Pro. The environmental impact assessment methods such as Eco-indicator 99, impact 2002+ and IPCC 100a were chosen which account for general categories of human health, ecosystem quality, resources as well as air emission through green house gas release [4]. Total damages were assessed by these methods and compared among them to find out which one imposes minimum/maximum burden to the environment. The finding of this study can be used to access the present scenarios of pollutions by the operation of inland vessels and may be useful while formulating some policy to combat pollution in near future.

2.0 DATA COLLECTION & RESEARCH METHODOLOGY

The present research is focused on collecting primary data and information to assess the operational pollutions done by different types of inland vessels in Bangladesh. Both formal and informal ways have been adopted to collect data from key informants like different Govt. Organizations, Shipyards, Design houses, Ship owners and Ship Operators. Data format and questionnaire were carefully designed to collect and record all relevant operational data systematically from operators (i.e. engine operators, greasers and masters)of different types of ships. Also the level of awareness of different stake holders has been assessed and their opinion regarding combating pollution of inland vessels has been gathered through field survey, discussion, interviews and using some open ended questionnaires.

Secondary source of data and information had also been explored from related private & government organizations, books, journal, research publication and official records that had been kept in published or unpublished form.

Sima Pro, an EIA (environmental impact assessment) database software, was used to assess the impact on environment by the operational of inland shipping vessels. The effect categories considered here included carcinogens, respiratory organic/inorganic, climate change, radiation, ozone layer depletion, aquatic acidification/eutrophication, land use, mineral extraction, fossil fuel extraction, etc. These effect categories have impacts on resources, human health, global warming, habitat alteration, biological diversity and other hazards [5,6] .

3.0 BRIEF DESCRIPTION OF INLAND VESSELS OF BANGLADESH WITH THEIR OPERATING ROUTES

Different types of vessels such as passenger, cargo, ferry, oil tankers, dumb barges, speed boats, sand carriers and dredgers are plying in the rivers and coastal areas of Bangladesh. However, the major portion of inland water vessels is covered by passenger vessels, cargo vessels, oil tanker and sand carrier (about 75%) and these vessels are considered as the major sources of environment pollution in Bangladesh [7]. Other vessels like speed boats, tug boats, dumb barges and dredgers have relatively small contribution in marine pollutions and that is why they have been excluded from this study.

For the convenience of data collection, passenger vessels, cargo vessels and sand carriers have been categorized as per length while oil tankers have been categorized as per its capacity for this study. Table-1 shows the categories of inland passengers, cargos and sand carriers and Table-2 shows main characteristics of these vessels including their routes. On the other hand, oil tankers have been classified according to their capacity and their classification along with their main characteristics are shown in Table-3.

Table 1: Categories of inland Passenger, Cargo and Sand Carriers

Category	**Type**	**Range (Length)**	**No. of Vessels Passenger (PS)**	**No. of Vessels Cargo (CS)**	**No. of Vessels Sand Carrier (SC)**
Cat-1	Small	Up to 30m	779	348	2065
Cat-2	Medium	30 to 50 m	220	1554	1346
Cat-3	Large	Above 50 m	62	311	-
Total			**1061**	**2213**	**3411**

Table 2: Main characteristics and routes for inland Passenger, Cargo and Sand Carrier

Ship Type	**Passenger (PS)**			**Cargo(CS)**			**Sand Carrier (SC)**	
Categories	Cat-1	Cat-2	Cat-3	Cat-1	Cat-2	Cat-3	Cat-1	Cat-2
L/B ratio	3.17~4.17	4.56~5.86	6.3~6.4	4.37~4.68	4.56~5.85	5.89~6.41	3.40~3.63	3.83~5.73
B/d ratio	2.96~5.18	3.60~3.95	4.8~5.8	2.68~3.83	2.44~2.53	2.92~3.12	3.26~4.07	2.19~3.97
Percentage	73%	21%	6%	16%	70%	14%	61%	39%
Main Route	Dhaka-Chadpur-Barisal-Potuakhali-Bhola			Dhaka-Chittagong_Khulna-Ashugang			Around Dhaka city riverine routes	

