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DEVELOPMENT OF A QUALITATIVE MATERIAL FLOW ANALYSIS FOR SHIP-GENERATED WASTE AT MONGLA PORT: THE ROLE OF SCIP PLASTICS PROJECT

S. Roksana *, Q.H. Bari*, S.M. Rafew, I.M. Rafizul*, M. Alamgir*, E. Kraft***, K. Susanne *** and M. Rahman******

**Department of Civil Engineering, Khulna University of Engineering & Technology, Khulna, Bangladesh*

*** Institute of Disaster Management, Khulna University of Engineering & Technology, Khulna, Bangladesh*
**** Faculty of Civil Engineering, Bauhaus-Universität Weimar (BUW), Germany*
***** Mongla Port Authority, Mongla, Bagerhat, Bangladesh*

ABSTRACT

Sundarbans mangrove forest and Pashur river have been facing constant threats due to marine waste generated from extensive import and export activities of ships at Mongla Port. Wastes from foreign ships are being collected by ship chandlers and subsequently dumped into the Mongla Port Municipality landfill area. However, it has been identified that during 2022, only 2.33% to 3.5% of foreign ships called for ship chandlers to collect waste. Additionally, it has been found that 2.33%–3.5% of ships produce 102.67 m3 of waste in total, with plastic making up about 30% of that amount. The objective of this study is to assess the role of the Sustainable Capacity Building to Reduce Irreversible Pollution by Plastics (SCIP Plastics) Project through analyzing the material flow of ship-generated waste at Mongla Port and thus propose a masterplan to for reducing as well as properly managing these wastes to protect the marine environment.

Keywords: Plastics Project, Material Flow, MARPOL V, Mongla Port, Waste, Ships**.**

INTRODUCTION

The ocean is the most important natural resource in the world which impacts all creatures', life, and the environment directly and indirectly. This ocean now has become the largest landfill by accumulating various types of waste like plastic, metals, glass, ceramics, textiles, paper, and timber (Schneider et al., 2018). These wastes are known as marine litter and the most harmful marine litter is plastic debris (Schneider et al., 2018). The main cause is that the chemical bond of the monomers responsible for the durability of plastic makes it resistant to different natural processes of degradation. Plastic waste does not decompose, rather they accumulate in landfill and marine environment (Barnes et al., 2009). Ardiansyah et al. (2022) have estimated that 30% of 2 billion solid waste in the world is not managed properly. If the scenario doesn't change, the number may increase to 3.4 billion tons by 2050. Solid plastic waste from land-based sources which enter the ocean is between 4.8 to 12.7 million tons (Jambeck et al., 2015). Among the generated waste one-third will be contributed by the countries of Asia alone (Mourshed et al., 2017). Additionally, according to Ardiansyah et al., (2022) 1.15-2.41 metric ton of plastic waste flows into the ocean from the global riverine system

Bangladesh is a coastal country with one of the most dynamic South Asian economies. However, over the last three decades, the waste volume has doubled every 15 years, with an average of 55% of the solid waste remaining uncollected in urban areas, with a collection efficiency ranging from 37% to 77% (Sirajul ISLAM, 2021). The country's plastic consumption in urban areas has been 2.07 kg per capita in 2005, which increased dramatically to 3.5kg in 2014 (Mourshed et al., 2017) . When this plastic waste goes into the marine environment, it becomes a hazardous substance. and slowly becomes a major threat to the marine ecosystem and environmental sustainability (Ardiansyah et al., 2022) . Being a riverine country and due to the geographic connectivity with the Bay of Bengal, Bangladesh has most of its international, and national imports and exports via ships. It has two major seaports, Chattogram port, and Mongla Port. About 4000 ships per year come to Chattogram port and 1500 ships come to Mongla port per year. These ships are one of the potential sources of marine waste. All maritime vehicles mandated under international convention MARPOL 73/78 of the International Maritime

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Organization and all the ports must have reception facilities for ship-generated waste (IMO, 1973, 1978).

