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Safe and Environmentally Sound Ship Recycling in Bangladesh
Work Package 2: Planning the management of hazardous materials

Hazardous Waste Assessment Report

Baseline, Methodology and Inventory

July 2016

Service supplier:

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Table of Contents

1. Glossary

AUW	Asian University of Women
APC	Air Protection Control
BRS	Basel, Rotterdam and Stockholm Conventions
BSCIC	Bangladesh Small and Cottage Industries Corporation
BELA	Bangladesh Environmental Lawyer's Association
BUET	Bangladesh University of Engineering and Technology
BSBA	Bangladesh Ship Breakers Association
CCC	Chittagong City Corporation
CDA	Chittagong Development Authority
CEPZ	Chittagong EPZ
CD	Customs Department
CPA	Chittagong Port Authority
CCCI	Chittagong Chamber of Commerce and Industries
CETP	Common Effluent Treatment Plant
CFC	Chlorofluorocarbons
EU	European Union
ETP	Effluent Treatment Plants
EPZ	Export Processing Zone
EIA	Environmental Impact Assessment
FBCCI	Federation of Bangladesh Chambers of Commerce and Industry
GEPIL	Gujarat Enviro Protection and Infrastructure Limited
HW	Hazardous Waste
HCB	Hexachlorobenzene
HCFC	Hydrochlorofluorocarbons
ILO	International Labour Organization
IMO	International Maritime Organization
ISRA	International Ship Recycling Association
IFESCU	Institute of Forestry and Environmental Sciences
IUCN	International Union for Conservation of Nature
KEPZ	Karnaphully Export Processing Zone
LDT	Light Displacement Tonnage
MCC	Model Custom Collectorate
MEA	Multilateral Environmental Agreements
MARPOL	International Convention for the Prevention of Pollution from Ships, 1973
MT	Metric Tonne
MOI	Ministry of Industries
MOC	Ministry of Commerce
MOEF	Ministry of Environment and Forests
MEA	Multilateral Environmental Agreements
MSW	Municipal Solid Waste
NGO	Non Governmental Organization
NORAD	Norwegian Agency for Development Cooperation
NBR	National Board of Revenue
NEMAP	National Environmental Management Action Plan
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated Biphenyl

POP	Persistent Organic Pollutants
RECP	Resource Efficiency and Cleaner Production
SBRI	Ship Breaking and Recycling Industry
SBRB	Ship Building and Ship Recycling Board
SRFP	Ship Recycling Facility Plan
SBC	Secretariat of the Basel Convention
SLF	Sanitary Land Filling
SOLAS	International Convention for the Safety of Life at Sea
SENSREC	Safe and Environmentally Sound Ship Recycling
TSDF	Treatment, Storage & Disposal Facilities
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
YPSA	Young Power in Social Action

2. Executive summary

The Safe and Environmentally Sound Ship Recycling (SENSREC) project is designed to enhance the development of safe and environmentally sound ship recycling in Chittagong, Bangladesh, with the aim of improving the standards and therefore the sustainability of the industry. Work package 2 addresses the development of downstream hazardous waste management capacity in the Chittagong region. With this aim in mind, an inventory of hazardous waste has been conducted in the ship recycling industry and neighboring industrial areas of the city.

The current report presents the results of this inventory, following which, design options and costings for hazardous waste management infrastructure will be developed, along with business cases to assist government and industry to establish the requisite infrastructure.

Methodology

The scope of this project encompasses two industrial perimeters: the ship recycling facilities and the other industrial sectors in Chittagong, both of which strongly differ in their evolution and dynamics as regards to their administration, regulation and economics. Therefore, two different approaches were adopted for inventorization and estimation of the hazardous wastes from both the ship recycling facilities and for the industrial areas, respectively.

Data on ship recycling activity in Chittagong was provided by the Bangladesh Ship Breakers Association. The inventory of hazardous wastes from the ship recycling industry was derived on the basis of benchmarks from similar countries, mainly India. Indian waste generation factors from ships[1] were used in combination with the average ship recycling activity that took place in Bangladesh between 2009 to 2015. The Indian waste generation factors were slightly modified to account for the certain waste types that have been actually reused and not disposed of in Chittagong.

In addition, the inventory of hazardous waste was compiled for the respective industrial sectors in Chittagong - which was based on the methodology presented in the SBC Guide[2]. This inventory corresponds to a *first generation inventory* as defined by the Guide, *i.e.* an inventory being undertaken in a setting where policies pertaining to management and regulation of hazardous wastes are in early stage of development.

The sectors were selected based on their pollution category assigned by the Department of Environment, as well as inputs collected during Stakeholder Consultation Workshops in August 2015. Data on hazardous wastes were collected from representative industries selected from the significant industrial sectors.

To ensure representativeness of the samples, the number of industries of a given sector surveyed represented at least 10% of the total number of industries of the sector in

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[1] Hiremath, A.M., Tilwankar, A.K. and Asolekar, S.R. *et al.* 2015. Significant steps in ship recycling vis-a-vis wastes generated in a cluster of yards in Alang: A case study. Journal of Cleaner Production 87, pp : 520-532.

[2] *Methodological guide for the development of inventories of hazardous wastes and other wastes under the Basel Convention*", 2014, Secretariat of the Basel Convention (Document UNEP/CHW.12/9/Add.1)

Chittagong's industrial areas. Data on hazardous waste were collected through a questionnaire from the surveyed industries. In cases of missing or unreliable data, benchmarks available in literature were used for the waste calculations. Finally, the data were extrapolated to the whole of the industrial area based on the total capacity installed by the respective sector in the study area (City of Chittagong and the surrounding industrial clusters in the adjoining peri-urban areas). The following industrial sectors were focused on:

- Textile
- Tannery
- Fertilizer
- Paper Mill
- Chemical, Pharmaceutical and Pesticide
- Paint and Varnishes
- Petroleum Refinery
- Cement Industry
- Rerolling mill (Auto)
- Cable industry
- Glass industry
- Healthcare institution
- Chittagong Port

Medical waste generation was computed based on the total number of beds available in various healthcare institutions of the city. In addition, available information was collected from the Chittagong Port Authority on the amount of waste generated from ships.

After completion of the inventorization process, some verification activities were conducted. These included: on-site visits to key industries to understand the nature of their wastes and the corresponding hazardous waste compositions, chemical analyses of selected waste samples, evaluation of the reported use of the certain waste streams and determining whether those were to be disposed of or in fact have any gainful use (*e.g.* in another industry) based on the current practices of management and general criteria of such wastes.

To ensure that the inventory results could be used for the planning of hazardous waste management infrastructure, the resulting hazardous waste categories were then classified between landfillable wastes and incinerable wastes.

Inventory of Wastes Generated by Ship Recycling Yards

The table below presents the results of the inventorization of wastes generated by the ship recycling yards in Chittagong:

Table 1 Estimates of hazardous waste quantities generated from the Chittagong ship recycling yards (MT/year)

Type of hazardous waste	Total (min-max)
Landfillable waste (both toxic and inert)	7'500-10'300
Incinerable waste	5'400-6'400
Bilge water	5'600-6'300
TOTAL	**18'500-23'000**

Landfillable hazardous wastes consist of asbestos and asbestos containing materials (2'100-2'800 MT/year), glasswool (1'300-1'700 MT/year) and other landfillable wastes including rusted iron scales, ceramic, incinerator ash, *etc.* (4'100-5'800 MT/year). These results show the range of hazardous wastes likely to be generated in current conditions in the Chittagong ship recycling industry.

It should be noted that the hazardous wastes generation from the ship recycling yards depends on two factors: the number of ships dismantled in the country and the quantity of hazardous waste contained in the dismantled ships. Both factors fluctuate considerably. The average of the recycling activity was computed for the years 2009-2015 to reflect the fluctuation in number of ships dismantled. The fluctuation of the quantity of hazardous waste contained in the dismantled ships was reflected by using low and high estimate waste factors.

In addition, both factors – the number of ships dismantled in the country and the quantity of hazardous wastes contained in the dismantled ships – may evolve differently in the future. The implications of the Hong Kong Convention and the EU Regulation on the ship recycling sector in Chittagong in general and more particularly on the number of ships arriving for recycling in future in Bangladesh is unclear.

Inventory of Wastes Generated by Industries

In the industrial areas, landfillable wastes primarily consist of the sludges from effluent treatment plants that are not suitable for incineration. Incinerable wastes include contaminated packaging materials, contaminated plastics and contaminated solid wastes, as well as toxic sludges generated by effluent treatment plants in individual industries or clusters and contain significant amounts of chemicals, solvents, cleaning agents and heavy metals.

The major hazardous waste generating sectors are:

- the iron and steel industry (re-rolling mills): tundish lining, APC dust
- the textile industry: contaminated packaging and contaminated ETP sludge
- the fertilizer industry: contaminated solid waste
- refineries: oily crude tank sediments
- the chemical industry: contaminated solid waste, contaminated ETP sludge
- tanneries: contaminated solid waste, contaminated ETP sludge
- healthcare institutions: medical waste

The verification process conducted after completion of the inventory led to a more exact interpretation of the hazardous nature of the waste reported and allocation to the most suitable treatment option. In some cases, it turned out that some waste streams were in fact not hazardous, or that they were currently used in another industry. Such waste streams were taken out of the hazardous waste management options.

Table 2, as shown below, details the results of inventorization of wastes generated by the industries in Chittagong (this table is depicted as Table 17 in section 7.2 of the detailed report).

Table 2 Estimates of hazardous wastes generated by waste type and treatment technology

Waste type	Total generation (MT/year)	Incineration (MT/year)	Toxic waste landfill (MT/year)	Inert landfill (MT/year)	Alternate gainful use / MSW landfill (MT/year)
Tundish lining	25'192				25'192
ETP sludge	19'165	3'443	324		15'397
APC Dust	11'131				11'131

Contaminated solid waste	3'965	3'965			
Contaminated packaging	3'626	3'626			
Oily crude tank sediments	1'459	1'459			
Contaminated plastic waste	1'282	707			575
Bleaching earth	910				910
Spent Lubricants	251	251			
Flesh	222				222
Maintenance scrap	124	124			
Oil and grease	89	89			
Chemical residues	88	88			
Trimming dust	72				72
Raw hides cutting	66				66
Shaving dust	54				54
Asbestos	40			40	
Other contaminated materials	25	24		1	
Glasswool and insulation material	8			8	
Total	**67'768**	**13'777**	**324**	**49**	**53'619**
Episodic and aperiodic waste	678	138	3	0	536
Grand total (Rounded–off)	**68'500**	**14'000**	**400**		**54'100**

In addition to the results shown above, biomedical waste generation from the hospital and health sector is estimated at 800 MT/year.

Conclusion

This assessment provides a useful picture of the hazardous waste situation of the ship recycling industry and surrounding industrial area of Chittagong, which can now serve as a basis for the next steps of the project, namely the planning of hazardous waste treatment and disposal infrastructure.

The table below shows the results of the inventorization of wastes generated by the ship recycling yards and the considered industrial areas in Chittagong (this table is depicted as Table 20 in section 8 of the detailed report).

Table 3 Approximate estimates of hazardous waste quantities generated from the Chittagong ship recycling yards and Chittagong industrial area (MT/year)

Type of hazardous waste	From the ship recycling yards (min-max)	From the industrial area	Medical waste	Total (min-max)
Landfillable waste	7’500-10’300	400#	-	**7’900-10’700**

(both toxic and inert)				
Incinerable waste	5’400-6’400	14’000[#]	800	**20’200-21’200**
Bilge water	5’600-6’300	-	-	**5’600-6’300**
TOTAL	**18’500-23’000**	**14’400[#]**	**800**	**33’700-38’200**

Refer to Table 2 for a further breakdown of these wastes

It is important to note here that this picture can evolve very fast depending on the arrival/growth/departure of big industrial players as well as changing production processes and input materials. In addition, in the absence of a legally enforced waste reporting system, the extent to which data is collected strongly depends on the willingness of the relevant stakeholders to share data.

The quality of the data also depends on the respondents’ understanding of the hazardous nature of their wastes. Thus, the importance of developing local competencies and know-how on hazardous waste identification and treatment will continue to grow in the future years. The final responsibility is for the future facility operator to capture the waste streams adapted to each landfill cell or incineration system.

An understanding of waste composition and its hazardous substance content requires specific knowledge of each industrial process and/or laboratory analysis. For this particular reason, what is important is to launch appropriate Treatment, Storage and Disposal Facility to give the opportunity for generators to follow best practices and develop specific skills.

3. Introduction

3.1 Project background and objectives

The Safe and Environmentally Sound Ship Recycling (SENSREC) project in Bangladesh is designed to enhance the development of safe and environmentally sound ship recycling in Chittagong, Bangladesh, with the aim of improving the standards and therefore the sustainability of the industry. The overall project is led by the Ministry of Industries of the Government of Bangladesh with technical support from the International Maritime Organization (IMO) and project funding from the Norwegian Agency for Development Cooperation (NORAD).

Work Package 2 of the project on planning the management of hazardous materials is managed by the Secretariat of the Basel, Rotterdam and Stockholm Conventions (BRS) with funding provided by the European Union. Work package 2 addresses the **development of downstream hazardous waste management capacity**. The same project is also developed in parallel in Pakistan.

While incremental steps are being taken to improve environmental and worker health and safety standards in the industry, particularly at the recycling facilities themselves, the ship recycling process cannot be environmentally sound unless suitable downstream infrastructure for the disposal of hazardous and other wastes is established.

For this reason, work package 2 (WP2) of the SENSREC project focuses on the development of inventories of hazardous waste in Bangladesh in the region where ship recycling takes place (Chittagong), looking beyond the wastes from ship recycling alone, and also encompassing other industrial activities in the Chittagong industrial area. Following the development of the inventories, design options and costings for hazardous waste management infrastructure will be developed, along with business cases to assist government and industry to establish the requisite infrastructure.

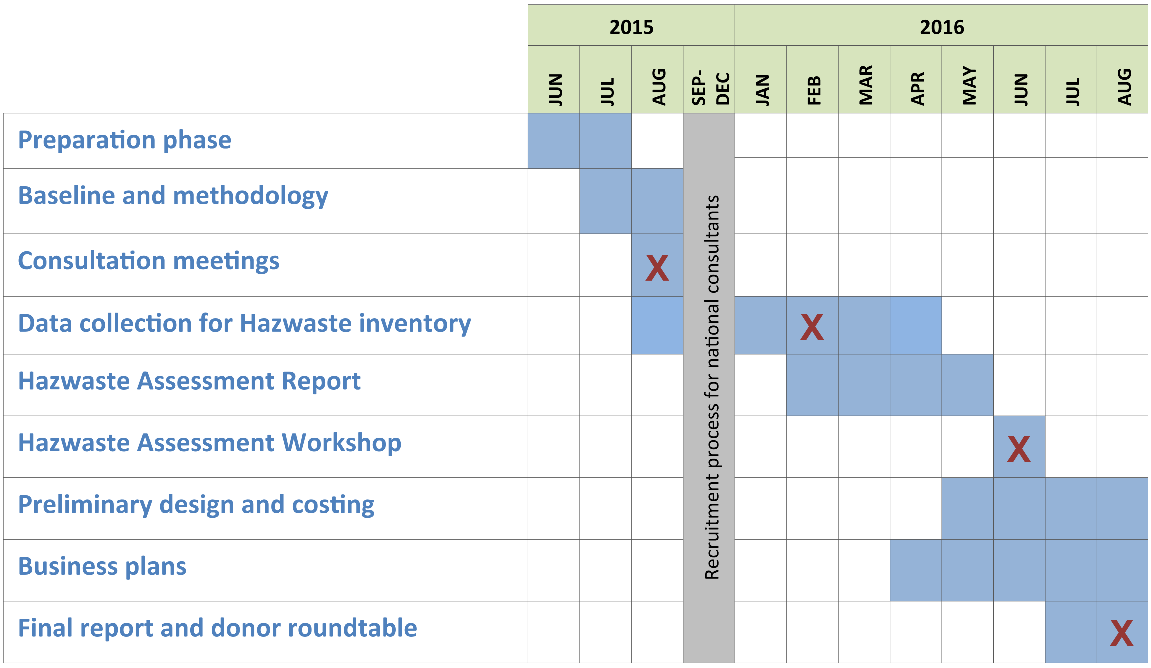
Sofies SA, an international consultancy company specializing in sustainability and waste issues, was retained in June 2015 through a competitive tendering process to undertake the different activities of WP2. A Senior National Consultant, supported by a Junior National Consultant, have been engaged through UNDP in Bangladesh in February 2016 to ensure local coordination, perform data collection tasks and feed local knowledge from Chittagong into the project.

The purpose of this report is to explain the approach for the inventory of hazardous waste generated both from ship recycling activities and industrial activities, and to present the results derived from the data collected.

3.2 Project milestones

A Stakeholder Sensitization meeting took place on 10 and 12 August in Dhaka and Chittagong, respectively, in which all project partners gathered to launch the project and discuss the main challenges. The results of this meeting were synthesized into a first deliverable in December 2015.

The next figures show the updated project planning.



	2015				2016							
	JUN	JUL	AUG	SEP-DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
Preparation phase	▨	▨		Recruitment process for national consultants								
Baseline and methodology		▨	▨									
Consultation meetings			X									
Data collection for Hazwaste inventory			▨		▨	▨ X	▨	▨				
Hazwaste Assessment Report						▨	▨	▨	▨			
Hazwaste Assessment Workshop										X		
Preliminary design and costing									▨	▨	▨	▨
Business plans								▨	▨	▨	▨	▨
Final report and donor roundtable											▨	▨ X

X international consultant's missions

Figure 1 Updated project planning

3.3 Purpose of this report

The aim of the report is to present the hazardous waste inventory methodology and the results in terms of waste quantities to be managed.

By way of an introduction, the report also includes baseline information on the project area, the ship recycling-related regulations as well as background information about hazardous waste management.

The content of this report was circulated among project partners and discussed during the Hazardous Waste Assessment Workshop that took place on June 15th 2016 in Dhaka. Subsequently, a set of verification steps were undertaken to refine the results. The final outcomes are presented in the results section of this report.

4. Baseline

4.1 The Project Area

Chittagong is a major coastal seaport city and financial centre in southeastern Bangladesh. The city has a population of more than 2.5 million while the metropolitan area has a population of over 6.5 million, making it the second largest city in the country. The city is located on the banks of the Karnaphuli River between the Chittagong Hill Tracts and the Bay of Bengal.

Chittagong is a major hub of trade and industry. The Port of Chittagong is the largest international seaport on the Bay of Bengal. The city is home to many of Bangladesh's oldest and largest companies, as well as the Chittagong Stock Exchange and the world’s largest ship recycling industry, which stretches over 18 kms of coast North-West of the city.

Imagery ©2015 TerraMetrics, DigitalGlobe, Map data ©2015 Google 2 km

Figure 2 Map with localization of the project areas

4.1.1 Ship Recycling in Chittagong

The world-wide shiprecycling industry dismantles far **more than 1,000 large ocean-going vessels per year**, such as container ships, bulkers, oil and gas tankers and passenger ships, in order to recover steel and other **valuable metals or recyclable items**. Nearly all ship recycling activities are concentrated **in five countries: the three South Asian countries (India, Bangladesh, and Pakistan), China, and Turkey**. Further capacity is available in North America (US, Canada, Mexico) and within the European Union (amongst others Denmark, Belgium and the UK). At present, South Asia is undoubtedly the global centre for ship recycling.