Table 3: Categories and main characteristics of oil tankers (OT) of Bangladesh

Category	**Type**	**Capacity (MT)**	**Total No**	**Share**	**L/B ratio**	**Draft range**	**Main Route**
OT Cat - 1	Small	Up to 1000	43	20%	4.5- 4.9	1.7m-2.5 m	Narayangong-Bhaghabari, Daulatpur, Kurigram, Gaibandha
OT Cat - 2	Medium	Above1000 to1750	136	65%	6.0 -6.8	3.0m-4.0 m	Chittagong-Naryangong, Bhairab Bazar, Barishal, Jhalakathi.
OT Cat - 3	Large	Above 1750	31	15%	5.0-5.8	4.0m-5.0 m	
		Total	210				

Since long, passenger vessels are very popular especially from capital city Dhaka to the southern part of Bangladesh. Mainly category-2 and 3 types of vessel are plying this long routes (Dhaka-Barisal-Potuakhali-Bhola) in Bangladesh. Catergory-1 types passenger vessels are mainly playing in and around Dhaka or other main district town. Every year over 95 million passengers are carried through different routes [1] by the passenger ships. Cargo ship is mainly responsible for carrying of various kinds of commodities like food,

food grains, jute & jute products, cement and clinker from Chittagong and Mongla Port to different inland river ports of the country. In addition, limited numbers of cargo vessels also visit to Kolkata (India) port under the Inter country transit and trade protocol agreement between the two countries. The sand carriers are used to carry sands from one place to another place within the local area. These vessels are of unique design, very indigenous in nature and maintain relatively lower speed during operation. Sands are picked from various rivers and they are generally plying in and around Dhaka city using the river Buriganga, Shitalakha, Turag and Balu. Figure 1 show the inland ports and other installation around the country used by different types of vessels of inland waterways. On the other hand, oil tanker fleet of inland shipping plays an important and significant role for the national economy of the country. Bangladesh Petroleum Corporation (BPC), authorized for the importation of crude oil, refined oil and lubricant for the country, distributes the oil products across the country using river transport routes. Two types of tankers-coaster tankers and shallow draft tankers are used to carry oil product from Chittagong to different depots such as Godenail, Narayangong, Bhairab Bazar, Barishal, Chadpur, Bhaghabari, Daulatpur-Khulna Chilmari-Kurigram, Balashi-Gaibandha, Sachna Bazar and Jhalakathi. Location of oil depots (marked ⬇) and oil intake point at Eastern Refinery Limited (marked ★) is also shown in Figure 1.

4.0 MODELLING OF POLLUTANTS DUE TO INLAND SHIPPING OPERATION

In this study, passenger ships, cargo ships, sand carriers and oil tanker ships have been considered as mentioned earlier. For passenger ships, amount of fuel consumption, bilge water and solid waste generated during plying long route vessels have been taken into consideration for environmental modelling. For cargo, sand carrier and oil tanker, solid waste is neglected due to involvement of few numbers of persons during operation of the vessel. For the calculation, it has been assumed that inland vessels are usually slow speed vessels where speed varies between 4 knots to 12 knots, with trading period 11 months per year and fuel type used is diesel oil.

On the other hand, from the field survey, it has been revealed that category 1 & 2 ships of different types are generally made using indigenous technology. For example: oil tankers of category 1 & 2 are single hull tankers having no separated ballast tank and no oil-water or bilge-water separator. Only dedicated cargo pump for loading and unloading purpose as well as bilge pump is seen in the engine room of these types of oil tankers. For loading the oil cargo at Eastern Refiner Limited (ERL) Chittagong which is situated on the bank of river Karnafuli (shown in Figure 2), many of these tankers need to cross Sandip-Hatiya Channel in empty condition. To maintain the ship stability while crossing this route, these vessels need to fill their cargo tank with salt water and once crossed the Channel, these vessels empty their tank through discharging the whole content of the oil water mixture of the tank before reaching intake point at Eastern Refinery Limited.