Being the second largest seaport in Bangladesh, Mongla port has become a part of the geometric growth of Bangladesh's shares in the maritime trade(Khondoker & Hasan, 2020). Thus, it needs a proper waste management plan and port reception facilities for ship-generated wastes. If these wastes are not managed properly there is a chance that the biodiversity of the Sundarbans mangrove forest will be threatened in near future. In the Mongla port, ships calling are in among them 80% are bulk cargo ships, 15 to 20% 15% -20% vehicle carrier ships, and 5% container ships. Because there is no mandatory policy for receiving port facilities in Mongla Port, approximately 15% to 20% of ships receive port facilities each month. As a result, there is a possibility that waste will be dumped into the Pashur River. The SCIP (Sustainable Capacity Building to Reduce Irreversible Pollution) Plastics Project is a collaboration project between regional partners of Khulna University of Engineering & Technology (KUET) Chittagong University of Engineering and Technology (CUET), Khulna City Corporation (KCC), Mongla Port Municipality in Bangladesh and European partners Bauhaus-Universität Weimar (BUW) and Institute of Social and Ecological Research (ISOE) in Germany. Its goal is to keep the waste rate at 75% while reducing it by around 14 percentage points throughout the project duration in Khulna and Mongla, which seems like a reasonable assessment. The purpose of this research is to assess the role of the SCIP Plastics Project in the material flow analysis of ship-generated waste at Mongla Port.

METHODOLOGY

For material flow analysis of ship-generated waste at mongla port, SCIP plastics project, department of Civil Engineering, KUET has directly been involved. The role of the SCIP plastics project regarding port waste management is described and hence represented in the following articles.

SCIP Plastics Project:

The SCIP (Sustainable Capacity Building to Reduce Irreversible Pollution) Plastics Project is a collaboration project between regional partners of Khulna University of Engineering & Technology (KUET) Chittagong University of Engineering and Technology (CUET), Khulna City Corporation (KCC), Mongla Port Municipality in Bangladesh and European partners Bauhaus-Universität Weimar (BUW) and Institute of Social and Ecological Research (ISOE) in Germany. This project's overarching objective is to establish a knowledge transfer center at KUET campus for the prevention and reduction of land-based marine plastic waste flow in the Bay of Bengal. This hub will train and bundle competencies in the fields of plastic prevention, substitution, and circular economy, develop sustainable guidelines, and provide policy advice. Marine plastic wastes have a working group about "Case Study of Mongla Port", which is one of the main focuses of this study on:

- Material flow analysis of goods at ports (Mongla, Chottogram) and
- Waste composition analysis at transshipment and repackaging units.

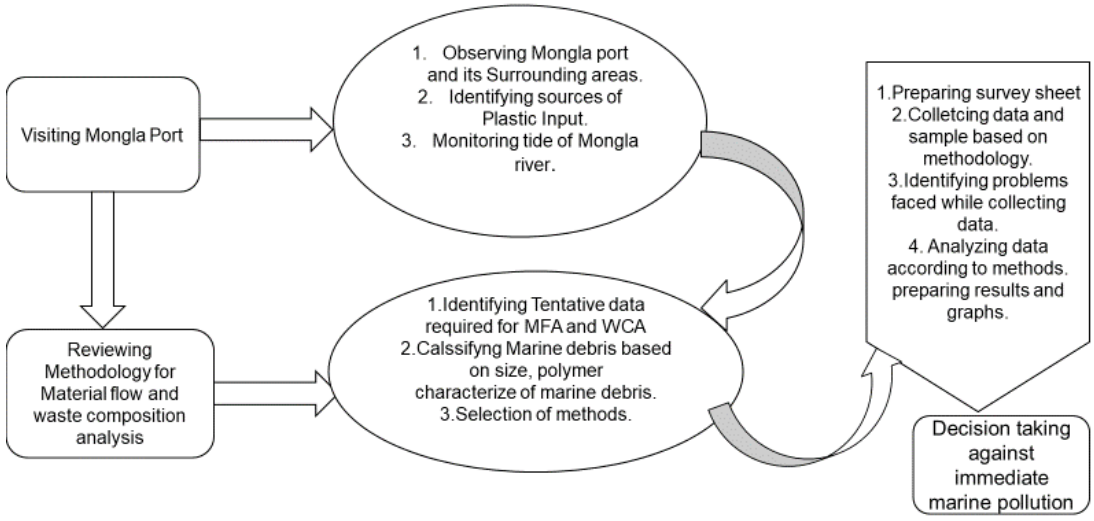

Figure 1: Flow diagram showing the methodology for "Case Study Mongla Port".