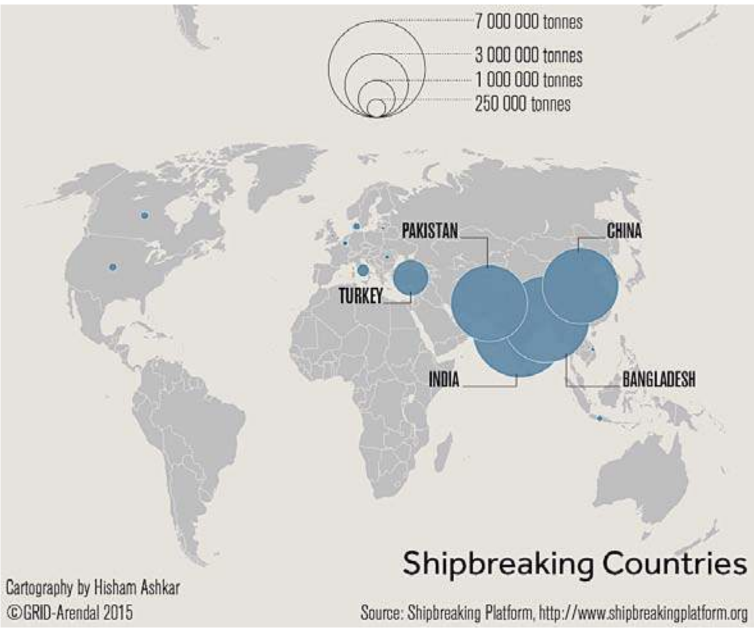


Figure 3: : Ship recycling Countries as stated on Shipbreaking Platform

Ship recycling in Chittagong started accidentally through the dismantling of Greek ship *M D Alpine* that was brought to shore near Fauzdarhat by the 1960's cyclone. It was dismantled in 1965 by Chittagong Steel House (Hossain et al, 2010). Subsequently, the Pakistani ship *Al Abbas* was salvaged, beached at Fauzdarhat and dismantled in 1974 by Karnafully Metal Works (Sujauddin et al, 2015).

These incidents draw the attention of a few entrepreneurs on the suitability of the coast line near Fauzdarhat for beaching. Over the years, the ship recycling industry in Chittagong has gone through lean and boom periods, to become the world's largest ship recycling industry in 2015 and now the ship breaking and recycling industry (SBRI) spans over 18 km coast of the Bhatoary-Fauzdarhat-Baroiyadhala area (Abdullah et al, 2010). SBRI consists of 150+ ship recycling yards, of which about 40 are in regular operation, another 40 are in intermittent operation and the rest are active occasionally or are closed. The industry directly employs over 200,000 laborers and accounts for the supply of half of all the steel products in Bangladesh.

Figure 4: Chittagong ship recycling yards (Source : Sofies SA)

A number of factors have pushed the growth of this sector over time which include the favorable beaching condition, the proximity of the beach to the industrial hub of Chittagong –

mainly the steel rerolling mills which consume most of the output from the industry, the availability of risk-taking entrepreneurs, access to abundant labour from the northern districts of Bangladesh, the weak legislative framework allowing the operation of the industry for decades even without it being considered as an industry (Sarraf et al, 2010), the high demand in the local market for scrap ferrous and non-ferrous metals and other cheaper items recovered from the industry (Gregson et al, 2010), access to finance from the formal financial institutions and informal money lenders, and the growth of a swarm of upstream and downstream industries forming an informal industrial symbiotic and inter-dependent network (Gregson et al, 2012) etc.

However, there is a list of objections against SBRI. The main objections are *poor labor management* due to the harsh work environment for the manual laborers, the lack of protective clothing and equipment, predominance of manual processes and a high rate of accidents (Saha et al, 2013; Hossain and Islam, 2006) along with *environmental damages* caused by poor hazardous waste management, coastal contamination, air pollution, the spread of hazardous materials into the environment, forest destruction etc. (Sarraf et al 2010, Muhibbullah et al, 2014, Sujauddin et al, 2015). Based on these objections, the Bangladesh Environmental Lawyer's Association (BELA) filed a petition to the High Court in 2008. This resulted in the order by the Bangladesh High Court directing the expert-supervised removal of hazardous wastes from ships before dismantling (Ahmed, 2011). It also ordered ship recycling yards to obtain Environmental Clearance Certificates (ECC) from the Department of Environment (DoE) in order to be allowed to import ships and the Government to formulate regulations to control SBRI. Due to the ruling by the High Court, in 2010, the import and dismantling of ships in Bangladesh was stopped. Ship recycling activities resumed a few months later. In 2011, the Ministry of Industry issued the Ship Breaking Waste Management Rules.

Currently, the SBRI is bound by the Ship Breaking and Ship Recycling Rules 2011 under the Ministry of Industry along with Environmental Protection Act 1995, and Environmental Protection Rules 1997 under the supervision of Department of Environment under the Ministry of Environment and Forest. The labor safety and the environmental management standards in the yards are showing signs of improvement - albeit slow. **The critical need right now from an environmental perspective is the establishment of a common waste management facility such as a treatment, storage and disposal facility** (TSDF) that may possibly include an incinerator and effluent treatment plant (ETP). Due to the improvements made, the flow of ships for dismantling has increased and for the last three consecutive years Bangladesh has become one of the global leaders in Ship Recycling.

4.1.2 Environmental impacts of the ship recycling industry in general and in Chittagong

Various techniques are used for ship recycling, with varying costs and degrees of environmental and social impacts associated (UNEP 2013):

Beaching	As its name indicates, in beaching, a ship is emptied of cargo and ballast, and is driven to a tidal flat on a high magnitude tide (spring tide). Following the stranding of the ship on the coast, the workers cut it into pieces, which are dragged closer to the beach. The beaching method may be unsuitable for the use of heavy lifting gear that can make the dismantling work safer. It also may not allow for containment of hazardous substances. Beaching is in the preferred method in Bangladesh, India and Pakistan.
Landing (or slipway)	This method involves driving the vessel onto the shore or on a concrete slipway connecting shore and sea. This method is typically used in areas where the tidal flow is low and easily predictable, thus facilitating the control and avoidance of spillage of toxic substances in the water. A mobile crane removes sections from the ship and the ship is progressively pulled further on the shore. Turkey practices the landing method.
Pier breaking (or along side)	The ship is immobilized on a wharf or quay in a sheltered harbour or river, and dismantled piece by piece in a top-down manner. A crane removes the pieces starting with the upper pieces, then the main body, until the bottom of the hull. The last piece may be lifted or sent to a dry dock for final cutting. Areas where pier breaking takes place are usually in calm water. This method is followed for instance in China and Europe.
Dry docking	The ship is driven to an enclosed, flooded dock, the water of which is subsequently pumped out. The ship is then dismantled piece by piece. This method provides a well-controlled environment in which dismantling activities are performed, and which minimizes the risk of environmental pollution. However the costs associated with dock building and maintenance are high and therefore dry-docking is presently rarely used for ship recycling

4.1.3 Chittagong industrial areas

Chittagong City Corporation (CCC) consists of 41 wards and is responsible for providing basic civic amenities to the city and also provides license for trade and industry. Another public authority, the Chittagong Development Authority (CDA) is also mandated with the development of the city in a planned manner.

Chittagong is a major industrial hub of Bangladesh and is home to a diverse range of industries, which are located in and around the city. The industries and plants are spread over a geographical area of about 160 km^2.

There are four old industrial zones within the metropolitan area which are Nasirabad heavy industrial area, Kalurghat heavy industrial area, Foujdarhat heavy industrial area and Patenga Heavy Industrial Area. In addition, there are two export-processing zones (EPZs) – the Chittagong EPZ (CEPZ) and Karnaphully EPZ (KEPZ). CEPZ has been established on a land area of 453 acres having 501 industrial plots where currently 167 industries are operational. KEPZ has a land area of 222.42 acres having 254 industrial plots where currently 57 industries are located (Table 4).

In addition, Bangladesh Small and Cottage Industries Corporation (BSCIC) has four industrial estates in different pockets of the city with 629 industrial plots which accommodates 273 operational and 26 dormant industries (Table 2)**.** On the opposite bank of the river Karnaphully, there are three fertilizer industries in the public sector along with a private EPZ and many private sector industries.

Chittagong port is the biggest port in the country, which supports the business prospects of these industries. Chittagong port handles almost 90 to 92 percent of the country's export and import.[3] As such, like every other international sea port, it accumulates or receives a considerable amount of waste.

Table 4: Export processing zones

EPZs	**Area**	**Plots**	**Operational**	**In the process of setting up**
Chittagong EPZ (CEPZ)	453	501	167	-
Karnaphully EPZ (KEPZ)	222.42	254	38	19
Total	675.42	755	205	-

Table 5: Industries in different Industrial Areas under BSCIC in Chittagong

BSCIC I/As	**Plots**	**Operational**	**Dormant**
Patiya	77	14	10
Kalurghat	71	29	3
Kalurgaht extended	255	120	7
Fouzdarhat	157	62	3
Sholoshahar	69	48	3
Total	629	273	26

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[3] http://cpa.gov.bd/

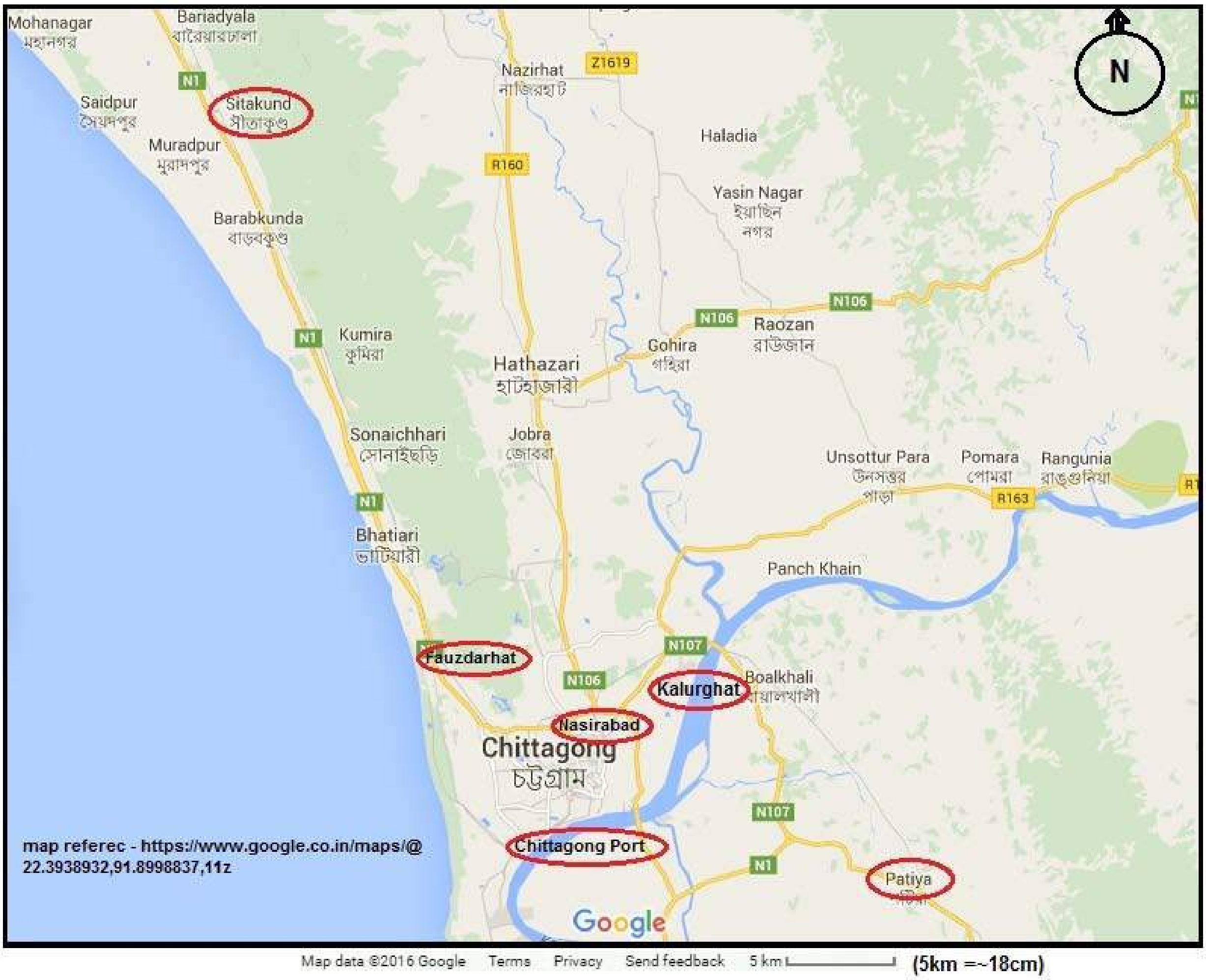

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Figure 5 Map of industrial areas considered in Chittagong

The Chittagong City Corporation (CCC) issues trade licenses for all types of industries and trading entities, which are renewed every year. However, a compiled updated list of such entities is not readily available on their website or in their office as a digitally summarized record. An estimate that is available on the government web portal of the Chittagong Chamber of Commerce and Industries (CCCI), based on a 2011 survey, states that in Chittagong there are 328 heavy industries, 4323 small and medium industries along with several other industries in nine sectors. 80 ship recycling industries were listed in 2011, against 152 (37 operating) in 2016. Table 6 shows a brief summary of the industries in Chittagong.

Table 6 Number of industries in Chittagong district (Source: CCCI, 2011)

SN	Category	Numbers (2011)
1	Heavy Industries	328
2	Small and Medium Industries	4323
3	Jute Mills	24
4	Government Textiles	5
5	Cement Industries	10

SN	Category	Numbers (2011)
6	Garments Industries and Textile Industries	647
7	Oil Refinery	1
8	Fertilizer Industries	3
9	Tanneries	19
10	Ship Recycling Industries	80
11	Ship Building Industries	30

4.1.4 Existing hazardous waste management facilities in the study area

The Chittagong City Corporation (CCC) is currently providing sanitary and waste management services to the city's residential, commercial and industrial areas. CCC's conservancy department collects and manages the municipal solid waste by using a fleet of vehicles, manpower and 3 dumping sites. Approximately 3000 people are engaged in the collection of recyclables from the landfill site and they are thus exposed to the associated hazards.

Figure 6 Location of the three dumping sites of Chittagong

A sizeable amount of industrial waste - including a considerable percentage of hazardous content - find its way into the waste stream which is handled by CCC. Unfortunately, CCC does not have any separate scheme for the management of industrial wastes except for medical wastes.

The management of healthcare wastes is still embryonic: only a few of the healthcare entities have an incinerator but those are seldom used. CCC has recently authorized a private entity – *Chittagong Sheba Sangstha* – to collect healthcare wastes from all healthcare entities on a contractual basis. DoE gives environmental clearances to the healthcare entities after confirming that they have signed contract with *Chittagong Sheba Sangstha*. They transport the hazardous biomedical wastes and dispose of it in the CCC's landfill site. Unfortunately, they follow open incineration at the landfill site and a bulk of the waste gets mixed up with municipal wastes.

Figure 7 Dumping site in Chittagong

In the industrial sector, some companies have reported to have dumping sites on private plots. A few of them (multinational firms) reported to have specific solutions for incineration: some chemical waste is sent to Lafarge-Surma cement plant accessible by boat in the north of the country (Sylhet), while one has recently installed an private incinerator on-site.

According to a report produced by TERA International (2004), the Port of Chittagong has developed a reception/disposal facility with two collection vessels, one for liquid wastes and the other for solid wastes, along with an oily water separation facility. Consultations with the port authority indicated that they are looking forward to ensuring better management of operationally generated waste from ships.

In addition to the above mentioned waste disposal sites, a large number of small to mid-range dumping sites are scattered around the city and in the vicinity of the industrial areas and the ship recycling yards.

4.2 Stakeholder Analysis

4.2.1 Government Organizations

Ministry of Industries (MoI)

Ministry of industries (MoI) is the central body for formulating; implementing; monitoring and updating appropriate policies related to industrial activities in Bangladesh. The functions of

MoI encompass determining and harmonizing national standards that are consistent with the international standards for commodities and services. It also oversees establishing, developing and regulating eco-friendly and safe industrial infrastructure.

Ship Building and Ship Recycling Board (SBSRB)

The “Ship Building and Ship Recycling Board” (SBSRB) is being established as the one-stop service provider under the MoI. Once operational, it will provide integrated services including granting required permissions and certificates for Ship breaking, recycling and other related activities in cooperation with other responsible departments and ministries.

Ministry of Environment and Forests (MoEF)

The Ministry of Environment and Forests was established in 1989 with a mission to ensure a sustainable environment and forests through conservation of ecosystems and biodiversity, to control environmental pollution and to address climate change. MoEF is principally responsible for conservation & survey of flora, fauna, forests and wildlife, prevention & control of pollution, forestation and regeneration of degraded areas and protection of the environment in the framework of legislation and monitoring and implementation of environmental agreements with other countries, international agencies and forums. Departments under MoEF include the Bangladesh Forest Department, Department of Environment (DoE), Bangladesh Forest Industries Development Corporation (BFIDC), Bangladesh Forest Research Institute (BFRI), Bangladesh National Herbarium (BNH) and Bangladesh Climate Change Trust (BCCT). The Ministry also plays a pivotal role as the Basel Convention competent authority and focal point in Bangladesh.

Department of Environment (DoE)

The DoE was placed under the MoEF in 1989 as its technical wing and is statutorily responsible for the implementation of the Environment Conservation Act, 1995. DoE is working to ensure sustainable environmental governance for pollution control. This department is solely responsible for issuing an ‘Environment Clearance Certificate’ (ECC) prior to the establishment of any industrial unit in Bangladesh and thus ship recycling yards as well. It also issues authorizations for handling hazardous wastes generated from ship recycling activities.

Ministry of Commerce (MoC)

The Ministry of Commerce is responsible for overall trade and commerce related activities of Bangladesh.

Customs Department

In cooperation with the SBSRB, the Customs Department visits a ship destined for recycling at the outer anchorage to check its inventory. Customs collect information about the personal effects of the crew, all stores and movable hazardous wastes/materials and gives its clearance for recycling only after being assured that the ship is not carrying any cargo or item that is contraband by Bangladesh laws.

Chittagong Port Authority (CPA)

Chittagong Port Authority (CPA) mainly provides necessary services and facilities to the port users efficiently and effectively at a competitive price. CPA issues a No Objection Certificate and beaching permission for a ship to be recycled upon reception of all required documents such as the Environmental Clearance certificate for the ship recycling yard from the DoE.

National Board of Revenue (NBR)

The National Board of Revenue (NBR) is the primary authority for tax administration in Bangladesh.

4.2.2 Industrial Organizations

Federation of Bangladesh Chambers of Commerce and Industry (FBCCI)

Federation of Bangladesh Chambers of Commerce and Industry (FBCCI) was established under the Trade Organization Ordinance, 1961 and Companies Act, 1913. This is the primary trade organisation of the country playing a pivotal role in a consultative and advisory capacity, safeguarding the interest of the private sector. The Chittagong Chamber of Commerce & Industry is a member of FBCCI.

Bangladesh Ship Breakers Association (BSBA)

Bangladesh Ship Breakers Association is a representative body of ship recyclers in Bangladesh established in 2003. This trade organization is working in the interests of ship recycling activities, safeguarding the rights of its members and ensuring environmentally sound ship recycling.