While quantification of fuel consumption for different size of ships operating in inland water ways, it has been found from the field study that the ship of exactly same size uses different engine power and at the same time ship of significant difference in length uses same power. It is well understood that engine power usually varies with cube of speed of ship and so same ship with different speed may have different engine power. But it is quite surprising to find out that some ship in the range of length 50 meter and in the range of 60-65 meter use the same power of engine even the design speed is same for both cases. It is found that there is a tendency of random choice of engine power only depending on sheer experience of the operators rather than taking expert advice from professional naval architect/ship designer. Also, there have been significant differences in power actually found on board ship with the power found in official documents. On the other

hand, analysing collected field data, it has been found that most of the ship uses low cost Marine Engine. However, fuel consumption of engine is verified by taking average running hour of the engine as well as fuel consumption data from log book of the engine where available. Also, first hand data of fuel consumption is verified using the fuel consumption of engine manufacturer catalogue. Since it is not possible to collect all data of fuel consumption for all types of ships, an effort has been given to co-relate engine power with the length of the ship so that the power of any ship (oil tanker) can be found from the co-relation equation. For example, Figure 2 showing the data of engine power (found from field study) is plotted against ship length. The co-relation found in this Figure 2 is used to approximate power for all the tanker ship operating in inland routes.

For calculation of solid waste generated by passenger carrying ship in Bangladesh, it is assumed that only medium to long distance route ships will generate solid waste and 40% of the passengers will use toilet during their journey to their destination. From the field study, it has been revealed that there is no storage tank for sludge waste, even though there is a provision of sludge tank and other arrangement in the official documents and drawings. Bilge, ballast water and oily water mixture data are based on field data and sometimes from verbal communication from the operators of the ship.

As mentioned before, in case of estimating pollutants like bilge, ballast water and oily water mixture, the first hand data collected by the researchers had to be verified using available scientific techniques. For example, quantity of bilge collected from field data is further verified considering running hour of bilge pump from the operators of the ships. Using capacity plan drawing along with sectional shape of the aft portion of ship, quantity of bilge water is further verified through measurement of height of bilge water for round trip operation by the ship where possible. Cargo tank filled with sea water for category 1 & 2 type oil tanker ships while crossing Sandip-Hatiya Channel for maintaining stabilityy has been further ascertained using tank calibration data of some tankers operating in these routes. The amount of water required to maintain stability while bay crossing (Shandip-Satiya Channel) by the ship is verified by using available stability manual of the ship where possible.

Figure 3 shows the approximate quantity (in %) of bilge and fuel needed by different types of inland vessels in Bangladesh per year.

In this paper, environmental impacts generated by the operation of different types of vessels are direct emission into air, soil and water mainly due to energy consumption; indirect impacts generated by materials consumption and by output wastes. The estimated quantity has been used as input to find out the impact on environment using Eco indicator 99 (I) of Sima Pro software, IMPACT2002+, IPCC100a etc. Sima Pro is the world most widely used Life Cycle Analysis software which offers standardization as well as the ultimate flexibility and it has some unique features such as parameterized modelling and interactive results analysis.

5.0 RESULTS AND DISCUSSION

Figure 4 shows the obtained results for the total environmental impacts, evaluated by the Eco-indicator 99 (H) for the operation of different types of inland vessels. In this Figure, the environmental impacts are values normalised and weighted; the normalisation reference value is the average environmental load because of one average European inhabitant over one year; the weighting values adopted were the default values of the software [8]. In Figure 4, CS stands for cargo ship, PS stands for a passenger ship, OT stands for oil tanker and SC stands for sand carrier. From this Figure, it is seen that oil tanker of catergory 2 plays dominant role in compare to other types of vessels in terms of total environmental impact value.

On the other hand, the IMPACT 2002+ estimates the cumulative toxicological risk and potential impacts associated with environmental emissions (organics and metals) to

human health and ecosystem . It consists of a fate model, meaning a combined mid-point and damage approach. All mid-point scores are expressed in units of a reference substance and related to four damage categories: human health, ecosystem quality, climate change and resources. Figure 5 shows the obtained results for the total environmental impacts, evaluated by the IMPACT 2002+ for the operation of different types of inland vessels. The trend of Figure 5 is same as the trend of the Figure 5 except the numerical value.