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Discussion Meeting between Mongla Port Authority and SCIP Plastics Project Team:

According to the methodology, the first step in completing this work was to visit Mongla Port, which is known to be a restricted region. Therefore, on September 2022, a discussion meeting involving high-ranking Mongla Port Authority officials and representatives from the SCIP Plastics Project was held. From these meetings access to Mongla Port was permitted, Mongla Port Authority will help SCIP Plastics Team by giving the necessary data required.

Discussion Meeting with the German Team for Data Collection and Analysis:

For the continuing process of "Case Study Mongla Port" work, bi-weekly meetings were held between SCIP plastics BUW side and KUET side along with the CUET side. These meetings were mainly focused to review the literature and finding a methodology for data collection and how the work will be continued. Table 1 shows the meeting log, where several meetings were conducted and will be conducted for the "Case Study at Mongla Port". Based on these meetings Mongla Port was visited, a meeting with the ship chandler was conducted, and a waste flow diagram was made.

Table 1: Meeting log for "Case Study Mongla Port"

Date	Topic	Remarks
August 2022	Organizational topics: Literature management software, Reporting vs. Master plan, Project wiki, the potential involvement of ISOE expertise	Detailed introduction of information collected so far regarding material flow analysis, and waste composition analysis. Approach towards activities and Mongla Port logistics were discussed.
August 2022	A short talk about preparing a meeting with Scientific Supervisors and the Project Lead on the 1st of September about a detailed work plan and responsibilities	Preparation and internal discussion for the ISOE meeting on the 25th of September Discussion about the current status and difficulties to get access to Port Authorities
September 2022	Presented the Survey Sheet and Waste Flow Diagram to Dr. Thomas and the other members. Outline a tentative boundary as the Study area	The decision was to find the data of the Survey Sheet from the literature if we cannot find the data from Ports.
October 2022	Report regarding a meeting with Port Authority Chattogram and the current status and field trips to Mongla Port	Agents collect waste as a service but foreign ships usually bring their waste to Chattogram Port before No waste handling facility within Mongla Port yet, planned for 2024
November 2022	Waste Flow Diagram for the Mongla Port (WFD_M) based on previous visits & meetings at Mongla port. reports collected from Mongla port & Rafia Traders (one of the vendors or ship chandlers) were presented. Waste Flow Diagram for the Chattogram Port (WFD_C) based on their visits & meetings at Chattogram port.	Inclusion of land-based wastes in WFD_M Identification of vendors & Sub-contractors lists and their overall activities for both the ports Infer economic side, recycling (if any) of both the ports? The water-based & land-based wastes are focused in the WFD_M.
November 2022	Waste Flow Diagram for the Chattogram Port (WFD_C) based on their visits & meetings at Chattogram port.	Focus on foreign ship wastes for now Include legend in WFD_C Develop a graphic that shows stakeholders and their interconnection (e.g. shipping company/ foreign ship --> calls ship agent -->

		contacts port --> sends vendor to ship --> collects waste ...)
November 2022	Waste Flow Diagram for Mongla Port (WFD_M) based on visits & meetings at the port. Discussion on data availability and "black boxes" (unknown remaining waste) in the diagram, options on how to get/generate data	Graphic overview/process diagram which shows waste collection from foreign ships including stakeholders and their interconnection (e.g. shipping company/ foreign ship --> calls ship agent --> contacts port --> sends vendor to ship --> collects waste ...) The vendor's list can only be obtained via the Traffic Department

Study Area:

The Port of Mongla is a link seaport in Mongla Upazila, Khulna Division, Bangladesh. It is a seaport of Khulna city to the north. It is Bangladesh's second-largest and busiest seaport. It is located near the coast of the Bay of Bengal and the Pashur River. Mongla is well-known as one of the most important ports in the Bengal delta. In this study, only the Mongla Port Jetty area (Figure 2) has been selected due to the ship calling the port to unload its cargo or container here.