4.2.3 Academic Organizations

Several public and private universities in Bangladesh are carrying out research activities on ship recycling and related environmental impacts.

University of Chittagong

The nearest public university is the University of Chittagong. The Institute of Forestry and Environmental Sciences (IFESCU), Institute of Marine Science and Fisheries, Department of Sociology and other relevant departments conducted field surveys and have published scientific articles on different aspects of ship recycling. IFESCU has a collaboration with Tokyo University, Kanazawa University and Kwansei Gakuin University; under which there are several completed and ongoing research programmes on ship recycling.

Bangladesh University of Engineering and Technology (BUET)

The Department of Naval Architects is carrying out various related studies on ship recycling. It has active research groups and has organized a number of seminars and conferences on the issue.

4.2.4 Non-Governmental Organizations

NGO Shipbreaking Platform

The NGO Shipbreaking Platform is an international coalition of environmental, human and labour rights organizations campaigning to prevent end-of-life ships from being beached in developing countries. Active since 2005, it counts as its members organizations from both shipowning as well as ship recycling countries, including Bangladesh.

Bangladesh Environmental Lawyer’s Association

Bangladesh Environmental Lawyers Association (BELA) is a public advocacy group that has raised concerns over the activities of the ship recycling industry as being detrimental to the environment and human rights. Carrying out continuous movements, it has brought cases before the Supreme Court of Bangladesh, one of which resulted in the ban of all ship recycling activities not meeting adequate environmental standards in 2009.

Young Power in Social Action (YPSA)

YPSA is a voluntary, nonprofit, social development organization that has conducted several projects on ship recycling activities, covering its difficulties and prospects in the national economy and its impact on natural environment as well.

4.3 Regulatory Aspects

4.3.1 At International level

Hazardous waste issues are the purview of three international Multilateral Environmental Agreements (MEAs), namely the Basel and Stockholm Conventions and the recently adopted Minamata Convention on Mercury (which has not yet entered into force). The Hong Kong Convention that specifically relates to ship recycling is also important given the number of hazardous components in end-of-life ships, although it has not yet entered into force.

Basel Convention (Transboundary Shipments of Hazardous Wastes)

The “Basel Convention on the control of transboundary movements of hazardous wastes and their disposal” came into force in 1992. It has been ratified by 184 member countries (Parties) and aims at reducing hazardous waste generation at source, environmentally sound management of these wastes, and reducing and regulating transboundary movement of hazardous wastes. The Convention regulates the transboundary movement of hazardous waste to avoid the threat to human health and environment, due to its improper management. **This is of particular importance to the ship recycling industry.** The system is based on the concept of prior informed consent - the receiving country must be informed by the exporting country about the details of the movement and agree to it in a written format before the movement can actually take place (which should include an inventory of hazardous substances of the shipment). This also applies to countries through which the waste transits. Chemical safety datasheets should also be provided for the hazardous substances identified (UNEP 2013). The Convention was ratified by Bangladesh on 1st April 1993. Nevertheless, there have been difficulties in enforcing the provisions of the Basel Convention with respect to ships bound for recycling, resulting in the Conference of the Parties to the Basel Convention requesting the International Maritime Organization to develop a legally binding instrument on ship dismantling (the Hong Kong International Convention on the Safe and Environmentally Sound Recycling of Ships).

Stockholm Convention (POPs)

The “Stockholm Convention on Persistent Organic Pollutants” entered into force in 2004 with 179 member countries (Parties) ratifying the Convention. It aimed at eliminating or restricting the production and use of Persistent Organic Pollutants (POPs), which are "chemical substances that persist in the environment, bio-accumulate through the food web and might have adverse effects on human health and the environment". Persistent organic pollutants act as powerful pesticides and serve a range of industrial purposes. Nine of the POPs are pesticides. The Stockholm Convention differentiates between two categories of POPs: (a)

Intentionally produced POPs, whose production and use are to be eliminated (Annex A) or restricted (Annex B) and (b) Unintentionally produced POPs, for which Parties are required to take measures to reduce total releases derived from anthropogenic sources, with the goal of their continuing minimization and wherever feasible ultimate elimination (Annex C). Article 6 sets forth waste related provisions to reduce or eliminate releases of the listed POPs that includes developing strategies for identifying stockpiles and products containing POPs and taking appropriate measures to handle, collect and dispose of POPs containing and contaminated wastes in such a way that the persistent organic pollutant content is destroyed or irreversibly transformed so that they do not exhibit the characteristics of persistent organic pollutants or otherwise disposed of in an environmentally sound manner. The Convention was ratified by Bangladesh on 12th March, 2007.

Minamata Convention (Mercury)

The Minamata Convention is a global treaty that aims at protecting human health and environment from the adverse effects of mercury. It has 128 signatories[4] as at 19 January 2013. As of today, only 23 member countries (Parties)[5] have ratified the Convention. However, it will only come into force once 50 Parties ratify the Convention. In this regard, the UNEP Global Mercury Partnership plays a key role to assist countries in achieving timely and effective implementation of the Minamata Convention. The partnership consists of stakeholders from governments, industry, NGOs, and academia who are dedicated to protecting human health and the environment from the impacts of mercury. Bangladesh signed the Convention on 10th October 2013; but is yet to ratify the Convention.

Hong Kong Convention (Ship recycling)

The “Hong Kong International Convention for Safe and Environmentally Sound Recycling of Ships” (the Hong Kong Convention) was adopted in May 2009. **The Convention is aimed at ensuring that ships, when being recycled after reaching the end of their operational lives, do not pose any unnecessary risk to human health, safety and to the environment**. It has not yet entered into force as it needs to be ratified by 15 member states and the following two conditions need to be met: (1) representation by 40 per cent of world merchant shipping by gross tonnage and (2) a maximum annual ship recycling volume of not less than 3 per cent of the combined tonnage of the ratifying states. Currently, only 4 States have ratified it which represents 2.3% of the gross world merchant shipping tonnage. As ships contain several hazardous substances and are sent for dismantling across borders, the Hong Kong Convention is closely related to the Basel Convention.

EU Ship Recycling Regulation

Anticipating the entry into force of the Hong Kong Convention, the European Union adopted its own legislation on ship recycling (EU Ship Recycling Regulation) in December 2013. The objective of the Regulation is to reduce the negative impacts linked to the recycling of EU-flagged ships, especially in South Asia.

Other relevant international instruments and initiatives

a) The Basel Convention Technical Guidelines for the Environmentally Sound Management of the Full and Partial Dismantling of Ships were developed with the intention of providing guidance to countries which have, or wish to establish, facilities for ship dismantling. The

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[4] http://www.mercuryconvention.org/News/GlobalMercuryPartnershipReachingOut/tabid/4821/Default.aspx
[5] http://www.mercuryconvention.org/News/GlobalMercuryPartnershipReachingOut/tabid/4821/Default.aspx

guidelines provide information and recommendations on procedures, processes and practices that must be implemented to achieve Environmentally Sound Management (ESM) at such facilities. The guidelines also provide advice on monitoring and verification of environmental performance.

b) **MARPOL**: The International Convention for the Prevention of Pollution from Ships covers the **prevention of pollution of the marine environment by ships from operational or accidental causes**. The Convention includes regulations aimed at preventing and minimizing pollution from ships - both accidental pollution and that from routine operations - and currently includes six technical Annexes, including Annex I Regulations for the Prevention of Pollution by Oil and Annex II Control of Pollution by Noxious Liquid Substances in Bulk.

c) The '**Safety and Health in Ship Breaking – Guidelines for Asian Countries and Turkey**' developed by the International Labour Organization focus on worker health and safety, one of the key issues in ship recycling facilities, particularly in South Asia. Though the guidelines are non-binding, they assist ship recyclers and competent authorities alike in implementing the relevant provisions of ILO standards, codes of practice and other guidelines on occupational safety and health and working conditions.

d) The International Maritime Organization (IMO) has published **Guidelines on Ship Recycling** (2003) amended in 2005, and **Guidelines for the Development of the Ship Recycling Plan** (2004). It has also developed six sets of guidelines that support implementation of the Hong Kong Convention.[6]

e) **The Montreal Protocol for Ozone Depleting Substances** is an international treaty designed to protect the ozone layer by phasing out the production of numerous substances that are responsible for ozone depletion. The treaty is structured around several groups of halogenated hydrocarbons – specifically Chloroflourocarbons (CFC) and Hydrochlorofluorocarbons (HCFCs) that were widely used refrigerants, as well as other uses as solvents and blowing agents for plastic foam manufacture etc., until their phase out under the Montreal Protocol. Refrigeration/AC equipment has historically used refrigerants and/or insulating foam such as chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs).

4.3.2 Relevant legislation in Bangladesh

Policy

National Environmental Policy (NEP), 1992

The National Environmental Policy was adopted by the cabinet in November 1992 and provides general guidance for the conservation of the environment. It includes descriptions on sectoral policies that are aimed at maintaining ecological balance and overall development through protection and improvement of the environment, protecting the country against natural disasters, identifying and regulating activities which pollute and degrade the environment, ensuring environmentally sound development in all sectors, ensuring sustainable long term and environmentally sound use of all national resources and actively remain associated with all international environmental initiatives to the maximum possible

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[6] http://www.imo.org/en/OurWork/Environment/ShipRecycling/Pages/Default.aspx

extent. The National Environment Policy embraces a number of different sectors including agriculture, industry, hospitals (health), energy, water, land, forest, fisheries, marine, transport, housing, population, education and science.

The National Environmental Policy contains the following specific objectives in respect to the development sector:

- To adopt corrective measures in establishment phase of any project that cause pollution and public health hazard;
- To conduct Environmental Impact Assessment (EIA) for all proposed public and private development project;
- To ban the establishment of any project that produces goods that may cause environmental pollution;
- To ensure sustainable use of materials and to prevent/reduce amount of their waste production.

National Environmental Management Action Plan (NEMAP), 1995

The National Environmental Management Action Plan, also referred to as NEMAP (GoB, 1995) is a wide-ranging and multi-faceted plan, which builds on and extends the statements set out in the National Environmental Policy. NEMAP was developed to address issues and management requirements during the period 1995 to 2005, and sets out the framework within which the recommendations of the National Conservation Strategy are to be implemented. NEMAP has the broad objectives of:

- Identification of key environmental issues affecting Bangladesh;
- Identification of actions necessary to halt or reduce the rate of environmental degradation;
- Improvement of the natural and built healthy environment;
- Conservation of habitats and biodiversity;
- Promotion of sustainable development;
- Improvement in the quality of life of the people

National Conservation Strategy, 2007

Bangladesh adopted a National Conservation Strategy in 2007 to protect and conserve natural resources. The last Five Year Plan also highlighted the need for protecting the environment for the betterment of the people. For the sustainable development sector, the report suggested various recommendations, including the following:

- All development projects, especially those based on imported raw materials, should be subjected to EIA and adoption of pollution prevention/control technologies should be enforced;
- No hazardous or toxic materials/wastes should be imported for use as raw materials;
- Import of appropriate and environmentally sound technology should be ensured;
- Complete dependence on imported technology and machinery for proposed development should gradually be reduced, so that project development is sustainable with local skills and resources.

Import Policy Order, 2012-2015

Import Policy Orders are made and issued in exercise of the powers conferred by section 3(1) of the Import and Export (Control) Act, 1950 by the Ministry of Commerce. Section 26(39) orders to submit a certificate to the effect that “no poisonous or hazardous waste except inbuilt materials of the ship is not being carried” issued by the last exporter or owner for importing scrap vessels. It also mentions that provision of Bangladesh Environment Protection Act 1995 and rules and regulations thereon shall be observed in the case of ship recycling.

Coastal Zone Policy, 2005

The Government developed the Coastal Zone Policy for providing general guidance so that coastal people can pursue their livelihoods under secured conditions in a sustainable manner without impairing the integrity of the natural environment. The goal of this policy is to create conditions, in which the reduction of poverty, development of sustainable livelihoods and the integration of the coastal zone into national process can take place.

Bangladesh Industrial Policy, 2010

In this respect, Government has reviewed industrial pollution classification system of red, yellow and green to ensure that transparent and effective business support services are available. The Government will take necessary measures for effective enforcement for proper running of individual and common Effluent Treatment Plants (ETP and CETP) in the industries.

Government will track major land, water and other related industrial projects and their impact on the environment and also create awareness among the local people on environmental protection, pollution, dumping of hazardous material on land and water.

Acts

Bangladesh Environment Conservation Act, 1995 (Amendment in 2010)

The Bangladesh Environment Conservation Act, 1995 issued by the Ministry of Environment and Forest aims at the conservation of environment, improvement of environmental standards and control and mitigation of environmental pollution in Bangladesh. Section 6(C) of the Act deals with the management of hazardous waste to avoid environmental damage. The act defines hazardous waste as *any waste which, due to its natural or its Physical, Chemical, Reactive, Toxic, Flammable Corrosive nature, on its own or when come in contact with other substances may create harm to the environment or human health*. According to the provision of this act, the Government shall control production, processing, import, export, storage, loading, supply, transportation, disposal, dumping etc. hazardous waste. Thus, it imposes a restriction on import and export of hazardous waste and transboundary movements of such kind of wastes as well.

Section 6(D) specifically imposes a restriction on environmental pollution and health hazards due to the ship recycling industry. This section mandates that the owner and importer of ships as well as the users of ship recycling yards have an obligation to ensure that ship recycling or cutting activities do not create any pollution and/or health hazards through the release of hazardous wastes.

Section 20 empowers the Government to make rules for carrying out the purpose of Act, for determination of environmental standards, regulation of industry, determination of safe procedures for the use, storage, import, export, transportation, disposal and dumping of hazardous substances, making list of hazardous waste, determination of the standards for effluent and discharge, etc. Additionally, section 13 empowers the Government to formulate and publish guidelines relating to the control and mitigation of environmental pollution, conservation and improvement of the environment. Thus, it is recommended that the Government formulates detailed guidelines for the handling/management of hazardous waste of the ship recycling industry and other industries as well.

This Act does not consist of any provision mandating fulfillment of the obligations under relevant international Treaties/Protocols such as the Basel Convention, Rotterdam Convention and Stockholm Convention.

The Environmental Court Act, 2000

The Environmental Court Act 2000 supports the Environmental Conservation Act (1995) and the Environmental Conservation Rules (1997) to establish environmental courts for the trial of offences relating to environmental pollution. It includes protocols for the establishment of the court and the court's jurisdiction, appropriate penalties and procedures for investigation, trial and appeal.

The Ship Recycling Act (proposed)

This Act has not been passed, however it was approved in principle by the Cabinet in 2015 and will be submitted to the Parliament for enactment. The Act will be a legal framework to regulate the ship recycling industry more effectively (Source: Ms. Parag, Ministry of Industries).

Rules and Ordinances

The Ship Breaking and Recycling Rules, 2011

The Ship Breaking and Recycling Rules, 2001 issued by the Ministry of Industries encompasses the overall administrative and legal framework for safe and environmentally sound ship recycling in Bangladesh. According to the section 3(3.1) rule, to import a vessel, obtaining a 'No Objection Certificate' from the Ship Building and Ship Recycling Board (SBRB) is mandatory by submitting an inventory of hazardous materials on board prior to the import of the ship at the outer anchorage. Again, Section 15 orders that each yard has to obtain approval of Ship Recycling Facility Plan (SRFP) from the Ministry of Industries. Each yard must have an authorization for handling hazardous waste generated from ship recycling activities issued by the DOE; registration as member of the Hazardous Waste Treatment, Storage and Disposal Facility (TDSF) which will be facilitated or operated by SBSRB under Ministry of Industries; temporary storage facility for Hazardous/Non Hazardous Waste /Materials and licenses for storage of L.P.G, Acetylene, Carbon dioxide, Oxygen & all other cylinder and flammable liquid in support of the SRFP.

It suggests that the ship recycling industry in Bangladesh must follow the guidelines developed under the Basel Convention in 1989, the Hong Kong International Convention for safe and environmentally sound recycling of ships, 2009 and provisions of this Act.

Environment Conservation Rules (ECR), 1997

Under the Environmental Conservation Act of 1995, Environment Conservation Rules were the first set of rules promulgated in 1997 and subsequently amended in February and August 2002, April 2003 and 2010. The Environment Conservation Rules of 1997 have set the National Environmental Quality Standards for ambient air, various types of water, industrial effluent, emission, noise, vehicular exhaust, etc. The rules specify the procedures to obtain environmental clearance and the requirement for IEE / EIAs according to categories of industrial and other development interventions. In compliance with the Environment Conservation Rule, 1997, it describes the mechanism for issuance of an environmental clearance certificate that has been introduced for new industries or projects after assessing project area and pollutants to be emitted or discharged by the industries or projects to be set up. For the highly polluting industries, environmental clearance is given after setting up an effluent treatment plant. Big housing projects fall within the purview since they generate sizeable quantities of effluent that needs to be treated.

4.4 Background information on hazardous waste management

Hazardous waste can be categorized in two broad categories: organic material, e.g. polymers or POPs, and minerals (inert material), such as heavy metals or asbestos.

Hazardous minerals are incombustible and must be landfilled, possibly after prior physico-chemical treatment. It is therefore important to minimize waste generation and enhance the recovery and recycling of the material (resource efficiency and cleaner production measures upstream can significantly reduce the amounts of waste produced), and for the remaining part, to ensure a safe final disposal option that prevents the release of the toxic compounds over the long-term. Physico-chemical treatment of the waste leads to the generation of toxic sludge that can be disposed of in specially engineered landfills.

Hazardous waste that is organic in nature can be destroyed, i.e. the toxic compounds can chemically be altered and transformed into harmless products. Incineration can possibly be coupled with energy recovery (waste-to-energy). Incineration requires a high investment cost (in the order of millions USD, Down to Earth 2009), but the technology can handle a broad spectrum of hazardous waste. Landfilling is an option, provided it is done under secure conditions, but there is always a risk of landfill failure in the long-term. Co-processing in cement kilns is an alternative to incineration. The initial investment is low due to low equipment requirements (mainly only a pre-treatment center) and the kiln temperature is high (up to 2000°C) (UNEP 2012).

In all cases, separation and isolation of the hazardous waste should be done as soon as possible (mixing of hazardous waste should absolutely be avoided), followed by careful packing and proper labeling of the waste, weighing and record keeping before the waste is sent for treatment and disposal.

Landfilling and incineration presents various advantages and drawbacks.

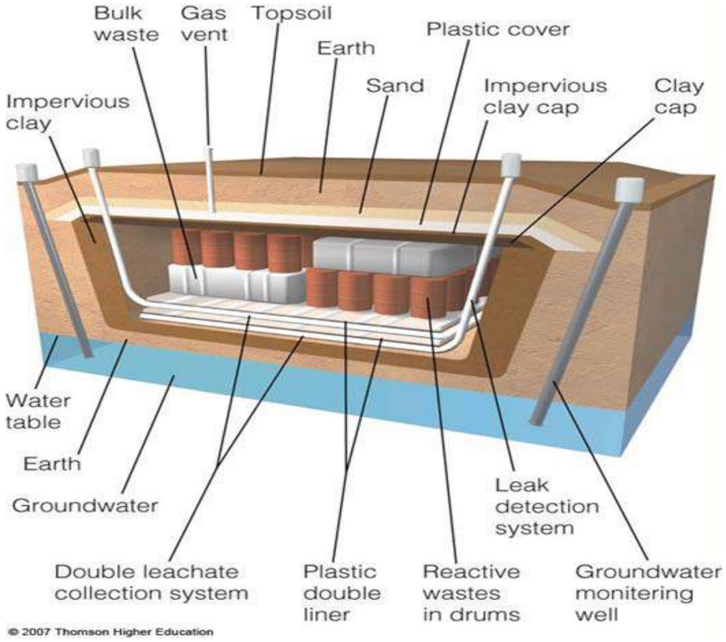


Figure 8 Example of sanitary landfill for hazardous waste (source: Thomson higher education 2007)

While landfilling is has relatively low investment and operation costs, it has considerable land requirements and requires maintenance over a long period of time, including post-closure of the landfill. It is also a possible source of environmental contamination in case of leaching or atmospheric emissions of hazardous compounds and requires control of the long-term evolution after its closure, etc.