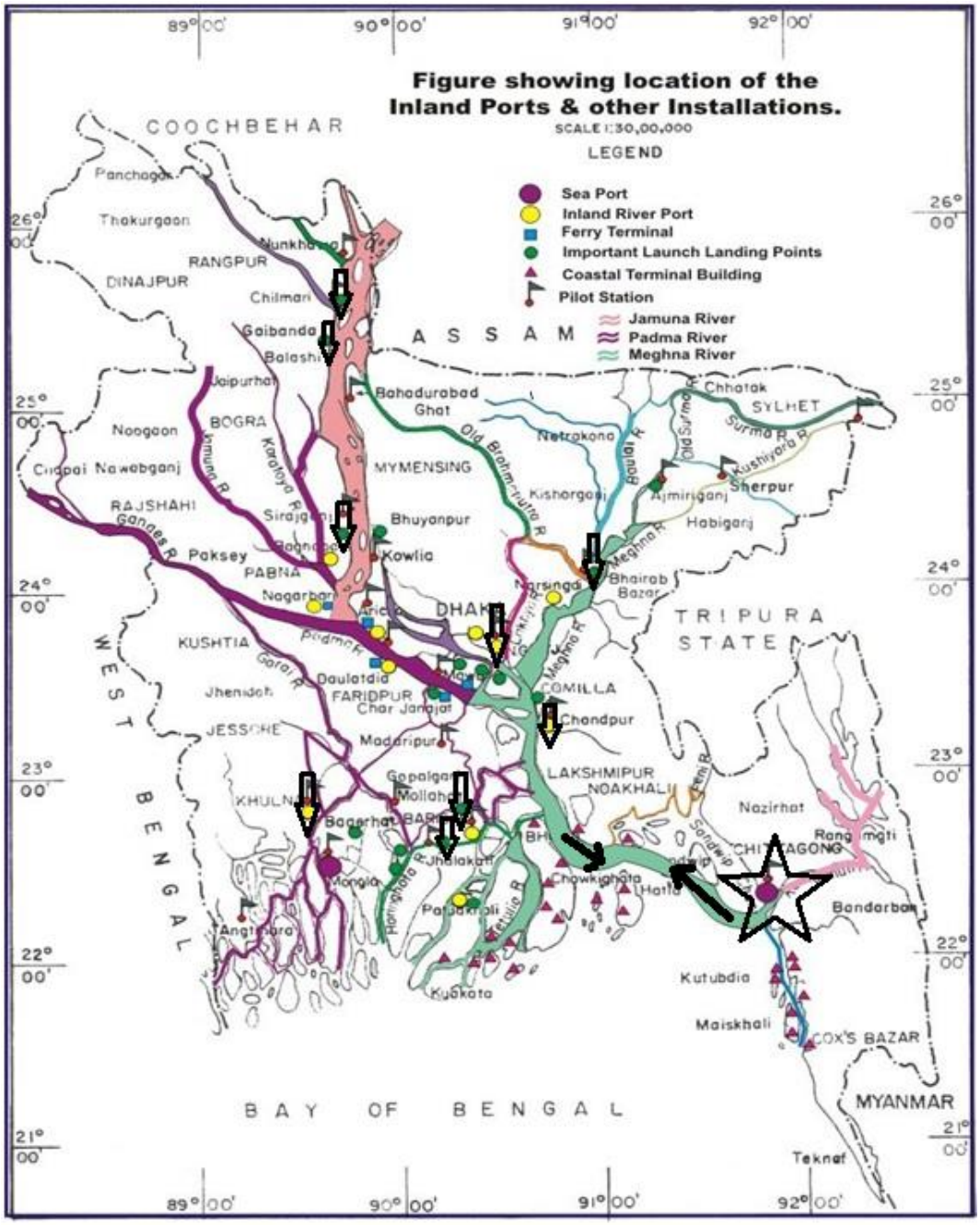

Figure 1: Location of the inland ports, terminals, oil depots and Intake Point for inland ships in Bangladesh.