Figure 2: Map of Study Area (Google Earth)

Types of wastes according to MARPOL Annex V:

According to the international convention MARPOL 73/78 of the International Maritime Organization, solid wastes have been categorized as MARPOL ANNEX V (IMO, 2014).

Table 2: Types of Wastes according to MARPOL Annex V (Source: Mongla Port Authority & (IMO, 2018)

Symbol	Waste type	Symbol	Waste type
A	Plastics	G	Animal carcasses
B	Food Wastes	H	Fishing gear
C	Domestics Wastes	I	E-waste
D	Cooking oil	J	Cargo residues (non-HME)
E	Incinerator ashes	K	Cargo-Residues (HME)
F	Operational wastes		

Data Collection:

Ship waste data from January to September 2022 has been collected from the traffic department of Mongla port Authority. Table 3, shows which types of data will be collected from Mongla Port and were collected from Mongla Port. To know about the waste flow three foreign ships have been visited (MV ANK AUN, MAERSK, and XIN LING) and two local ships have been visited (Marine -5 and Newtec) on October 2022The surrounding area of Mongla Port has been observed. Questioner survey has been conducted with ship chandlers.

Table 3: Required Data Types

Types of data	Information	Collected
Mongla Port Access	Getting permission for entering a Restricted port area	Could visit Mongla Port jetty, Cargo loading – Unloading area.
Ships generated wastes data	2022 to 2024 can be collected	2022 (January to September)
Ships calling to Mongla port	Availability of Foreign ships in Mongla Port	Three ships have been visited
Ship chandler information	Chandler is collecting waste and doing other work on ships	From July to September 2022, information have been collected
Cargo & ships handled at Mongla Port	2009-2010 to 2023 -2024 can be collected	2009-2010 to 2022 -2023 (up to Sep 22) have been collected
All ships information	2009-2010 to 2023 to 2024 can be collected	2009-2010 to 2022 -2023 (up to Sep 22) have been collected
Local ship	Open access visit the local ship and gathering information about them	2 ships have been visited
How much waste is produced in Mongla Port (Restricted area)	For material flow analysis, this data can be collected	Will be provided later
Information about the cleaner working in the Mongla Port	Mongla Port office cleaner and Mongla Port (Restricted cleaner) are different.	Will be provided later
Where Port wastes are being Dumped	–	Mongla Port Municipality
Monthly how many ships take Mongla Port facilities, or call ship chandlers	Will be provided later	Will be provided later

Material Flow Analysis:

Using the principle of conservation of mass, the net change of a particular material stock is given by the total inflows minus the total outflows from the stock (Brunner & Rechberger, 2016).

$$\sum INPUT = \sum OUTPUTS + \Delta STOCK \ldots\ldots\ldots\ldots\ldots (1)$$

Here inputs are the goods coming to the ships; outputs are the generated waste and stock change is the goods change the duration of the ship staying in the mongla port.
Using this mass balance method and STAN software material flow analysis of waste generated in the ship will be done.

RESULTS AND DISCUSSION

Ship Visit:

It was found that the ships that come to port are bulk cargo ships, vehicle carrier ships, and container ships which is shown in Figure. 3. Table 4 shows the voyage time of local ships and foreign ships which was found by interviewing ship crew members.