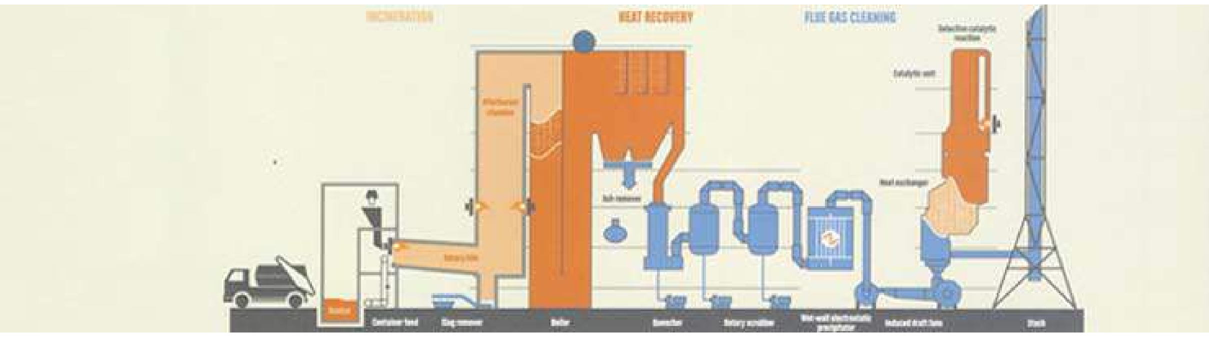


Figure 9 Example of hazardous waste incineration facility (source: http://www.gepil.in/hwm-incineration.shtml)

In contrast, incineration has been criticized for being a source of atmospheric pollution, of generating important quantities of residues (bottom ashes, slag) that necessitate further treatment, and of failing to recover the thermal energy (except in the case of waste-to-energy). For these reasons, the generation of hazardous waste to be treated and disposed of should be minimized through efficiency measures as well as recovery, recycling and reclamation.

5. Scope of the Inventory

As required in the terms of reference for this project, the development of the inventory of hazardous waste follows the methodology presented in the **SBC Methodological Guide for the development of hazardous waste inventories** (Document UNEP/CHW.12/9/Add.1).

5.1 Definition of hazardous waste and priorities

The Bangladesh Environment Conservation Act, 1995, defines hazardous waste as *any waste which, due to its natural or its Physical, Chemical, Reactive, Toxic, Flammable Corrosive nature, on its own or when it comes into contact with other substances, may create harm to the environment or human health*.

Generally, the extensive waste-recycling sector achieves a very high rate of reuse of the industrial waste, which is positive in terms of resource efficiency. However part of the reused materials might contain hazardous materials and there is a big challenge in identifying and diverting these materials from their “spontaneous”, mostly informal market (e.g. e-waste recyclers). Materials that are considered as “waste” by the industries and yard owners such as contaminated sludge, asbestos, waste oil, oily sands, etc. shall be targeted as priorities as they will be the “most accessible market” for the TSDF (treatment, storage, disposal facilities). At a later stage, the TSDF may also receive other types of hazardous waste, once the regulatory and institutional framework is sufficiently developed to prevent hazardous material re-entering the market without the required precautions.

Nuclear waste and other releases, such as emissions of atmospheric pollutants and diffuse emissions of pollutants to the water, were not included in the scope of this study.

5.2 Type of inventory and classification of the hazardous waste

This work is based on the methodology presented in the **SBC Methodological Guide for the development of hazardous waste inventories** (Document UNEP/CHW.12/9/Add.1). The inventory corresponds to a *first generation inventory* as defined by the guide, i.e. an inventory being undertaken in a setting where hazardous waste policies are in early stage of development.

In contrast, *second generation inventories* may be conducted in contexts where the waste legislation and enforcement are more advanced. This sets the stage for the maintenance of records on various waste categories, monitoring, tracking and information transfer on the substances contained in the waste. This is a prerequisite for an easy access to the exact nature of the waste, which makes the classification of the waste as per the categories provided in the Basel and Hong Kong Conventions possible.

Such information is generally not available in countries where waste policies are at early stage of development, such as in the case of this project. In fact, most of the waste generators simply do not know about the hazardous substances contained in the waste. Many categories listed in the Conventions are not practical for *first generation inventories* on the ground for the following reasons:

i. The Basel category is defined based on a toxic substance (e.g. polychlorinated biphenyl, PCB) as opposed to the type of waste (e.g. sludge). The waste generator may know the type of waste, but might not be aware of the toxic substances it contains.

ii. Unless chemical analyses are performed, it is not possible to determine whether the waste contains or not toxic substances.

iii. The categories are not exclusive, which poses a risk of double counting. E.g. heat exchange oils may be accounted for in Y8 waste mineral oils and in Y10 waste containing PCBs.

Therefore, instead of using the categories of the Convention, the categories of the Indian hazardous waste classification system were adopted in this work: **categories are formulated based on the waste disposal option**. **The waste streams are thereby classified as recyclable, landfillable or incinerable.** The Indian hazardous waste classification system is presented as one recommended approach in the **SBC Methodological Guide for the development of hazardous waste inventories** (Document UNEP/CHW.12/9/Add.1). The methodology adopted is further detailed in section 6.2.

5.3 Sectors considered

The primary focus of this inventory is the ship recycling industry located in Chittagong. For this reason, we give particular attention to the hazardous waste generated as a result of ship recycling activities. As per requirement of the project terms of reference, **the scope of the inventory is extended to the nearby industrial areas in Chittagong.**

5.4 Specific exclusions from the scope of the inventory

Informal activities are not considered in the scope of this work. It is assumed that informal activities that lead to the generation of waste are negligible in the Chittagong ship recycling sector. Yet, the informal sector plays an important role post waste generation, especially in terms of waste trading and processing (e.g. cable processing). Informal activities are also certainly relevant in Chittagong in general. While the informal sector would not have a demand for a waste treatment facility, its potential role of “competitor” in acquiring and channeling the waste should be kept in mind at the time of planning of the waste treatment facility. It also goes without saying that as waste policies evolve and are strengthened, hazardous waste produced by the informal sector should also be addressed.

6. Inventory methodology

The scope of this project looks at two perimeters – the ship recycling yards and Chittagong's industrial areas – which strongly differ in their dynamics, administrative and regulative set-up and economic evolution. Therefore, the approach to conduct the hazardous waste inventory needs to be adapted differently.

6.1 Hazardous waste inventory from the ship recycling industry in Chittagong

While yard owners have a good understanding of what type of unwanted waste is generated from ship recycling activities, reliable records on the amounts are not readily available. In response to the demands of the Hong Kong Convention and the new European Legislation, yards have initiated a record maintaining process, but from the field visits it was apparent that record keeping needs substantial improvement in terms of measuring and documenting various waste fractions, as these are usually reported without weighing and control and only based on visual estimations.

Quantities of waste highly vary from ship to ship. Deriving quantitative data from interviews or field investigations is therefore unlikely to yield any reliable results.

For this reason, the inventory of hazardous waste from the Chittagong ship recycling yards will be derived **based on benchmarks from similar countries**.

As a first step, data from Turkey was analyzed to understand the factors determining the type and quantity of waste in a ship, especially asbestos (see Annexure 10.1). **The conclusions are that ship type, year of construction and to a certain extent ship size are important factors that influence the waste content of the ships.**

Conditions prevailing in the ship recycling industry in Turkey differ strongly from Asian countries, and for this reason we preferred to derive waste generation factors based on data from the Indian ship recycling industry. Therefore, as a second step, waste factors derived from the ship industry in Alang in India were reviewed and compared with waste figures received from the Alang TSDF (sections 6.1.1 to 6.1.3). The Indian factors were slightly modified to account for certain waste types that actually are reused, and not disposed of (section 6.1.4).

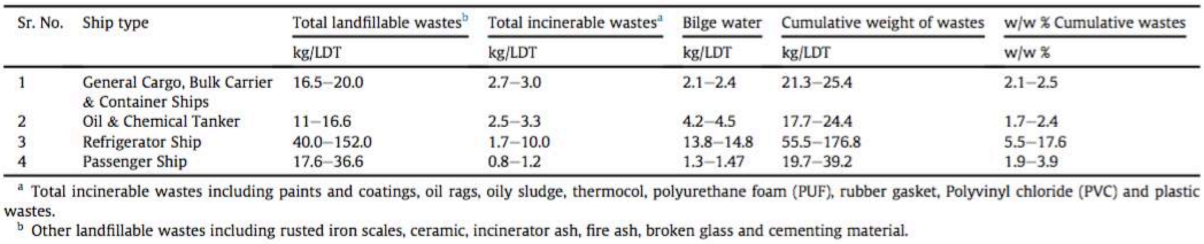
Finally, in order to take into account the variable activity of the yards, LDT dismantled over the last years (2009-2015) is averaged out (section 7.1). The ship dismantling figures of Chittagong are multiplied with the waste factors obtained previously to estimate the waste quantities generated in the country. Information about the number, type and size of the ships dismantled in Chittagong was obtained from the ship breakers.

This inventory does not include "legacy waste sites" on private lands as well as on municipal landfills. In the absence of any hazardous waste infrastructure, yards often resorted to burying hazardous waste such as asbestos on their own land. Although not in the scope of the current inventory, the issue of legacy wastes should certainly be addressed in the future to avoid any derived pollution.

6.1.1 Waste factors from ship recycling yards – Indian benchmarks

Hiremath et al. (2015) produced waste generation factors based on a study of ships recycled from 2011 to 2013 at Alang facilities (Table 7 and Table 8). Instead of looking at separate waste streams, they combined the waste streams based on their final disposal pathways, basically whether they are landfillable or incinerable. This approach is in line with the hazardous waste classification system of India and it is also highlighted by the SBC guide as an example of a useful classification system. This is of direct relevance for the current project, as this classification allows the estimation of the need for landfill and incineration capacity required. Hiremath et al. did not quantify the materials that are considered as recyclable in India, because they have a market value and are intended for disposal.

Table 7 Waste factors in kg/LDT for landfillable waste, incinerable waste and bilge water generated from the ship breaking industry in India (Hiremath et al. 2015)

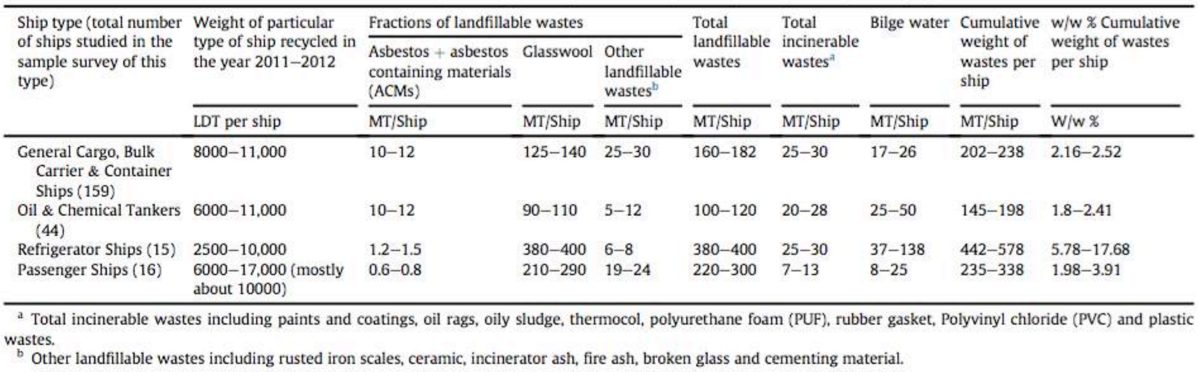


Sr. No.	Ship type	Total landfillable wastes[b]	Total incinerable wastes[a]	Bilge water	Cumulative weight of wastes	w/w % Cumulative wastes
		kg/LDT	kg/LDT	kg/LDT	kg/LDT	w/w %
1	General Cargo, Bulk Carrier & Container Ships	16.5–20.0	2.7–3.0	2.1–2.4	21.3–25.4	2.1–2.5
2	Oil & Chemical Tanker	11–16.6	2.5–3.3	4.2–4.5	17.7–24.4	1.7–2.4
3	Refrigerator Ship	40.0–152.0	1.7–10.0	13.8–14.8	55.5–176.8	5.5–17.6
4	Passenger Ship	17.6–36.6	0.8–1.2	1.3–1.47	19.7–39.2	1.9–3.9

[a] Total incinerable wastes including paints and coatings, oil rags, oily sludge, thermocol, polyurethane foam (PUF), rubber gasket, Polyvinyl chloride (PVC) and plastic wastes.

[b] Other landfillable wastes including rusted iron scales, ceramic, incinerator ash, fire ash, broken glass and cementing material.

Table 8 Waste factors in MT/ship with break-down of landfillable waste into Asbestos + Asbestos Containing Materials (ACMs), Glasswool and Other landfillable waste (Hiremath et al. 2015)



Ship type (total number of ships studied in the sample survey of this type)	Weight of particular type of ship recycled in the year 2011–2012	Fractions of landfillable wastes			Total landfillable wastes	Total incinerable wastes[a]	Bilge water	Cumulative weight of wastes per ship	w/w % Cumulative weight of wastes per ship
		Asbestos + asbestos containing materials (ACMs)	Glasswool	Other landfillable wastes[b]					
	LDT per ship	MT/Ship	MT/Ship	MT/Ship	MT/Ship	MT/Ship	MT/Ship	MT/Ship	W/w %
General Cargo, Bulk Carrier & Container Ships (159)	8000–11,000	10–12	125–140	25–30	160–182	25–30	17–26	202–238	2.16–2.52
Oil & Chemical Tankers (44)	6000–11,000	10–12	90–110	5–12	100–120	20–28	25–50	145–198	1.8–2.41
Refrigerator Ships (15)	2500–10,000	1.2–1.5	380–400	6–8	380–400	25–30	37–138	442–578	5.78–17.68
Passenger Ships (16)	6000–17,000 (mostly about 10000)	0.6–0.8	210–290	19–24	220–300	7–13	8–25	235–338	1.98–3.91

[a] Total incinerable wastes including paints and coatings, oil rags, oily sludge, thermocol, polyurethane foam (PUF), rubber gasket, Polyvinyl chloride (PVC) and plastic wastes.

[b] Other landfillable wastes including rusted iron scales, ceramic, incinerator ash, fire ash, broken glass and cementing material.

As can be seen from the table above, landfillable waste factors published by Hiremath et al. are dominated by glasswool (about 77-98% of landfillable waste) with factors ranging between 125-140 MT/ship for general cargo and bulk carrier ships.

6.1.2 Discussion of the Indian asbestos waste factors

Asbestos factors calculated based on the study published by Hiremath et al. are presented in the next section in Table 9. Asbestos generation factors vary strongly between India and Turkey. The data from the Aliaga Ship Breakers' Association and the study conducted by Gramman et al. (2007) both suggest asbestos recycling factors in Turkey which are lower than those published by Hiremath et al. by an approximate factor of 10. One possible hypothesis is that this difference is due to the different asbestos identification process followed in both countries. Asbestos is found in many forms, and often resembles other materials. Its identification is therefore not always straightforward.

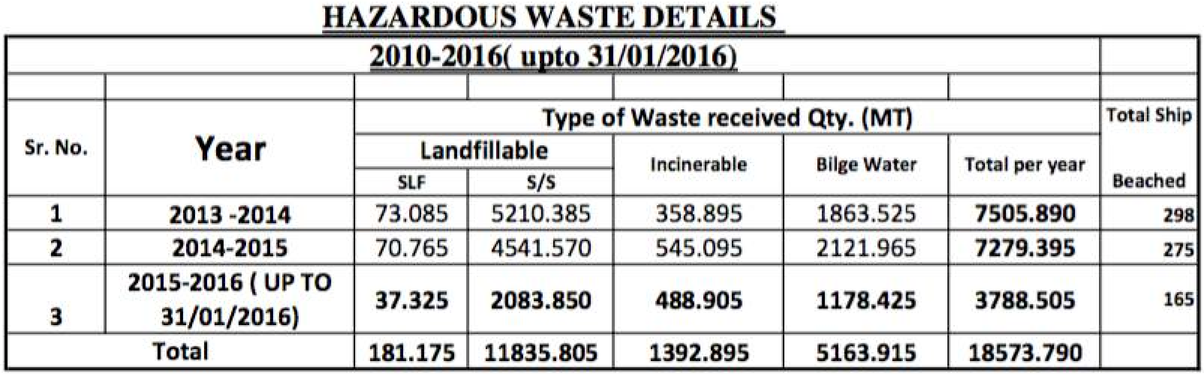
Turkish ship recyclers follow a very detailed process to identify asbestos, involving sample measurements. They thereby ensure that only the material that has been formally identified as asbestos is removed. In other words, the material disposed of as asbestos probably corresponds entirely to real asbestos, and not to other similar materials.

In contrast, in countries where asbestos sampling is less systematic, such as could be the case in India, it is likely that the so-called asbestos waste is in reality "potentially-containing asbestos" waste, which also includes non-asbestos fractions. In conclusion, the quantities of waste labeled and treated as asbestos are likely to be higher than in Turkey.

Considering that conditions in Bangladesh are more comparable to India than Turkey, it was decided to use the higher asbestos factors published by Hiremath et al. (2015) for the assessment, keeping in mind that the occurrence of asbestos in ships will most likely reduce with time. We assume that as a consequence of the International Convention for the Safety of Life at Sea (SOLAS), and the future entry into force of the Hong Kong Convention, the ships dismantled will contain decreasing asbestos content in the future.

6.1.3 Comparison between waste factors and quantities reported by the TSDF in Alang

The hazardous waste generated in the ship recycling yards of Alang is sent to the Treatment, Storage and Disposal Facility (TSDF) operated by Gujarat Enviro Protection and Infrastructure Limited (GEPIL). The total notified area of this facility is seven hectares. This facility, located in the vicinity of the yards, handles 600 to 800 MT of hazardous waste every month.



HAZARDOUS WASTE DETAILS

2010-2016(upto 31/01/2016)

Sr. No.	Year	Type of Waste received Qty. (MT)					Total Ship Beached
		Landfillable		Incinerable	Bilge Water	Total per year	
		SLF	S/S				
1	2013 -2014	73.085	5210.385	358.895	1863.525	7505.890	298
2	2014-2015	70.765	4541.570	545.095	2121.965	7279.395	275
3	2015-2016 (UP TO 31/01/2016)	37.325	2083.850	488.905	1178.425	3788.505	165
Total		181.175	11835.805	1392.895	5163.915	18573.790	

Figure 10 Quantities of hazardous waste received yearly by the Alang TSDF in India from the ship yards. The extreme right column shows the number of ships beached in Alang in the year (source : GEPIL). SLF: secured engineered landfill facility. S/S: solidification and stabilization.