IPCC GWP 100a was also used to estimate global warming potential within the SimaPro LCA modeling tool. In this method, Greenhouse gases released as air emissions are normalized to the global warming potential of an equivalent mass of carbon dioxide (CO_2eq) acting over 100 years. Figure 6 shows the obtained results for global warming potential evaluated by the IPCC 100a for the operation of different types of inland vessels. From this Figure, it is seen that sand carries are contributing highest in terms of global warming.

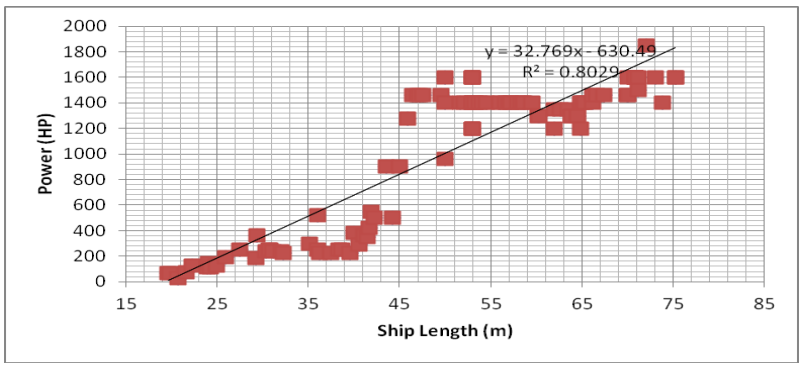

Figure 2: Power and ship length co-relation for approximation of fuel consumption (oil tanker)

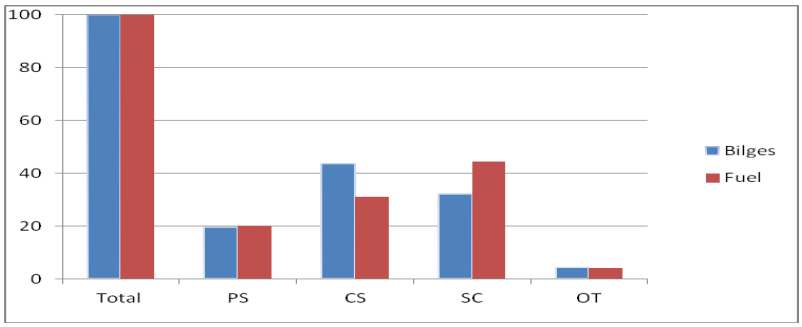

Figure 3: Relative quantities of bilge and fuel consumption by different types of inland vessel per year

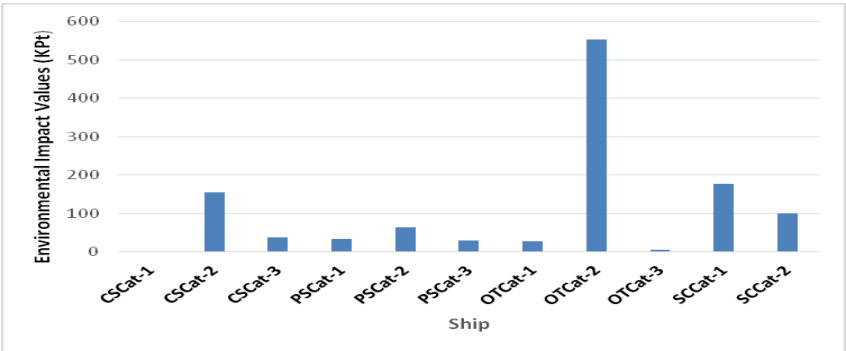

Figure 4: Total environmental impact, normalised and weighted, for the operation of inland vessels assessed by IMPACT 2002+ method