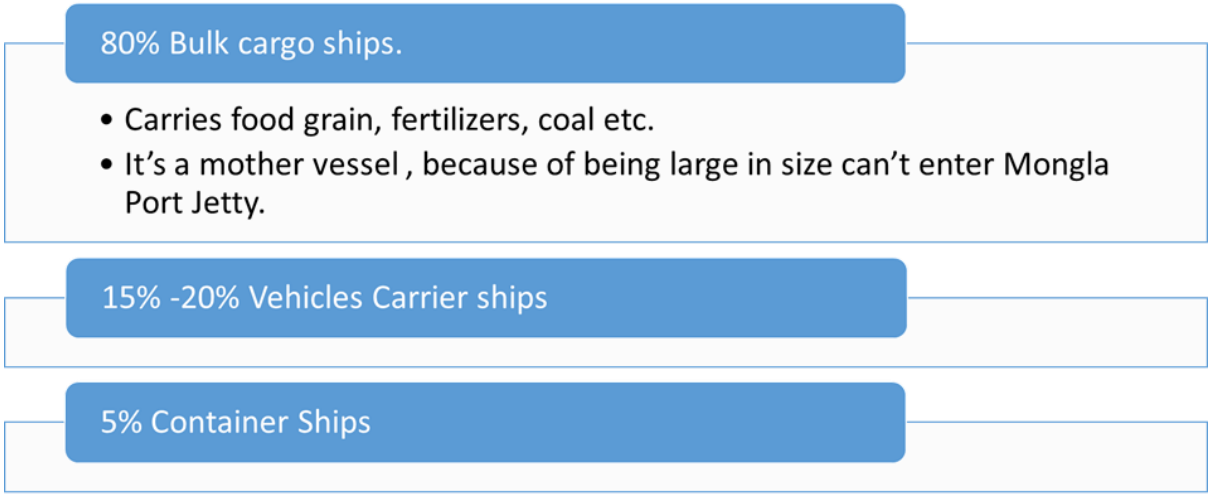

Figure 3: Ship Information

Table 4: Voyage time of foreign and local ships

Foreign Ship		**Local Ship**	
Port Name	Voyage time (days)	Port Name	Voyage time (days)
Mongla to Malaysia	5	India to Sheikhbari	4
Malaysia to Singapore	3 to 4	Sheikhbari to Mongla Port	1
Singapore to China	2		
China to Malaysia	3 to 4		
Malaysia to Bangladesh (Chattogram port or Mongla Port)	5		
Total voyage time	18 to 20	Total voyage time	5

Foreign Ship visit:

Three different ships namely XIN ZIL ANG5, MV ANK AUN, and MAERSK were visited on October 2022 to investigate the respective waste management protocols.

XIN ZIL ANG5

The whole crew of the dredging vessel XIN ZIL ANG5 is from China. There were 22 crew members in total. There were two water purification systems on board the ship, one for cleaning river water to produce drinkable water and the other for purifying bathroom and kitchen water to use for other uses. Every ten days, garbage is collected by ship chandlers, who are chosen by the shipping firm. The

amount of garbage produced by that ship ranged from 0.3 m3 to 0.5 m3. They strictly adhere to MARPOL ANNEX V; however, they do produce a little amount of food waste due to the proverbial "you have to consume every food" mentality that is prevalent in China. XIN ZIL ANG5 ship visit is shown in Figure 4.

Figure 4: XIN ZIL ANG5 ship visit

MV ANK AUN

The Turkish ship MV ANK AUN was a machinery carrier. It transported building supplies and electrical cables for "The Rooppur Nuclear Power Plant" in 601 bundles totaling 2581 tons. According to the MARPOL ANNEX V waste classifications, there were six rubbish containers available in the garbage collection area on the ship deck shown in Figure 5.

Figure 5: MV ANK AUN ship garbage collection area and categorized wastes bins

MAERSK

The container ship MAERSK originated in Malaysia. There are 15 to 20 days in total for the expedition. It spent 48 hours in the Mongla Port. 22 Filipino crew members were working on the ship. The ship was 168 meters long and 36 meters wide. Each container was 9 feet 6 inches in length, and

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each row had six containers. The ship could accommodate 2080 TUS. The waste containers were set up per the MARPOL ANNEX V waste categories, and the place for garbage collection was on the deck shown in Figure 6. When there is too much waste and it cannot be transported to a port, it is compressed into little pieces and placed in the designated bins. It had disposed of trash at the port of Chittagong, which is equivalent to 20 to 25 geo bags. The task of gathering and disposing of these wastes is performed by ship chandlers. 3500 tons of water, 500 tons of fuel, one month's worth of food, as well as first aid supplies and medication, were kept on board for the crew members.

Figure 6: MAERSK ship garbage collection area and categorized wastes bins

Local Ship visit:

Two local ships were visited on October 2022, both of which belonged to the "Deya Shipping Company" and had arrived from India. These ships were anchored in the Pashur River rather than the Mongla Port jetty.