GEPIL shared aggregated figures on the hazardous waste quantities received annually by the TSDF in Alang (Figure 10). To evaluate how the GEPIL data stands with regard to the factors computed by Hiremath et al. (2015), the theoretical minimal and maximal waste quantity generated by the ships has been computed by multiplying the lowest and highest factors respectively published by Hiremath et al. by the number of ships dismantled reported by GEPIL.

Comparing the minimum and maximum hazardous waste quantities thus obtained (Annexure 10.3) with the GEPIL figures (Figure 10), it can be observed that the landfillable and incinerable waste figures reported by GEPIL (5'283 MT and 359 MT respectively) are significantly lower than the theoretical minimal waste scenario for landfillable and incinerable waste (29'000MT and 2'086MT respectively). In contrast, bilge water shows a similar order of magnitude (1'864 MT reported by GEPIL and 2'384 MT in the minimum waste scenario). The main hypothesis to explain this discrepancy is that a significant fraction of the waste, especially insulation material such as glasswool, are in a usable condition and are sold instead of being sent for disposal, thus reducing the quantities received by the TSDF.

In fact, if a similar exercise is conducted to estimate theoretical hazardous waste quantities, but **without** the glasswool waste factors, the results are much closer to the GEPIL figures for landfillable waste (Annexure 10.4). The theoretical range for landfillable waste thus obtained lies between 2’000MT/year and 12’000MT/year, while GEPIL’s reported figure for 2013 is 5’283MT.

We conclude that **the waste factors reported by Hiremath et al. (2015), indeed provide a range of credible and useful set of waste production factors that can be used to arrive at the estimates of a variety of categories of hazardous waste that are generated in ship recycling activities in South Asia**. **The glasswool factor presents an exception, and should be reduced under the assumption that part of the glasswool is sold off instead of sent to the TSDF.**

6.1.4 Hazardous waste factors used for the ship recycling industry

As explained in previous sections, the waste factors published by Hiremath et al. (2015) are applied to Bangladesh, except for the glasswool factor. From discussions with the management of the Alang TSDF, it appeared that most glasswool is recovered, and only a small amount of it finds its way to the TSDF (personal communication with Mr. P. Bhatti, March 2016). In addition, during the field visits to the yards in Chittagong, yard representatives suggested that 95% of the glasswool is recycled by contractors who sell it as insulation in various industries. It therefore seems reasonable to assume that only 5% of the glasswool is sent to the TSDF, while 95% is recovered and recycled because it is found in a useable condition. The waste factor is adapted accordingly.

As mentioned in section 7.1 the variables that influence the waste generation from ship recycling activities are: ship type, year of construction and to a certain extent ship size. When transferring the waste factors determined from the Indian case to the Bangladeshi case, these variables are accounted for as follows:

- Ship type: the factors by Hiremath et al. (2015) are already disaggregated by main ship category, and can therefore be directly applied;

- Year of construction: the ship construction year is relevant, as older ships tend to contain more hazardous substances due to lower restrictions and building standards in the past. In fact, the analysis of Turkish data shows that hazardous substances such as asbestos “peak” in vessels built in the early 1970s (Appendix 10.1). Hiremath et al. (2015) mentions that ships are dismantled after a life span of 22-25 years on an average. It is likely that their factors therefore do not contain hazardous substance “peaks” such as observed in the Turkish data. The year of construction is not available for ships dismantled in Chittagong, but it is likely that on an average they are built after the mid-1970s. We therefore assume that the factors can be directly applied.

- Ship size: we use factors expressed in terms of metric tonne per LDT to account for size effects.

The final factors used for the estimation of the hazardous waste to be sent for treatment and disposal are presented in Table 9 and Table 10.

Table 9 Waste factors used for the calculations – landfillable waste fractions (based on Hiremath et al. 2015, and modified by assuming that only 5% of the glasswool is sent to the disposal facility, while 95% is reused / recycled)

Ship category	Asbestos + ACMs		Glasswool (only 5%)		Other landfillable waste		Total landfillable	
	Low	High	Low	High	Low	High	Low	High
	kg/LDT	kg/LDT	kg/LDT	kg/LDT	kg/LDT	kg/LDT	kg/LDT	kg/LDT
General Cargo	1.0	1.3	0.6	0.8	2.6	3.3	4.3	5.4
Bulk carrier	1.0	1.3	0.6	0.8	2.6	3.3	4.3	5.4
Oil & Chemical tanker	1.0	1.5	0.5	0.7	0.5	1.5	2.0	3.7
Container	1.0	1.3	0.6	0.8	2.6	3.3	4.3	5.4
Refrigerator Ship	0.1	0.6	2.0	7.4	0.6	3.0	2.7	10.9
Passenger Ship	0.05	0.1	0.8	1.7	1.5	2.8	2.3	4.6
Other	1.0	1.3	0.6	0.8	2.6	3.3	4.3	5.4
Assumption: "Other" ships correspond on an average to General Cargo ships								

Table 10 Waste factors used for the calculations - total landfillable / incinerable / bilge water (based on Hiremath et al. 2015 and modified by assuming that only 5% of the glasswool is sent to the disposal facility, while 95% is reused / recycled)

Ship category	Landfillable waste (glasswool : only 5%)		Incinerable waste		Bilge water	
	Low	High	Low	High	Low	High
	kg/LDT	kg/LDT	kg/LDT	kg/LDT	kg/LDT	kg/LDT
General Cargo	4.3	5.4	2.7	3.0	2.1	2.4
Bulk carrier	4.3	5.4	2.7	3.0	2.1	2.4
Oil & Chemical tanker	2.0	3.7	2.5	3.3	4.2	4.5
Container	4.3	5.4	2.7	3.0	2.1	2.4
Refrigerator Ship	2.7	10.9	1.7	10.0	13.8	14.8
Passenger Ship	2.3	4.6	0.8	1.2	1.3	1.5
Other	4.3	5.4	2.7	3.0	2.1	2.4
Assumption: "Other" ships correspond on an average to General Cargo ships						

6.2 Hazardous waste inventory from the Chittagong industrial area

6.2.1 Data collection

Identification of hazardous waste generating industrial units was the starting point for the inventorization task. The Department of Environment in Bangladesh has categorized industries into Red, Orange A and Orange B and Green categories. The categorization of industries is essentially based on the pollution index of the industries.

Based on the information provided by DoE, as well as the information collected during the stakeholder workshop held in Chittagong, the following industrial sectors were identified:

List of industries selected for survey and waste estimation (Red category) :

- Textile industries
- Tanneries
- Fertilizer Industries
- Paper Mills
- Chemical, Pharmaceuticals and Pesticide Industries
- Paint and Varnishes
- Petroleum Refineries
- Cement Industries
- Rerolling mills (Auto)
- Cable Industries
- Glass industries
- Healthcare entities
- Chittagong Port

A questionnaire was developed (Annexure 10.2) which was administered to a sample of industries. To develop a climate of trust, an introductory letter issued by the Ministry of Industries (MoI) was also provided.

In order to ensure representativeness of the sample of industries, we targeted a minimal sampling intensity of 10%, i.e. that the number of industries of a given sector surveyed should represent at least 10% of the total number of industries of the sector in Chittagong's industrial areas. We considered the capacity of the industries in the sample selection, in order to include industries with higher production capacities in the sample. Accordingly, we selected fifty industries for the collection of data for which a survey plan was prepared and the actual questionnaire survey was administered. We received data back from 29 industries across different sectors. The details of the industries surveyed and their percentages are shown in Table 11**.**

Table 11 The survey plan with number of industries in different sectors and number of industries surveyed from each sector for this study

Sector	Brief description	Number of Industries	Number of industries included in the survey	% of industries covered
Textile industries	The textile sector in Chittagong is engaged in the production and dying of yarns and fabrics from different natural and synthetic fibers. They use water and dyes of different composition. Textile dying and washing are also integral part of their activities. The amount produced falls short to meet the demand of garment industries and a substantial percent of fabric is imported.	~ 50	9	~18%
Tanneries	The tannery sector in Chittagong is	2	2	100%

	engaged in tanning the locally sourced raw hides of bovine, goat and lambs into finished leather of various thickness and quality.			
Fertilizer Industries	Urea Fertilizer industries uses locally available natural gas as the basic raw materials to produce Urea and Ammonia. Di-Ammonium Phosphate (DAP) fertilizer is produced by using phosphoric acid, sulfuric acid and Ammonia. On the other hand, Triple super phosphate (TSP) and Single super phosphate (SSP) fertilizers are manufactured by using imported Rock sulfur, Rock phosphate and Phosophoric acid.	5	2	40%
Paper Mills	Paper mills in Chittagong are engaged in virgin paper production from tree and bamboo resources; paper production from imported pulp and some of the plants recycle used papers. Offset paper, writing and printing paper, newsprint and carton papers are made in these plants.	16	2	13%
Chemical, Pharmaceuticals and Pesticide Industries	Chemical industries produce chemicals including cosmetics, lifestyle products and toiletries, agrochemicals, pesticides, pharmaceuticals etc. Depending on the industry, natural products as well as synthetic chemicals including aromatic substances and preservatives are used as raw materials. Chemical industries in Chittagong meet the bulk of demand in Bangladesh for products under aorementioned categories except pharmaceuticals.	~10	5	50%
Paint and Varnishes	The whole range of powder and liquid paints, emulsions, pigments, varnishes and paint related liquors such as terpene are manufactured in these industries by using imported pigments and locally sourced petroleum products.	~10	2	20%
Petroleum Refineries	Public sector refinery in Chittagong uses crude oil, caustic soda, NaOH, Anti corrosion agent, demulsifying agent, ammonia, merox, tetra-chloro ethylene, methanol etc., to produce LPG (Liquefied Petroleum Gas), Naphtha, SBPS (Special Boiling Point Solvent), MS (Motor Spirit), HOBC (High Octane Blending Comp.), MTT (Mineral Turpentine), SKO (Superior Kerosene Oil), HSD (High Speed Diesel), JBO (Jute Batching Oil), FOHS (Furnace Oil High Sulfur) and Bitumen. Private	9	2	22%

	sector refineries uses condenset from gas fields to produce Motor Spirit, Diesel, Mineral Turpentine and Special Boiling Point Solvents			
Cement Industries	The cement industry in Chittagong produces ordinary Portland cement (OPC), Portland Composite Cement (PCC), ready-mixed concrete, aggregates etc from imported clinker and other imported raw materials.	10	2	20%
Rerolling mills (Auto)	Auto-Rerolling mills in Chittagong use gas furnace, electric arc furnace or induction furnace to melt imported or locally sourced scrap iron to produce billet from which different iron and steel products such as bar, angles, box etc are made. In some mills, heated scraps from ship breaking yards are directly rerolled into rebars.	8	1	12%
Cable Industries	The cable industry produces insulated electric cables for electric wiring besides LT and HT Power cables. It also produces all aluminum and steel reinforced aluminum conductors. The industry uses raw materials which include Wire and strips of Fe, Cu and Al, Sb_2O_3, TiO_2, Paraffin wax, Chloroparaffin, PVC resin, Conducting PVC compound (cabelac), Stabilizer for PVC compound, Chalk powder, Graphite powder, Carbon black paste for PVC, Red/ yellow/ blue pigment, Di-octyl phthalate, Cyclohexanone, Calcium stearate, Termite repellent, Gummed cotton tape, Nylon semiconducting tape, Krepp paper, Calcined clay, Tribasic lead sulphate, Di-basic lead phthalate, Soft PVC tape, Hard PVC tape.	1	1	100%
Glass industries	Glass industries produce Clear and Color Float Glass, Silver Coated Mirror, and Tempered Glass from Silica sand, Dolomite, Limestone, Feldspar, Soda Ash, Salt Cake, Coal Powder, Ag and Cu, Paints etc.	2	1	50%

There is another class of “episodic waste” generated by process industry routinely during the course of operational maintenance of various unit operations. For example, the cartridges of microfiltration, ultrafiltration and nanofiltration or from reverse-osmosis used for separation of mother-liquor from the dyer pigment in the paint-pigment industry or pharmaceutical and fine chemical industry are disposed after the useful life of the cartridges is exhausted. Typically, such installations are fitted with cartridges so that the membrane unit can be replaced with a new cartridge and the old cartridges are sent for treatment and disposal. In the case of the biomedical waste and biochemical pharmaceutical industries, the cartridges need disinfection and detoxification before shredding and incineration. Also, several kinds of captive and commercial utility services (hot and cold) have episodic emissions of insulation materials which are to be incinerated or landfilled.

Unfortunately, during the course of field visits and investigations, we could not obtain such information from the industry surveyed. Nevertheless, effort has been made in this inventory to categorically include a notional emission rate to recognize the existence of such emissions from the process industry. It was felt that in the absence of such categorical mention of the episodic and aperiodical waste, the inventory would remain incomplete and unrealistic. Therefore, it was assumed that episodic and aperiodic waste is generated at a rate of 1% of the total waste quantity compiled.

Medical waste was highlighted during the stakeholder consultation, and therefore was retained here as a sector to consider. The medical waste was computed based on the total number of beds available in various healthcare institutions of the city (Table 12), and multiplied by waste factors, as per the methodology developed by WBPCB & Disha (2010).

Table 12 Number of beds available in various healthcare institutions in Chittagong

Health Sector	No. of Beds
General Hospital	2’611
Private Hospital	2’655
Child Care	650
Eye	170
Maternity	305
Total	**6’391**

In addition, available information was collected from the Chittagong Port Authority on the amount of waste generated from ships.

6.2.2 Data analysis and extrapolation

A closer look at the data received highlighted that there is divergence and inconsistency in the data from similar kinds of industries. This can be attributed to the following reasons:

- Some units might have better practices as compared to others
- Differences in installed production processes and technologies may result in varying plant efficiencies and waste generation rates
- Book keeping practices of industries for waste generation may not be a priority since there is no stringent reporting requirement from the regulatory authorities
- Actual measurement of waste is not very common, therefore, most of the figures are best guess estimates

Total Waste production in the sector at Chittagong = (sum of the total waste generated by surveyed industries in the sector **DIVIDED BY** Total Production Capacity of the surveyed industries in the sector) **MULTIPLIED BY** Total Capacity of the sector at Chittagong

To address this variability in data quality, the figures that seemed strongly unrealistic were discarded. In addition, in case of missing or unreliable data, benchmarks available in literature were used for the waste calculations. This is the case, for example, for the calculation of chemical residues from the paper industry, or ETP sludge from the paper industry.

The sample of industries that were surveyed represented only a fraction of the total industries that existed in the study area. Thus, the data obtained required extrapolation. This was achieved based on the total capacity installed in the study area. Total installed capacities of the industries under the same sector were grouped for extrapolation.

6.2.3 Categorization by disposal option

In a first step, the Indian criteria for segregation of hazardous waste according to their disposal option (incineration, landfill, or recycling) were used to categorize the waste streams. The benchmark document used has been attached in Annexure 10.6 [7].

In a second step, during the verification of the results (see section 6.2.4) the categorization was refined. Upon further investigation, which included site visits to better understand the nature of the waste, waste streams which were previously reported as hazardous and without any apparent use were further distributed between incineration, toxic waste landfill and inert landfill. The inert landfill is part of the hazardous waste management facility, and serves in storing non-reactive toxic substances, such as asbestos. If it turned out that the waste actually has a market value and does not need to be disposed of, it was categorized in the category ‘alternate gainful use’. Alternatively, if the investigations showed that the waste was actually non-hazardous, it was allocated to MSW landfill.

In general, the understanding of waste composition and its hazardous substance content requires specific knowledge of each industrial process and/or laboratory analysis. This level of analysis goes beyond the scope and timeframe of this first generation inventory. As a result for some waste categories, the discussion of their hazardous constituents remains obscure and will require further investigation by the future facility operator to capture the waste streams adapted to each landfill cell or incineration system.

6.2.4 Verification of the results

After completion of the inventory process, some verification activities were conducted. These included:

- On-site visit to key industries to understand the nature of their waste and its hazardous composition. One chemical (consumer products) industry, one chemical (chemicals, paints and varnish) industry, two textile industries and one tannery were visited.
- Chemical analysis of waste samples to determine the hazardous substances contained. Unfortunately the time required to ensure active collaboration from the concerned industries exceeded the timeframe available to complete this inventory. The results of the analyses will therefore be used at a later stage of the project.
- Evaluation of the use of certain waste streams and whether these are to be disposed of or have any gainful use (e.g. in another industry) based on current practices of management and general criteria of such wastes.

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[7] http://mpcb.gov.in/hazardous/images/pdf/Report%20with%20Annexure/Annexure%20-%20I.pdf

6.2.5 Growth projection

The economy of Bangladesh is changing rapidly. The country is gradually moving from an agrarian economy towards an industrial economy. It has maintained a steady GDP growth of > 6% throughout the last decade. We can consider that the rate will hold for the coming years if the overall local political and global economic conditions remain stable.

Long-term projections of the growth of individual industrial sectors at different locations in the country is very challenging due to the dependence of growth on many factors. Yet to ensure proper planning of the hazardous waste management facility, it is necessary to account for the growth in relevant hazardous waste generating industrial sectors in Chittagong.

We therefore compiled growth rate estimates based on sectorial growth trends in the country as well as the probable expansion of various industries in Chittagong. To achieve this, we collected inputs directly from the relevant industries about their growth trends and expansion plans. High- and low-growth rate scenarios have been developed on this basis and have been refined based on comments from economists based at the Chittagong University with knowledge of the industries in the city (personal communication with Prof. Mohammad Mahfuzur Rahman and Prof. Mohammad Nur Nabi on June 30th and July 1st 2016).

7. Inventory results

7.1 Waste from ship recycling in Chittagong

Figure 11 shows the number of ships recycled in Bangladesh since 2009. The total number is more or less constant over the years, except for 2010 and 2011, years in which a significantly smaller number of ships were recycled. In 2010, a ruling by the High Court closed the ship recycling yards from March to November following court action by Non-Governmental Organizations. There were also instances of closures by the Court in 2009.

Ships are dominated by bulk carriers. Some ships cannot be allocated to any of the ship types listed by Hiremath et al. (2015), and are labeled as “Other”. This category includes a large range of specialized vessels such as fishing boats, Floating, Production, Storage & Offloading ships, dredger or drilling ships. The data for years 2014 and 2015 also include year of build. The average lifespan of ships recycled in 2014 and 2015 is 27.8 years, which is higher than the average age of 22-25 years mentioned for ships recycled in India.