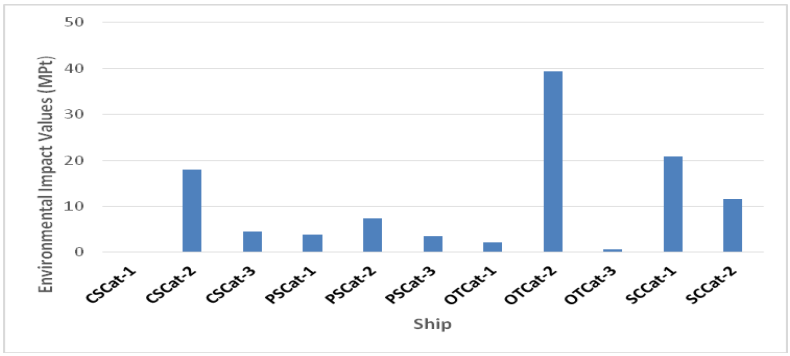

Figure 5: Total environmental impact, normalised and weighted, for the operation of inland vessels assessed by 'Eco-Indicator 99 (I) method

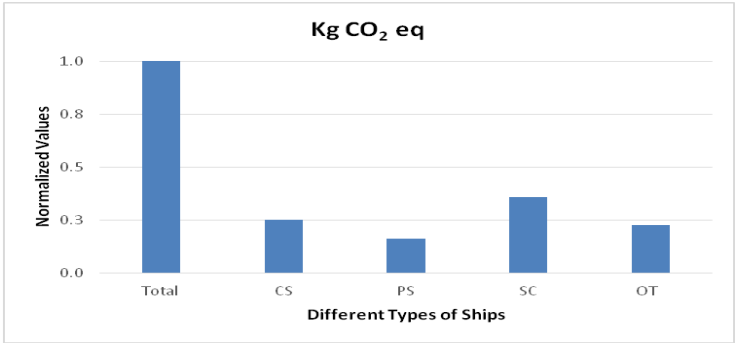

Figure 6: Impacts of GHG (assessed by IPCC 100a) by the operation of inland vessels in Bangladesh

6.0 REMEDIAL MEASURES

Generally the effect of marine pollutions is irreversible and therefore it is well understood that such effects might create everlasting damage to the marine ecosystem [7]. Field data collected during this study reveals that most of the operators of ships of inland routes are not at all aware of the fact that oil-water or bilges directly thrown into environment is very harmful for the marine aquatic system. Some waste reception facilities can be set up near intake point to avoid releasing huge amount of such pollutant to Karnafuli river and its surrounding environment for maintaining stability. Provision may be made mandatory to collect bilges & solid waste for on board tank of each vessel which will be discharged after treating it environmentally. Regulatory authority may take proper steps to set up such facilities to combat operational pollution done by huge number of inland vessels every year. Bilge-water separator for oil tankers should be mandatory for all vessels following the MARPOL convention [9,10] 1973/78.

7.0 CONCLUSIONS

In this paper, an effort has been made to quantify and model various types of pollutants discharged by inland ships that are plying inland and coastal water ways in Bangladesh. The following calculation can be made on the basis of the present assessment:

- Based on the environmental impact modelling and assessment done by Eco-Indicator 99 (I) and IMPACT 2002+ methods, it is found that inland oil tankers of category 2 (plying in inland and coastal routes in Bangladesh) are making the highest contribution of pollutions in terms of total environmental impact values among different types of ships of inland shipping. The second and third contribution of pollutions come from sand carriers and cargo ships of inland shipping.

- Comparing among the quantity of Green House Gas emission by different types of vessels considered in this study, it is found that about 35% of CO_2 equivalent green house gas is released by sand carrier ships operation per year in Bangladesh. The second and third contribution of GHG release come from cargo ships and oil tankers category of inland shipping in Bangladesh.
- By providing oil-reception facilities, mandatory implementation of bilge-water separator to all tanker ships etc, operational environmental burden imposed by different types of ships including oil tanker can be reduced substantially.

8.0 LIMITATIONS

There are uncertainties in such analysis. One should be aware of these uncertainties while using this study for comparison with others. The reasons behind these uncertainties are usually due to uncertain data, uncertainties on the correctness of the model, uncertainties caused by incompleteness of the model, different opinion on weights of various impact categories, etc.

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