Marine-5

This ship generates oil waste primarily as a result of water entering the engine room, and they dumped the mixed oil water into the river. Furthermore, the goods they carried were fly ash, slag, clinker, and lime, and some of these goods remained on the ship after they were unloaded. "Our hatch size in the ship is 500 tons, and the waste remaining from fly ash is around 1 ton, which is not valuable to us," said the ship's driver of Marine-5. As a result, we dump this waste into the river. However, clinker is a valuable waste that remains in the hatch and weighs about 500kg, which we sell." They dump their food waste into the river but store and sell plastic water bottles. Every month, approximately ten bottles were stored.

Newtech

In this ship, a different scenario was observed. "He had completed DPTC courses Class IV and Class V," said Ship Driver of Newtech. He learned from there that any waste should not be thrown into the river because it pollutes it. He also learned how to be environmentally friendly by separating waste and disposing of it properly. That's why now he has two separate bins, one for food waste and another for plastic water bottles". These plastics were sold to nearby land or port vangari shops, and food waste was dumped on a nearby river bank or at a secondary disposal point.

Waste Composition analysis:

From 2022 till date total waste generated on 35 ships was 102.67m^3 where 30.66m^3 plastic waste, 20.07 m^3 of food waste, 25.04 m^3 of domestic waste, 1.73 m^3 of cooking oil, 16.6 m^3 of incinerator waste, 5.54 m^3 operational waste, 0.5 m^3 of animal carcasses, 0.6 m^3 fishing gear and 2.23 m^3 of E. Waste. The season does not have many effects on waste generation and it was observed that Plastic waste is produced more than any other waste in the ships. The result shows that among the total waste 30% of plastic waste has been produced which is shown in Figure 7.

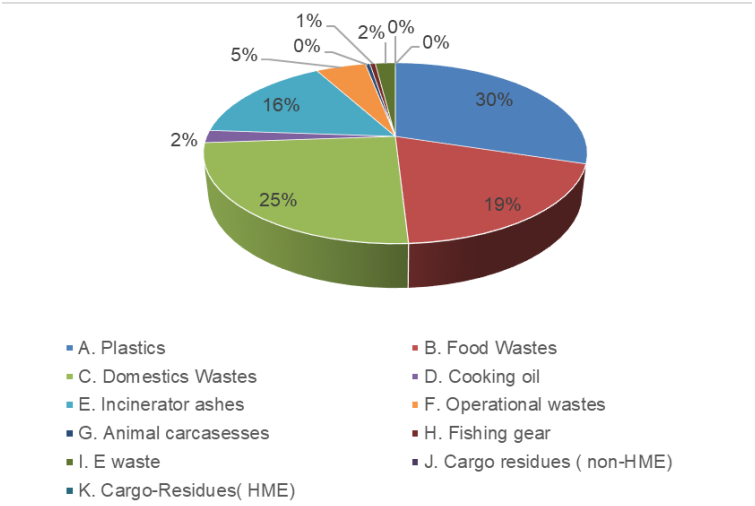

Figure 7: Waste Composition Analysis of Ship-Generated wastes

Material Flow Analysis:

From visiting foreign ships and questionnaire surveys of ship chandlers it was found that there is a garbage collection area in all foreign ships where wastes are put in different types of waste bins. These different types of waste are categorized as MARPOL ANNEX V as shown in Figure 6 and Figure 7. Then these wastes are collected by ship chandler and they weigh the wastes and dumped them into Mongla Port Municipality. Sometimes they throw food waste into the river, they sell the plastic valuable waste in recycling shops in Mongla Port Municipality The foreign ships' cargo is unloaded in the restricted area of Mongla Port (shown in Figure 8 with blue line) while unloading from cargo and loading into the trucks a small fraction of wood and plastic remains as residual from in the port area. It is generated due to the vibration of cargo unloading from ships. These residues are cleaned by the cleaners hired by Mongla Port and dumped into the Mongla Port Municipality which is shown in Figure 8. The blue line with question marks shows that it is unknown whether or not the port cleaners dump these fractional wastes directly into the river. Local ships major sells their plastic waste which is PET bottles to fariwala and dump food waste into the river, sometimes on the river bank shown in Figure 8.