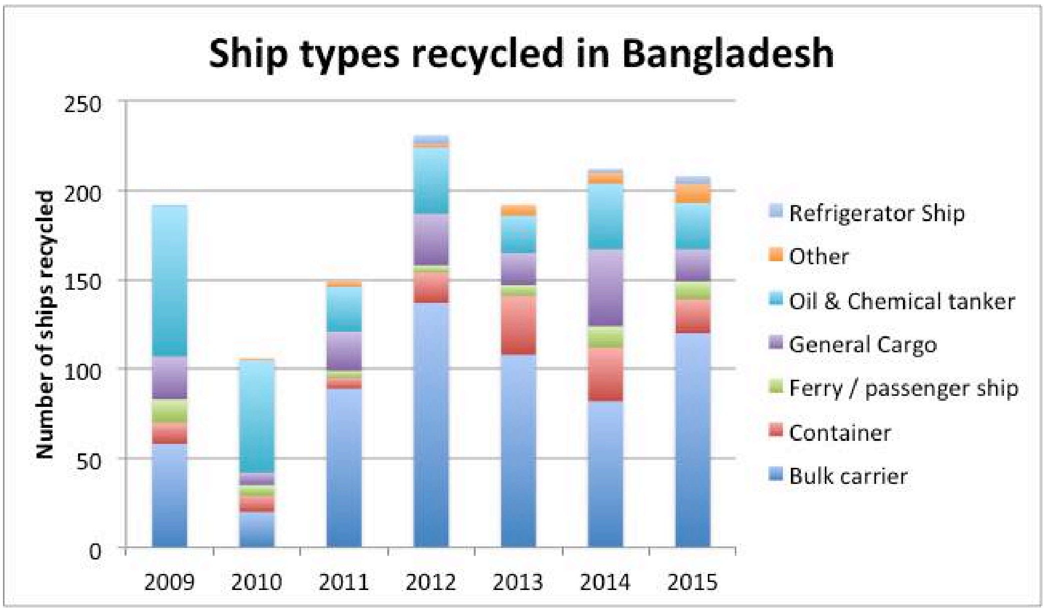

Figure 11 Ships recycled in Bangladesh by type and year

In general, ships recycled in Bangladesh exhibit similar features in terms of size to those recycled in India. Yet this observation is not applicable to all categories. For instance, Hiremath et al. (2015) combined cargo ships with bulk carriers and container ships. The average weight reported comes to 8-11’000 LDT/ship, which is a reasonable figure for the combination of these various types of ships. However when considered separately, general cargo ships are typically smaller than the average bulk carriers and container ships. In Bangladesh, general cargo ships recycled in the last two years have an average size of < 4’000 LDT/ship.

In the absence of factors for the “Other” category, we decided to apply the factors proposed for General Cargo; as the ships included in this category strongly vary from each other and from one year to the other and no trend can be established for this category. This assumption is supported by the fact that the category “Other” encompasses only a small fraction of the ships dismantled (Figure 11).

The total, summed up LDT recycled in Bangladesh fluctuated over the years (Figure 12). The average LDT recycled between 2009 and 2015 is shown in the table below.

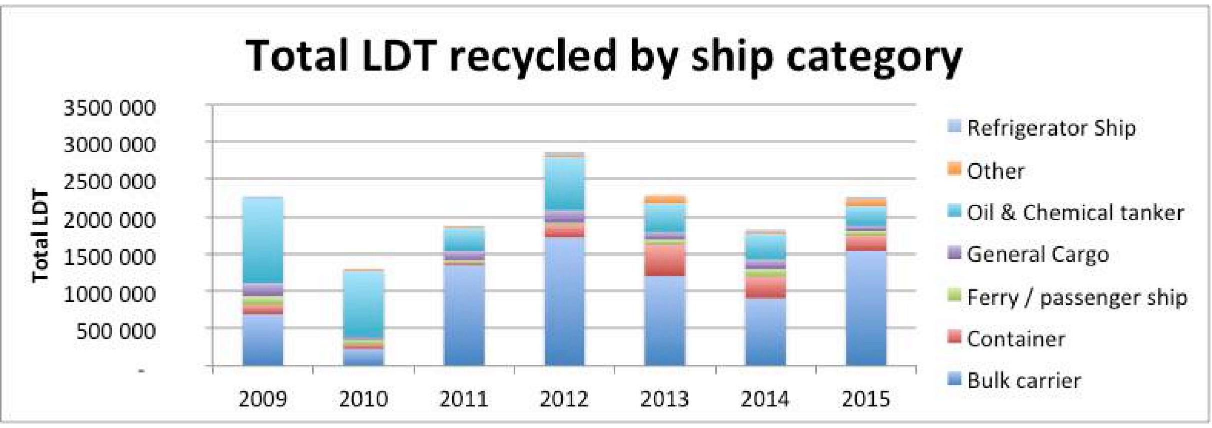

Figure 12 Total LDT of ships recycled in Bangladesh by type and year

Table 13 Average LDT recycled between 2009 and 2015 by ships category

Type of ship	Average 2009-2015 (LDT)
General Cargo	111'486
Bulk carrier	1'094'566
Oil & Chemical tanker	579'542
Container	186'583
Refrigerator Ship	7'873
Passenger Ship	67'680
Other	44'616
Total	**2'092'346**

The average LDT profile (2009-2015) (Table 13) was multiplied with the factors derived by Hiremath et al. The calculated waste quantities thus obtained are presented in the tables below. The waste generation by type of ship is shown in Annexure 10.5.

Table 14 Calculated waste quantities generated from ship recycling in Bangladesh (tonne/year)

Waste category	Low estimate	High estimate
Landfillable waste	7'475	10'252
Incinerable waste	5'397	6'384
Bilge water	5'649	6'273

Table 15 Break-down of landfillable waste between asbestos and asbestos containing materials (ACMs), glasswool and other landfillable waste (tonne/year)

Within landfillable waste	Low estimate	High estimate
Asbestos + ACMs	2'093	2'767
Glasswool	1'269	1'673
Other landfillable waste	4'112	5'812
Total landfillable waste	7'475	10'252

These results show the range of hazardous waste likely to be generated in current conditions in the Chittagong ship recycling industry.

In summary, the hazardous waste generation depends on two factors: the number of ships dismantled in the country and the quantity of hazardous waste contained in the dismantled ships. Both factors fluctuate considerably. The average of the recycling activity was computed for the years 2009-2015 to reflect the fluctuation in number of ships dismantled. The fluctuation of the quantity of hazardous waste contained in the dismantled ships was reflected by using low and high estimate waste factors.

Both factors – the number of ships dismantled in the country and the quantity of hazardous waste contained in the dismantled ships – may evolve differently in the future. The effect of the Hong Kong Convention and the EU Regulation on ship recycling on the number of ships dismantled in Bangladesh is unclear. While yards work towards becoming compliant with the Convention in the hope that the number of ships will increase, it is possible that higher prices offered by competitors based in non-Party countries may make access to the ships more difficult. As for the content of hazardous waste in ships, substances subject to international regulations such as asbestos are likely to reduce with time as more stringent ship building standards are applied worldwide.

7.2 Waste from the Chittagong industrial area

7.2.1 Results of the inventory

As a result of the inventory and data interpretation, the total annual hazardous waste generation from Chittagong industrial areas by waste stream is presented in the tables below.

The major hazardous waste generating sectors are:

- the iron and steel industry (re-rolling mills): tundish lining, APC dust
- the textile industry: contaminated packaging and contaminated ETP sludge
- the fertilizer industry: contaminated solid waste
- refineries: oily crude tank sediments
- the chemical industry: contaminated solid waste, contaminated ETP sludge
- tanneries: contaminated solid waste, contaminated ETP sludge
- healthcare institutions: medical waste
- Port of Chittagong: mixed hazardous waste

The verification process conducted after completion of the inventory led to a more exact interpretation of the hazardous nature of the waste reported and allocation to the most suitable treatment option. Some numbers were amended based on the findings. In particular, the major changes observed are:

- reallocation of some waste streams between incineration, toxic landfill and inert landfill based on the nature of the waste and the hazardous compounds contained. This was the case for instance for ETP sludge.
- withdrawal of some waste streams from hazardous waste management options due to their non-hazardous nature or current usage in another industry. This is the case, for instance, for tundish dust, APC dust, bleaching earth, flesh, raw hides cuttings, shaving and trimming dust, some contaminated plastic waste (mainly plastic drums that can be washed), and some ETP sludge.
- reduction of the APC dust generated in the re-rolling mills based on updated industry data and a reviewed sector total capacity.
- reduction of the ETP sludge quantity generated from the chemical industry based on updated industry data.
- the addition of episodic and aperiodic waste assumed based on the total figures.
- update of the figures for flesh, trimming dust, glasswool and insultation material and other contaminated materials.

Table 16 Estimated hazardous waste generation in Chittagong by sector and treatment technology

Type of waste by sector	Total generation (MT/Y)	Incineration (MT/Y)	Toxic waste landfill (MT/Y)	Inert landfill (MT/Y)	Alternate gainful use / MSW landfill (MT/Y)	Remark
Cable						
Contaminated solid waste	14	14				
Glasswool and insulation material	8			8		Glasswool is an inert material
Spent Lubricants	1	1				
Cement						
Contaminated solid waste	22	22				
Spent Lubricants	42	42				
Chemical						
Asbestos	40			40		Asbestos is an inert material
Bleaching earth	910				910	Currently used by soap manufacturer to produce low cost cleaning soap
Contaminated packaging	62	62				
Contaminated plastic waste	500	255			245	Some of the plastic waste consists in plastic drums, which are washed and sold off.
Contaminated solid waste	8	8				
ETP sludge	3'610	10			3'600	1) This ETP sludge is generated by agrochemical and pesticides industries and therefore it cannot be landfilled. It is presently sent for incineration to the Lafarge-Surma cement plant 2) Based on on-site investigations, this sludge was found to be non-hazardous since it is generated by a cosmetics industry, which manufactures products for skin application that do not contain hazardous compounds. It can be used in a MSW landfill or possibly in land applications.
Other contaminated materials	22	21		1		Glass waste is an inert material
Spent Lubricants	6	6				
Fertilizer						

Type of waste by sector	Total generation (MT/Y)	Incineration (MT/Y)	Toxic waste landfill (MT/Y)	Inert landfill (MT/Y)	Alternate gainful use / MSW landfill (MT/Y)	Remark
Contaminated solid waste	2'620	2'620				
ETP sludge	9	9				The sludge comes from a urea fertilizer industry. In the absence of analysis, it is assumed that this sludge contains toxic compounds and must be treated by incineration.
Spent Lubricants	0	0				
Glass						
Spent Lubricants	2	2				
Paints						
Contaminated plastic waste	46	23			23	Some of the plastic waste consists in plastic drums, which are washed and sold off.
ETP sludge	147	147				Due to paint related solvents, dyes and chemicals, this sludge is considered toxic. Presently most of the sludge is sent to a captive incinerator in Dhaka.
Other contaminated materials	3	3				
Spent Lubricants	1	1				
Paper						
Chemical residues	88	88				
Contaminated solid waste	101	101				
ETP sludge	11'797				11'797	This was estimated based on benchmarks (Bajpai 2015) which gave a sludge figure of 40-50kg/MT of paper. In reality, most paper mills in Chittagong do not have an ETP, and therefore do not generate sludge. Yet it is likely that paper mills such as the State-owned Karnaphully mill should soon get equipped with ETPs, as fund from the Government has been secured with this objective, and for this reason sludge from this sector was considered here. As sludge samples are not available at the moment, the nature of the sludge is unclear. ETP sludge from the paper industry often finds gainful use. But the exact nature of the sludge and whether it is contaminated with heavy metals will need to be determined through chemical analyses after

Type of waste by sector	Total generation (MT/Y)	Incineration (MT/Y)	Toxic waste landfill (MT/Y)	Inert landfill (MT/Y)	Alternate gainful use / MSW landfill (MT/Y)	Remark
						construction of the ETP.
Oil and grease	88	88				
Spent Lubricants	19	19				
Refinery						
Oil and grease	0	0				
Oily crude tank sediments	1'459	1'459				
Spent Lubricants	44	44				
Rerolling						
APC Dust	11'131				11'131	ACP dust is currently exported to China for metal recovery. The total quantity has been reviewed based on a verification of the installed capacity.
Tundish lining	25'192				25'192	This inert waste can be gainfully reused into construction material.
Tannery						
Contaminated solid waste	1'200	1'200				
ETP sludge	324		324			This was estimated based on benchmarks FAO report (1996). In reality, no running ETP is available in the tanneries as of now, but they are likely to be developed in the future. Tannery effluent contains heavy metals such as Chromium. The sludge should preferably be landfilled.
Flesh	222				222	Currently used as chicken feed
Raw hides cutting	66				66	Currently sold off
Shaving dust	54				54	Currently sold off but it may contain hazardous substances from tanning process
Trimming dust	72				72	Currently sold off but it may contain hazardous substances from tanning process
Textile						
Contaminated packaging	3'565	3'565				
Contaminated plastic waste	735	429			306	Some of the plastic waste consists in plastic drums, which are washed and sold off.

Type of waste by sector	**Total generation (MT/Y)**	**Incineration (MT/Y)**	**Toxic waste landfill (MT/Y)**	**Inert landfill (MT/Y)**	**Alternate gainful use / MSW landfill (MT/Y)**	**Remark**
ETP sludge	3'277	3'277				Currently, the sludge is often sent to brick kilns. This practice may release toxic compounds. Incineration under controlled conditions is preferred.
Maintenance scrap	124	124				
Spent Lubricants	135	135				
Total	**67'768**	**13'777**	**324**	**49**	**53'619**	
Episodic and aperiodic waste	678	138	3	0	536	Approx. 1% of total wastes has been assumed as additionally generated episodic and aperiodic waste.
Grand total	**68'446**	**13'914**	**327**	**49**	**54'155**	

Note:
Contaminated packaging: flattened boxes (soiled with dies, pigments, chemicals, etc.), carton box lined with polymeric layers etc
Contaminated plastic: soiled plastic drums that cannot be sold off, bags etc.
Please note that the ETP sludge is expressed by the industries in dry weight as it usually undergoes some drying process, mainly solar drying. Yet in reality, this process may not remove the moisture entirely. The sludge might need to undergo further drying before incineration.

Table 17 Estimated hazardous waste generation by waste type and treatment technology

Waste type	Total generation (MT/Y)	Incineration (MT/Y)	Toxic waste landfill (MT/Y)	Inert landfill (MT/Y)	Alternate gainful use / MSW landfill (MT/Y)
Tundish lining	25'192				25'192
ETP sludge	19'165	3'443	324		15'397
APC Dust	11'131				11'131
Contaminated solid waste	3'965	3'965			
Contaminated packaging	3'626	3'626			
Oily crude tank sediments	1'459	1'459			
Contaminated plastic waste	1'282	707			575
Bleaching earth	910				910
Spent Lubricants	251	251			
Flesh	222				222
Maintenance scrap	124	124			
Oil and grease	89	89			
Chemical residues	88	88			
Trimming dust	72				72
Raw hides cutting	66				66
Shaving dust	54				54
Asbestos	40			40	
Other contaminated materials	25	24		1	
Glasswool and insulation material	8			8	
Total	**67'768**	**13'777**	**324**	**49**	**53'619**
Episodic and aperiodic waste	678	138	3	0	536
Grand total	**68'446**	**13'914**	**327**	**49**	**54'155**

Table 18 Summary of the effluent treatment plant (ETP) sludge generation by sector

Sector	Total generation (MT/Y)	Incineration (MT/Y)	Toxic waste landfill (MT/Y)	Alternate gainful use / MSW landfill (MT/Y)
Paper	11'797			11'797
Chemical	3'610	10		3'600
Textile	3'277	3'277		
Tannery	324		324	
Paints	147	147		
Fertilizer	9	9		
Total	**19'165**	**3'443**	**324**	**15'397**

In addition to the results shown above, biomedical waste generation from the hospital and health sector is estimated at 800 MT/Y (based on 6’400 beds).

Finally, the Chittagong Port accumulates or receives a considerable amount of waste consisting of Oily wastes, Sewage, Garbage or discarded merchandise of different types that may also need special attention as they, sometimes, are hazardous in nature. Unfortunately, data from **the Port of Chittagong** was very scarce, as a system to maintain waste records is yet to be developed. A study[8] shows that landfillable waste amounts to 8’640 MT/year, but at this stage it is not possible to determine what is the hazardous fraction.

7.2.2 Key findings and discussion on the inventory results

As described in the tables above, the total hazardous waste estimates are approx. 14’000 MT/year of incinerable hazardous waste, 400 MT/year of landfillable waste (both toxic and inert), 800 MT/year of biomedical waste and a fraction of potentially hazardous waste from the Port of Chittagong. Approx. 54’100MT/year of the waste initially identified as hazardous waste actually has an alternate gainful use or can be disposed of in a MSW landfill.

1. **The steel industry (re-rolling mills) is the biggest generator of landfillable waste with about 40’000 MT/year of hazardous waste production**.

   This result reflecting the importance of the steel recycling activities is very interesting as it is very much related with the project scope. Here two main wastes types are produced:

   - **Tundish lining[9] residue** is mainly composed of silicate and magnesium but often also contains phosphate, chemicals and heavy metals such as Aluminum or Chromium. This waste can go to inert landfill provided the TCLP analysis reveals that the presence of toxic trace metals is not significant and the matrix need not be committed to disposal into hazardous secured landfill. Even better and economic solution could be developed and implemented under strict legal guidelines and

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[8] TERA international, 2004, Report on Chittagong port trade facilitation project, Bangladesh by Asian Development Bank and Bangladesh Ministry of shipping, Chittagong Port Authority (TA 4136-BAN)

[9] In the steel processing called « continuous casting », an intermediate vessel, called a tundish, is used to transfer liquid steel from a steel teeming ladle to the mould. It requires the use of refractory lining, which exist in different forms of products (bricks, spray, powder etc..) and often contains several chimicals and heavy metals (http://ispatguru.com/tundish-and-its-role-in-continuous-casting/).

control. For example, the matrix may be crushed size-graded and used into manufacture of hi-strength industry-grade construction material. This waste is recyclable to recover metal content.

- **Air protection control (APC) dust:** The process of steel making from secondary sources can lead to generation of significant quantities of particulate matter consisting of many metals and hazardous substances, hence the need for an efficient and effective air pollution control system to be in place. The composition of the APC dust can vary depending upon the type of furnace used, though a large constituent of this waste is expected to comprise of iron dust. Conventionally, this dust is difficult to handle and is sent to hazardous waste landfills for disposal. However with development of technology it is now possible to produce briquettes from this dust and recycle it into steel manufacturing in composite steel plants. It seems that in the case of Chittagong, the dust is exported to China, most likely for zinc and iron recovery. Managing ACP dust hazardous waste is important as mills are more and more encouraged to use APC systems, which would lead to growing quantities of APC dust.

2. **Effluent treatment plant (ETP) sludge is a considerable waste stream**

   Depending on the industry considered, ETP sludge may contain **a significant amount of chemicals, solvents, cleaning agents and heavy metals**. Sectors generating hazardous ETP sludge include the textile, chemical (in particular agrochemical and pesticides industries), tannery, fertilizer and paint sectors. The disposal method for this sludge depends both on the hazardous product content and on the type of wastewater treatment of the ETP. Often, the high solvent and organic content prevents the landfilling option and requires controlled incineration. Currently, this sludge is dumped on industrial land plots, used as fuel in brick kilns if its calorific value is high (in an artisanal way with high human and environmental contamination risks) or, in the case of some multinational companies, dried into briquettes and sent for incineration to the Lafarge-Surma cement plant or are incinerated at their captive facility.

   In contrast, ETP sludge produced from the paper industry, as well as cosmetics industry, is not considered hazardous as it is not contaminated with toxic components, and can be used for energy generation, land application or disposed in a MSW landfill.

3. **Approximately 10’000 MT/year of packaging, plastics and mixed solid waste contaminated with hazardous substances are generated, which goes into the incinerable waste category.** This waste comes from various industrial sectors as a by-product of specific production process (i.e. dye packaging from the textile industry).

4. **An estimate of approximately 800 MT/year of medical waste is generated from healthcare institutions**. According to DoE, medical waste should be given to authorized waste collecting entities, but medical waste often ends up in municipal landfills, or is traded in the informal recycling sector. Some healthcare entities have their own incinerator, but some synergy is foreseeable with the future TSDF.

5. **The Port of Chittagong reports about 9’000 MT/year of mixed waste** (mostly non-hazardous) going to an on-site landfill facility reported to be poorly managed. Part of this waste is potentially hazardous but there are no specifics. Port authorities are keen on investing in an incinerator, both to burn part of their waste, as well as to sell waste management services. Further investigation is needed here.

6. **Data quality:** The result of this first generation inventory shows the lack of existing know-how and a reporting system for industrial hazardous waste. Because no official or any government data on hazardous waste could be obtained, the inventory was based on a combination of sample survey and some benchmark data. Despite strong support from MoI, access to industries and responsiveness on hazardous waste questions was very limited (50% non-response). However the data collected was accurate and could serve for the extrapolation. The verification process was crucial in improving the data quality and interpretation of the results. **The resulting estimated quantities therefore provide a useful order of magnitude for each hazardous waste category**.

7. **POPs content** : Due to the absence of records on POPs generated or contained in industrial waste, precise data on POPs was not available during the inventory. However POPs are expected to occur in the following industries: paint industry (e.g. PCBs contained in plastifiers, dyes etc.), pharmaceuticals, cable manufacturing, metal recycling (e.g. dioxins and furans captured in the air pollution control system), agrochemical industry, petroleum refineries, healthcare wastes, incineration systems, waste from the pesticide industry, and tanneries. The inventory revealed that some waste types, such as ETP sludge, are sent to brick kilns to be used as fuel. Depending on the composition of the waste, this process may be a considerable source of dioxins and furans. In general, burning waste in uncontrolled conditions is a well-acknowledged source for POP production and release. Though we did not come across mentions of stockpiles of banned pesticides such as DDT during the inventory, such stockpiles are likely to exist in Chittagong and to be a source of emissions (Nøst et al. 2015). Beside, POPs, in particular PCBs, PAHs, and HCB have been measured in high concentrations near ship breaking yards (Nøst et al. 2015). They are expected to be released from the following sources: improper disposal or burning of POP-containing materials from the ships, e.g. paints (PCBs, etc.), wires, PCB-containing transformers and capacitors, as well as burning of scrap and organic material during the ship breaking process. The development of a safe hazardous waste management infrastructure will provide a safe option to get rid of POP stockpiles and POP-contaminated materials and contribute in reducing open burning of waste and associated POP emissions.

8. **Current hazardous waste management practices** (see also Annexure 10.7): Several waste streams have a value chain, and are sold to a third parties. For instance, one industry reported that the bleaching earth they get from refining essential oils is used in the low-grade soap manufacturing industry. From a resource conservation perspective, the reuse and recycling of waste materials is laudable. Yet, not all waste recycling practices are safe for humans and the environment. For instance, in some cases ETP sludge is sold to brick kilns as fuel. Depending on the composition of the ETP sludge, this may lead to the release of very toxic compounds such as dioxins into the environment. Among the industries selected in this survey, some multinational companies are sending their waste to the Lafarge-Surma cement plant located in the north of the country. It is probable that due to their dominant position and international character, they may have relatively higher waste management standards than small players, which have less financial resources and know-how towards an optimal waste management system. Some waste streams are already in the focus of the government. For instance, asbestos, and healthcare waste are to be handled as per government instructions. Exchanges between public authorities and industry also take place on the management of oily sediments and textile sludge.

9. **Evolving hazardous waste composition and the role of a potential TSDF operator:** This inventory gives a snapshot of hazardous waste quantities and categories among a sample of industries. It is important to note here that **this picture can evolve very fast depending on the arrival/growth/departure of big industrial players as well as**

changing production processes and input materials. This shows the importance of **developing local competencies and know-how on hazardous waste** identification. The final responsibility is for the future facility operator to capture the waste streams adapted to each landfill cell or incineration system. An understanding of waste composition and its hazardous substance content requires specific knowledge of each industrial process and/or laboratory analysis. For this particular reason, what is important is to launch TSDF facilities to give the opportunity for generators to follow best practices and develop specific skills.

10. **Resource efficiency and cleaner production (RECP):** As previously mentioned, most waste streams of value are recycled into the market. In some situations however, the current production processes produce mixed or aggregated by-products or waste that cannot be recovered and end up being disposed of. Chittagong's industries could benefit from RECP best practices in order to avoid resource wastage and hazardous substance dissemination. Typically, Tundish liner could have better utilization and properly treated ETP sludge could avoid containing some harmful components. By doing so the overall quantities of hazardous waste could be significantly reduced. UNIDO typically supports these kind of activities world-wide.

7.2.3 Sectorial growth perspective

The table below shows the expected growth of the considered industrial sectors.

Table 19 Size and expected annual growth rate of the industrial sectors considered

Sector	Sector growth projection	Comment on growth rate
Cable	3-5%	Registered and unregistered cable manufacturers are growing in number due to the ship breaking activities. The demand is on a rise due to housing and industrial expansions. Eastern cables has a higher installed capacity than what it currently produces and will increase production as demand increases.
Cement	4-6%	Though the production capacity is higher than local demand, the export growth is compelling. The industries in Chittagong are planning to expand. Year on year growth basis the growth is expected to be between 4-6% .
Chemical	10-12%	During the inventory survey, the major players in this sector have reported about 10% year on year growth.
Fertilizer	2-5%	Most of the fertilizer industries are remaining closed for a considerable portion of the year due to shortage in natural gas supply. The grim business outlook prevents new investment. Since the government is planning to import LNG in the near future, the situation may change.
Glass	7-8 %	It was heard from PHP glass that they are going to double their capacity. We can consider 7-8 percent growth to accommodate the doubled capacity.
Paints	7-10%	Elite paint, Berger paints, etc. are reporting a steady growth rate of 7-10%.
Paper	10-12%	There is still considerable potential of growth. In the new exclusive economic zones (EEZs), considerable investments are made in the ready-made garment sector, which consumes a lot of paper. Due to the proximity to the port, pulp based paper industries prefer Chittagong as location. The sector is supposed to double with the doubling of the ready-made garment sector.
Refinery	7-8%	Installed capacity of ERL will be tripled in the next 3-5 years. As the country's demand is increasing, new refineries from the private or public sector may come into play in next ten to twenty years. Growth rate of 7% is considered to adjust the tripling of capacity of ERL.
Rerolling	7-10%	Current production surplus is more than 50% of the total domestic demand. However, the export is increasing. Therefore, potential for growth exists. In our recent visit to BSRM we came to know that they are doubling their capacity. Other existing big players are also establishing new facilities while new rerolling mills are also in the process of establishment. We can consider 7-10% year on year growth to reflect the planned expansion.
Tannery	8-10%	There were 19 tanneries, 17 have been closed and of the remaining two one has to halt production due to ban by DoE for not having ETP. The other is establishing an ETP to remain in the business besides doubling the capacity. If the TSDF is established, the possibility of new entrant increases. Therefore, it is reasonable to consider a 10 year doubling time which is equivalent to 8-10% year on year growth.
Textile	10-12%	Many new exclusive economic zones (EEZs) are planned, with a number of them in Chittagong, in which considerable investments are made in the ready-made garment sector. 10-12% growth rate will hold, if everything remain calm, since the industry is doubling in five years on an average.

8. Conclusion

This hazardous waste assessment report gives a comprehensive picture of the hazardous waste situation related to the SBRI yards and other Chittagong industrial areas.

Table 20: Approximate estimated hazardous waste quantities generated from the Chittagong ship recycling yards and Chittagong industrial areas (MT/year)

Type of hazardous waste	From the ship recycling yards	From the industrial area	Medical waste	Total (min-max)
Landfillable waste (both toxic and inert)	7’500-10’300	400	-	**7’900-10’700**
Incinerable waste	5’400-6’400	14’000	800	**20’200-21’200**
Bilge water	5’600-6’300	-	-	**5’600-6’300**
TOTAL	**18’500-23’000**	**14’400**	**800**	**33’700-38’200**

In addition to the quantities in the table above, a fraction of the 8'700 MT/year of mixed waste generated by the Chittagong port should be considered.

Legacy waste sites are not included in this analysis. However when the time comes, these sites should also be remediated, which will increase the quantity of materials to be disposed of at TSDF.

The lack of suitable hazardous waste management facilities is confirmed and most existing practices are causing environmental hazards.

Through a first generation inventory, estimates of the overall hazardous waste streams in Chittagong have now been made available. Based on this estimate, the suitable waste infrastructure needed to fill the existing gaps can now be planned and designed, together with an adapted business model and operating scheme.

These are the some of key questions to be raised in the next project phase:

- From the overall hazardous waste streams, what are the most critical streams that need to be captured by the hazardous waste facilities? How can the development of the facility be phased?
- What is the required infrastructure: landfill, incinerator, transfer station, temporary on-site storage?
- What are the site selection criteria: geographical location of facilities in relation to the ship recycling yards and the different industrial areas; safety, environmental, and technical requirements?
- What revenue model is to be recommended for the TSDF, considering the best and most applicable practices observed abroad (i.e. India, Turkey)?
- What institutional and regulatory accompanying measures are required to ensure sustainable development of hazardous waste management in Chittagong and guarantee a safe and long-term operation of the proposed facilities?
- How to ensure that recycling practices are conducted in an environmentally and socially sound manner, and how can hazardous waste streams currently recycled or used in a way that does not meet international standards can be re-directed to the facility?

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10. Annexure

10.1 Analysis of ship recycling data from Turkey

We would like to understand what are the main factors that determine the type and quantity of waste in a ship based on ship age, ship type, ship size, etc. The Ship Recycling Industry Association of Aliaga, Turkey, maintains detailed reports on the quantities of hazardous waste generated from their yards; but we used this data instead (for the years of 2014 and 2015) to understand the determinant factor to estimate waste generation from the ship recycling industry, focusing particularly on asbestos.

The data show that in Turkey, the construction year of the recycled ships peaks in around 1975-1980, i.e. the lifetime of the ships reaches on an average 35 years of which Cargo ships are the most common category (Figure 13).

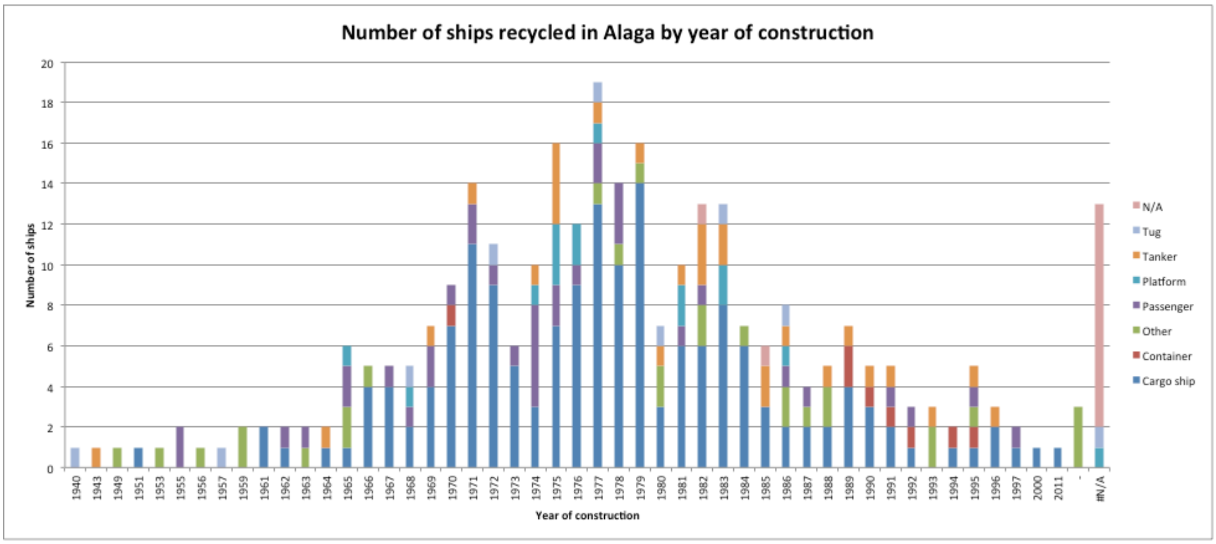

Figure 13 Number, category and year of construction of ships recycled in Allaga, Turkey, in 2014-15.

On an average, the ships dismantled are relatively small (approx. 3’500 LDT on an average). The heavier vessels are platforms and containers, as shown in the following table:

Table 21: Average LDT of the ships dismantled in Aliaga in 2014-2015

Ship category	Average LDT of the ships
Cargo ship	2'738
Container	9'250
Passenger	6'567
Platform	12'824
Tanker	7'844
Tug	2'274
Other	3'610

The analysis of Figure 14 highlights the overwhelming majority of hazardous waste present in cables (>80% by weight). The terminology of “waste” should be considered carefully, as this category probably includes reusable cables, which should in fact not be considered by waste. Beside, in some countries, cables have a market value, even if they cannot be used anymore, as they provide valuable material to the recycling industry. In India for instance, cables and e-waste are considered as recyclable materials and not considered in the estimation of hazardous waste to be disposed of (S. Asolekar, personal communication). Other waste types, such as asbestos, have no market value. Given their highly hazardous nature if no safe disposal infrastructure is developed, such waste streams would become a direct threat to human health and the environment.

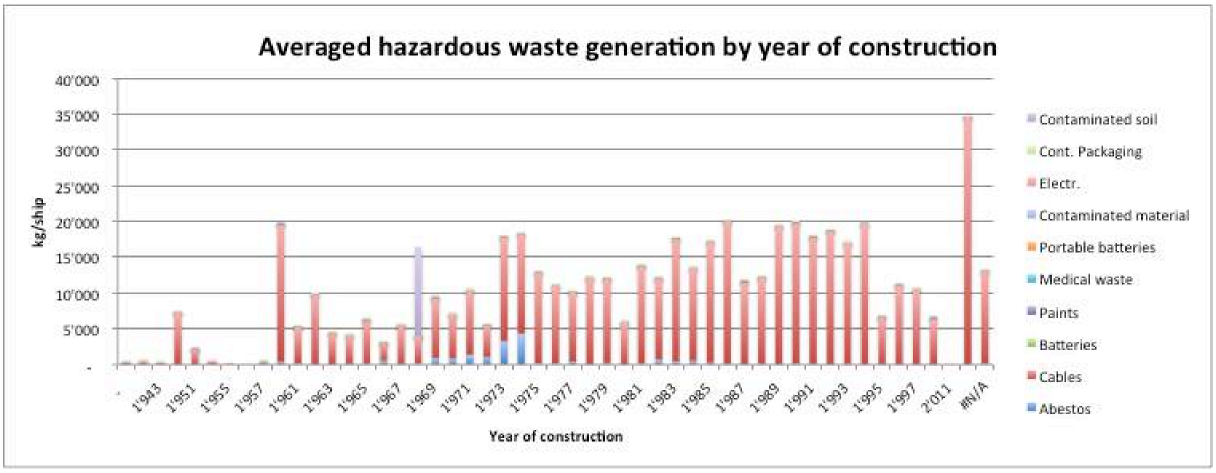

Figure 14 Hazardous waste generation factor averaged by year of construction. Data from Ship Recycling Industry Association of Aliaga, Turkey, collected from ship dismantled in 2014 and 2015.

A detailed look at the asbestos waste generated from the ships provide us with a better understanding of what are the factors to be considered for the estimation of waste from the ship recycling industry. The maximum amount of asbestos found in a single vessel was 22’340kg, collected from a passenger ship constructed in 1974 in Greece. Other ships that released >8’000kg asbestos per ship were all passenger ships constructed in Greece, Albania or Spain (Almeria)[10]. Asbestos was extensively used in passenger ships as fire isolation material. The asbestos content in passenger ships decreased after the 70s. In 1973, the average content of asbestos collected in passenger ships was 19’340kg/ship, but after 1975, it did not exceed 500kg/ship and fell as low as 10kg/ship in 1995 (Figure 15). In other ship categories the asbestos content is much smaller (Figure 16). Therefore, to conclude we can say, **that ship categories are an important factor to assess asbestos content.**

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[10] Although the Turkish data are quoting Greece and Albania as the ship building countries for a number of ships, expert inputs suggest that this is highly unlikely. Rather, it is possible that the Turkish data are mistakenly referring to country of build as opposed to flag State

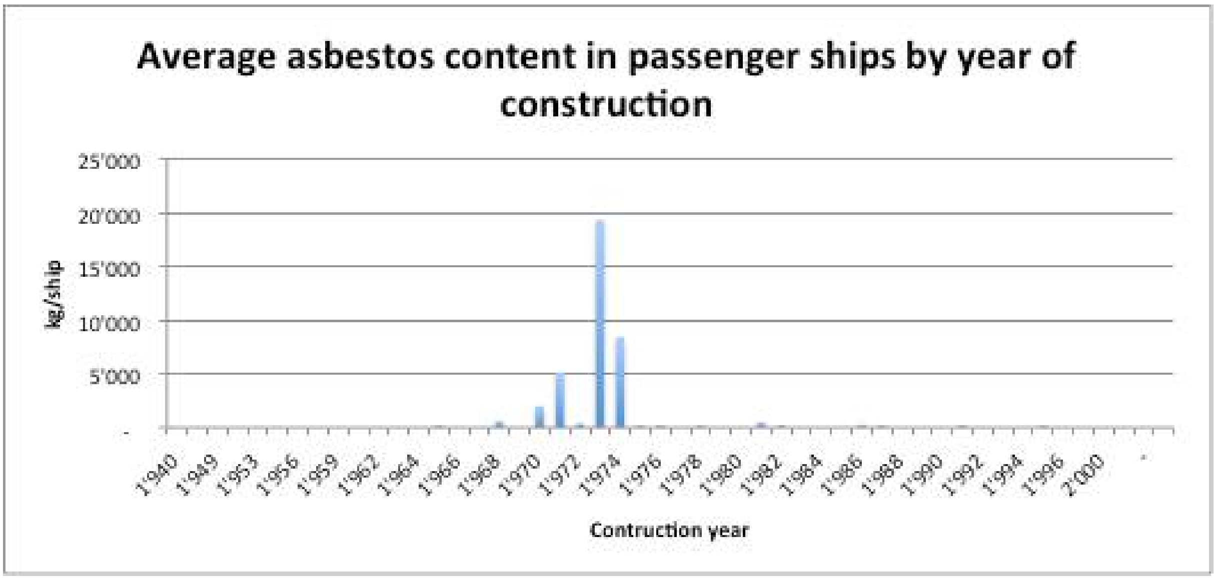


Figure 15 Average asbestos content in passenger ships by year of construction

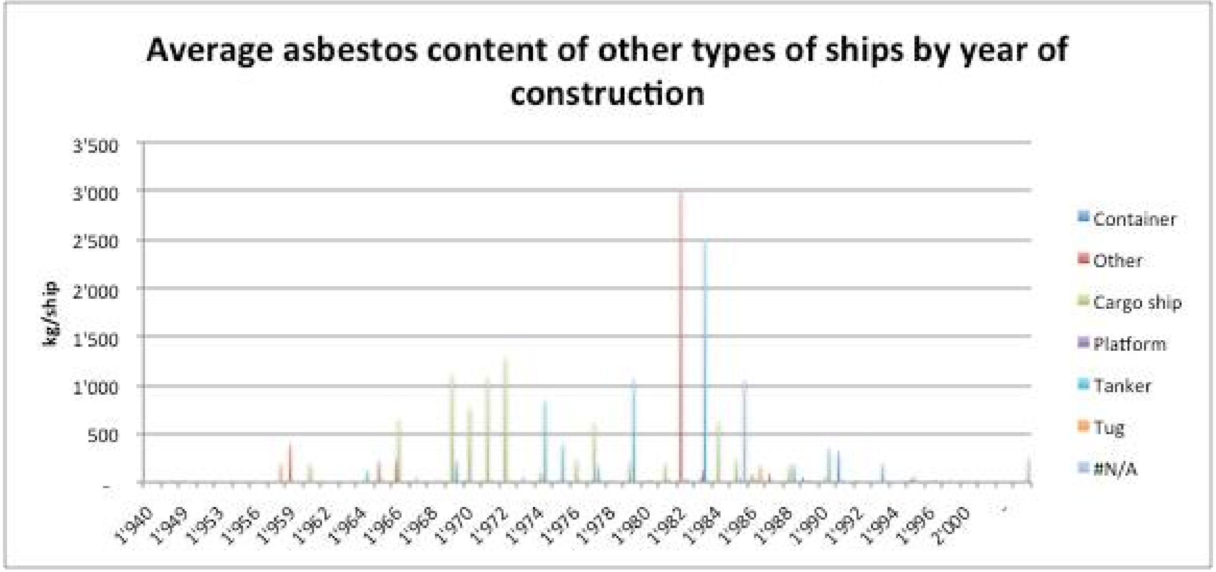


Figure 16 Average asbestos content in other ships (excluding passenger ships) by year of construction. #N/A: type of ship not available.