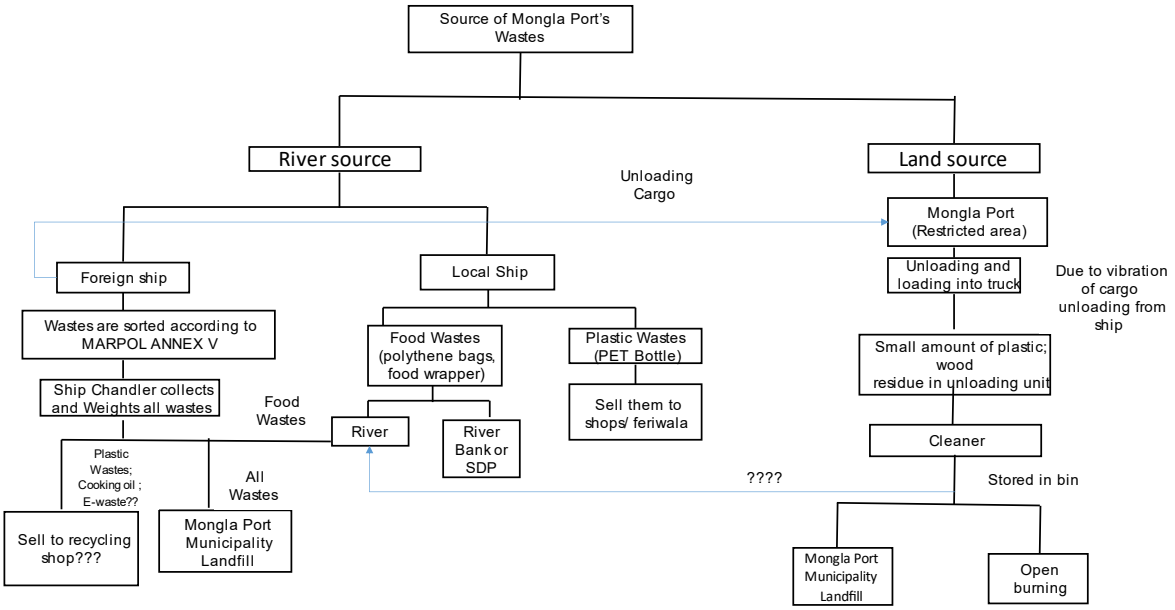

Figure 8: Waste flow diagram in river source and land source

CONCLUSIONS

Being a riverine country connected with the Bay of Bengal, Bangladesh has most of its international national imports and exports via ships. Mongla Port being the second-largest port in Bangladesh and located near the Sundarbans mangrove forest has become vulnerable due to excessive marine waste due to extensive import and export activities. Waste from foreign ships was gathered by ship chandlers, who subsequently dumped it at the Mongla Port Municipality However, it was identified that in the year 2022, 2.33% to 3.5% of foreign ships required ship chandlers to collect waste, and accordingly, 96.5% to 97.67% of foreign ships didn't contact ship chandlers for collecting wastes. This suggests that these ships might discharge their garbage into the Pashur River. Additionally, it was found that 2.33%–3.5% of ships produce 102.67 m^3 of waste in total, with plastic making up about 30% of that amount. However, the local ship divides its waste into two categories: food waste and plastic water bottles. They sometimes discard these food wastes on the riverbank nearby before selling plastic bottles to fari wala. The Mongla Port Authority must develop a suitable plastic waste management plan for ships otherwise there is a substantial likelihood of ecological imbalance occurring in both the Pashur River and the Sundarbans. The Khulna-based Mongla Port's procedures for managing plastic trash are being influenced by the SCIP plastics project initiatives. It plays a significant part in the material flow analysis of ship-generated waste at Mongla Port because the project will aid in the creation of an ideal master plan for reducing marine debris at harbors, actions against immediate marine pollution, and a master plan with countermeasures for direct input of plastics into the water body. It will also assist in developing port welcome facilities in Mongla Port.

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