Although many second hand ferries of Japanese origin are used in the Mediterranean basin, we saw that the passenger ships containing >10’000kg asbestos were built in the Mediterranean basin itself and not in Asia. We suppose that such high asbestos quantities reflect construction practices that are not followed anymore. The more recent passenger ships analyzed exhibited smaller asbestos quantities. **Thus the year of construction proves to be a relevant factor to estimate waste quantities.** With the analysis we can say that, ships constructed after 1975 is a reasonable option, as over time, the ships dismantled in recycling yards will have been built in more recent years. In fact, Turkey is a special case, as the Turkish ship recycling industry specializes in a regional market of smaller Mediterannean trading ships, which tend to be older. In contrast, in India, the average lifetime of recycled ships is currently 22-25 years (Hiremath et al. 2015), implying that the majority of the ships received were constructed after the 1990. This is representative of what is observed at international level.

The impact of vessel size on the asbestos content is less clear. Figure 17 shows that it is difficult to observe a distinct increase of asbestos with vessel size. This may be due to the fact that ships recycled in Turkey are rather small in size, and that therefore large vessels are less represented in this dataset. Going one step further, Neser and Unsalan (2007) have assessed whether the asbestos/LDT ratio shows any trend with increasing LDT but no clear correlation could be obtained. Yet we find it reasonable to assume that larger vessels will have higher probabilities to contain hazardous waste than smaller vessels, especially for waste types such as sludge, contaminated rags etc. even if the increase is not necessarily absolutely proportional to the ship size.

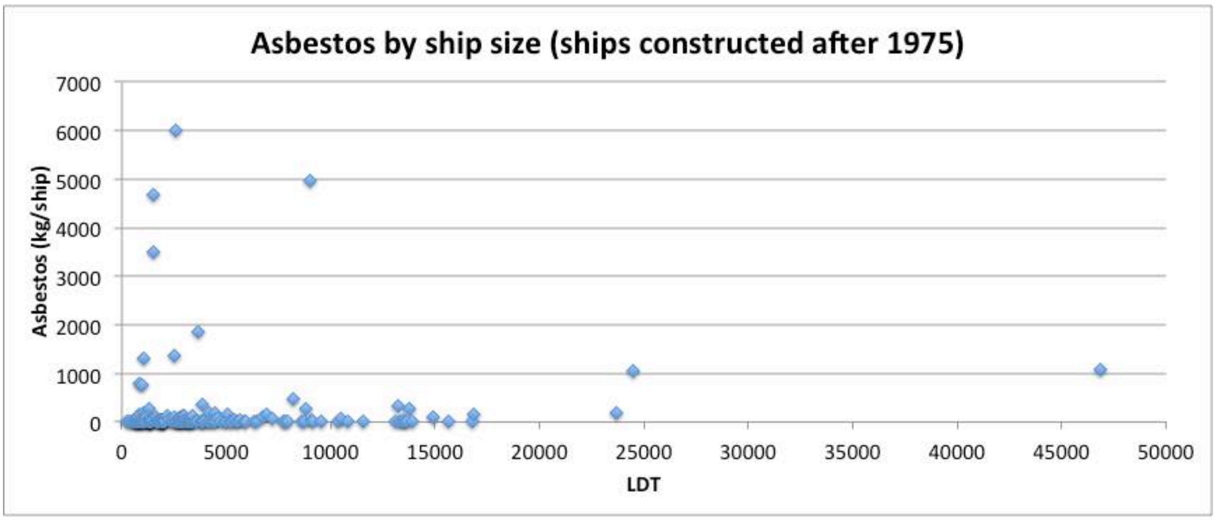
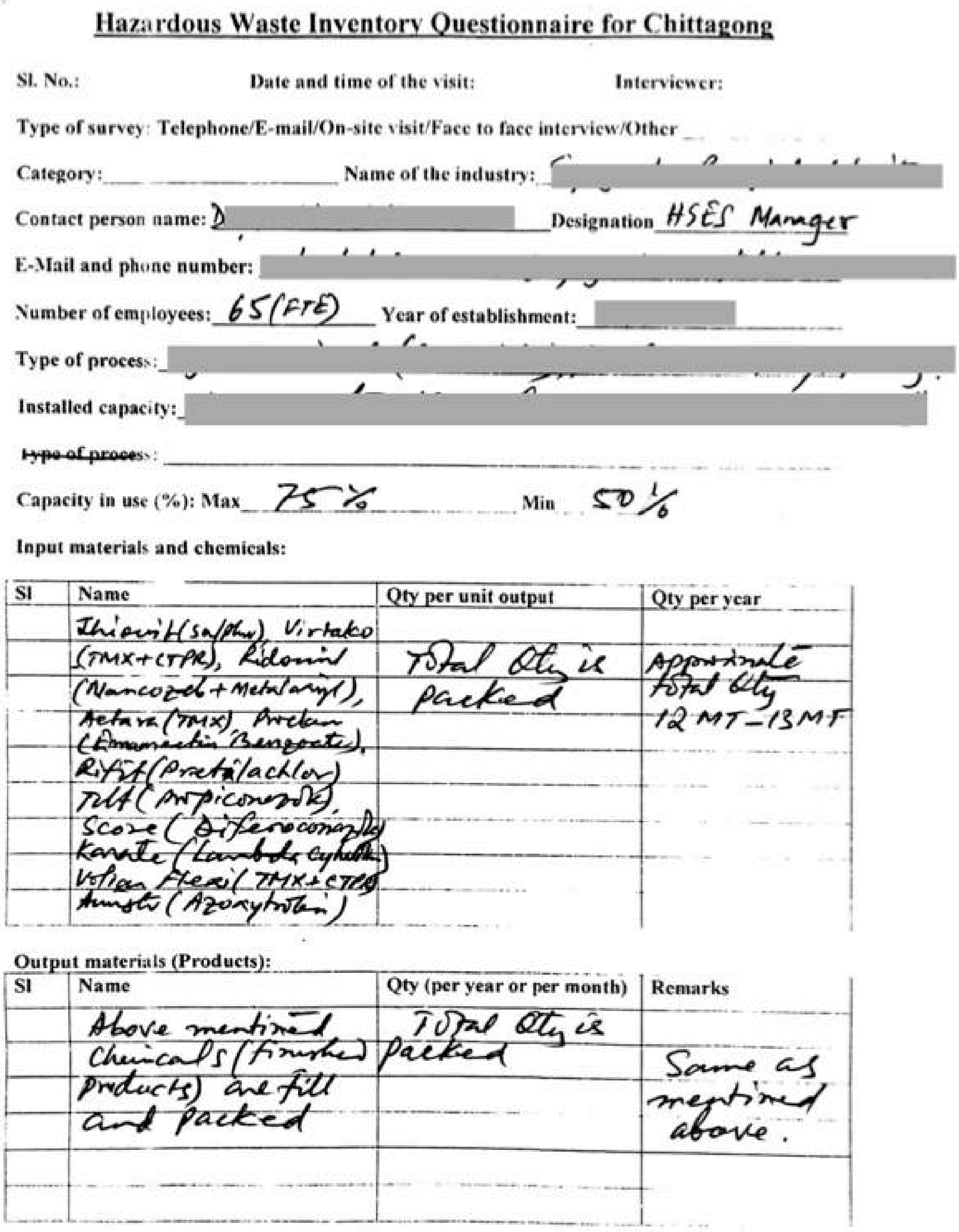


Figure 17 Asbestos content in ships by ship size (for ships constructed after 1975 to remove exceptional asbestos quantities contained in passenger ships constructed before hand)

In conclusion, we consider that ship type, year of construction and to a certain extent ship size are important factors that influence the asbestos content of the ships.

10.2 Example of filled questionnaire for the survey of hazardous wastes from industries



Hazardous Waste Inventory Questionnaire for Chittagong

Sl. No.: **Date and time of the visit:** **Interviewer:**

Type of survey: Telephone/E-mail/On-site visit/Face to face interview/Other

Category: **Name of the industry:** [redacted]

Contact person name: [redacted] **Designation** HSES Manager

E-Mail and phone number: [redacted]

Number of employees: 65(FTE) **Year of establishment:** [redacted]

Type of process: [redacted]

Installed capacity: [redacted]

~~Type of process~~:

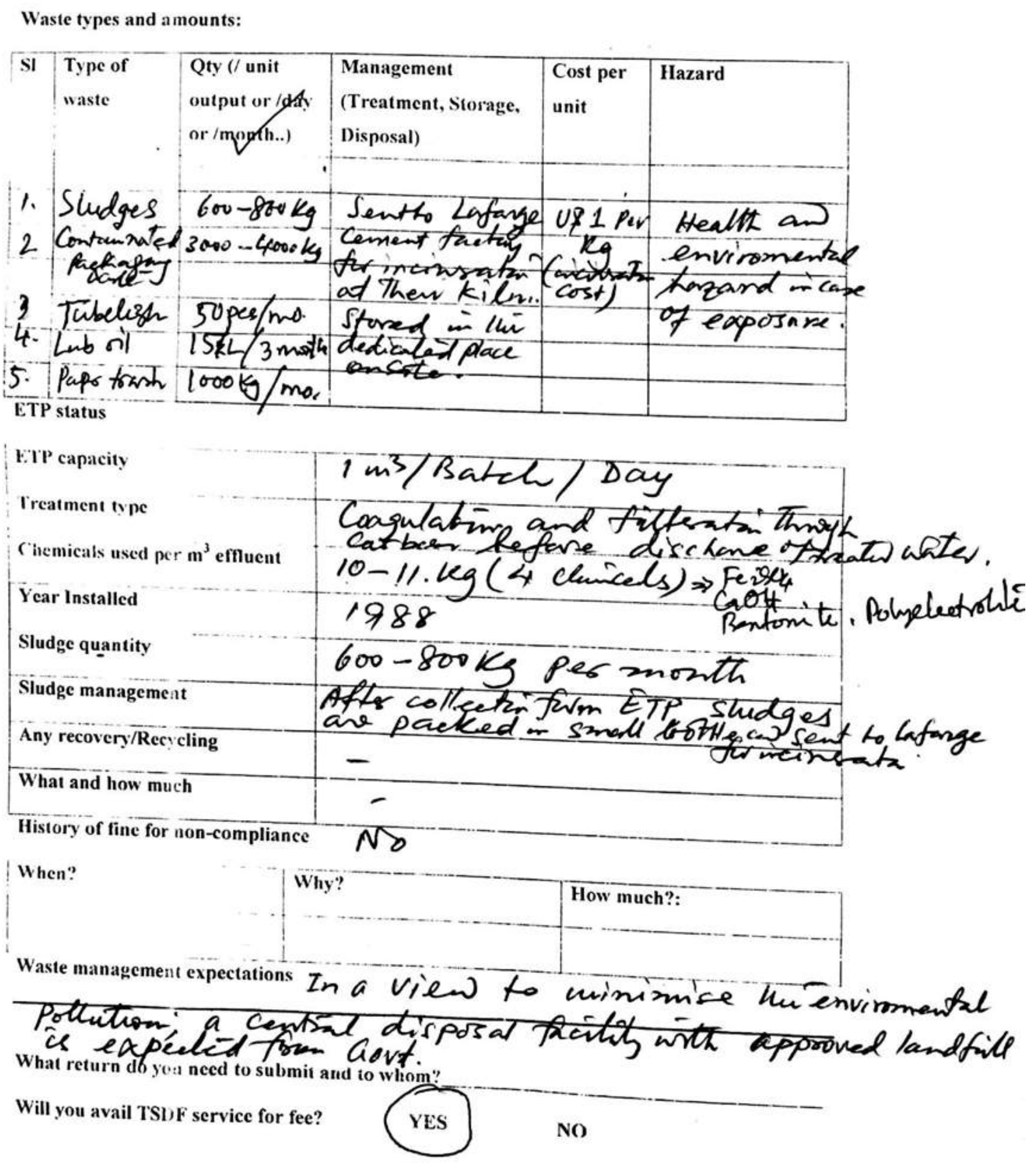
Capacity in use (%): Max 75% **Min** 50%

Input materials and chemicals:

Sl	Name	Qty per unit output	Qty per year
	Thiovit(sulphur), Virtako		
	(TMX+CTPR), Ridomil	Total Qty is	Approximate
	(Mancozeb+Metalaxyl),	packed	Total Qty
	Actara(TMX) Proclaim		12 MT–13MT
	(Emamectin Benzoate),		
	Rifit(Pretilachlor)		
	Tilt(Propiconazole),		
	Score(Difenoconazole)		
	Karate(Lambda cyhalothrin)		
	Voliam Flexi(TMX+CTPR)		
	Amistar(Azoxystrobin)		

Output materials (Products):

Sl	Name	Qty (per year or per month)	Remarks
	Above mentioned	Total Qty is	
	Chemicals (Finished	packed	Same as
	products) are fill		mentioned
	and packed		above.



Waste types and amounts:

Sl	Type of waste	Qty (/ unit output or /day or /month..)	Management (Treatment, Storage, Disposal)	Cost per unit	Hazard
1.	Sludges	600-800 Kg	Sent to Lafarge Cement factory for incineration at their kiln.	US$ 1 Per Kg (incineration cost)	Health and environmental hazard in case of exposure.
2	Contaminated Packaging Scale	3000 - 4000 kg			
3	Tubelight	50 pcs/mo.	Stored in the dedicated place onsite.		
4-	Lub oil	15 KL/3 month			
5.	Paper trash	1000 Kg/mo.			

ETP status

ETP capacity	1 m³/Batch/Day
Treatment type	Coagulating and filtration through Carbon before discharge of treated water.
Chemicals used per m³ effluent	10-11. kg (4 chemicals) ⇒ $FeSO_4$, $CaOH$, Bentonite, Polyelectrolite
Year Installed	1988
Sludge quantity	600-800 Kg per month
Sludge management	After collection from ETP sludges are packed in small bottles and sent to Lafarge for incineration.
Any recovery/Recycling	–
What and how much	–
History of fine for non-compliance	No

When?	Why?	How much?:

Waste management expectations In a view to minimise the environmental Pollution, a central disposal facility with approved landfill is expected from Govt.

What return do you need to submit and to whom?

Will you avail TSDF service for fee? [✓ YES] NO

10.3 Theoretical hazardous waste quantities generated in Alang

Table 22: Theoretical hazardous waste quantities generated in Alang. The minimum and maximum hazardous waste estimates are derived by multiplying minimum and maximum factors published by Hiremath et al. (2015) by the number of ships reported by GEPIL

Theoretical range of hazardous waste quantities based on factors published by Hiremath et al. (2015)							
Theoretical minimum waste		**Factors - minimum**			**Minimum waste estimates**		
Year	**Number of ships**	**landfillable waste MT/ship**	**incinerable waste MT/ship**	**bilge water MT/ship**	**landfillable waste MT**	**incinerable waste MT**	**bilge water MT**
2013	298	100	7	8	29 800	2 086	2 384
2014	275	100	7	8	27 500	1 925	2 200
Theoretical maximum waste		**Factors - maximum**			**Maximum waste estimates**		
Year	**Number of ships**	**landfillable waste MT/ship**	**incinerable waste MT/ship**	**bilge water MT/ship**	**landfillable waste MT**	**incinerable waste MT**	**bilge water MT**
2013	298	400	30	138	119 200	8 940	41 124
2014	275	400	30	138	110 000	8 250	37 950

10.4 Theoretical hazardous waste quantities generated in Alang without glasswool

Table 23: Range of theoretical hazardous waste quantities generated in Alang excluding the glasswool fraction. The minimum and maximum hazardous waste estimates are derived by multiplying minimum and maximum factors published by Hiremath et al. (2015) by the number of ships reported by GEPIL

Theoretical range of hazardous waste quantities based on factors published by Hiremath et al. (2015), excluding the glasswool fraction							
Theoretical minimum waste		Factors - minimum			Minimum waste estimates		
		landfillable waste (without glasswool)	incinerable waste	bilge water	landfillable waste	incinerable waste	bilge water
Year	Number of ships	MT/ship	MT/ship	MT/ship	MT	MT	MT
2013	298	7.2	7	8	2 146	2 086	2 384
2014	275	7.2	7	8	1 980	1 925	2 200
Theoretical maximum waste		Factors - maximum			Maximum waste estimates		
		landfillable waste (without glasswool)	incinerable waste	bilge water	landfillable waste	incinerable waste	bilge water
Year	Number of ships	MT/ship	MT/ship	MT/ship	MT	MT	MT
2013	298	42	30	138	12 516	8 940	41 124
2014	275	42	30	138	11 550	8 250	37 950

10.5 Calculated waste quantities by type of ship

Table 24: Calculated landfillable waste quantities generated from ship recycling in Bangladesh by type of ship (kg/year)

Landfillable waste	**Low estimate**	**High estimate**
General Cargo	474'252	600'310
Bulk carrier	4'656'182	5'893'817
Oil & Chemical tanker	1'183'921	2'117'922
Container	793'706	1'004'677
Refrigerator Ship	21'308	86'206
Passenger Ship	156'159	309'242
Other	189'793	240'240
Total	**7'475'320**	**10'252'416**

Table 25: Calculated incinerable waste quantities generated from ship recycling in Bangladesh by type of ship (kg/year)

Incinerable waste	**Low estimate**	**High estimate**
General Cargo	301'013	334'458
Bulk carrier	2'955'328	3'283'698
Oil & Chemical tanker	1'448'854	1'912'488
Container	503'774	559'749
Refrigerator Ship	13'384	78'727
Passenger Ship	54'144	81'216
Other	120'463	133'848
Total	**5'396'960**	**6'384'185**

Table 26: Calculated bilge water quantities generated from ship recycling in Bangladesh by type of ship (kg/year)

Bilge water	**Low estimate**	**High estimate**
General Cargo	234'121	267'567
Bulk carrier	2'298'589	2'626'959
Oil & Chemical tanker	2'434'075	2'607'938
Container	391'824	447'799
Refrigerator Ship	108'644	116'516
Passenger Ship	87'984	99'490
Other	93'694	107'079
Total	**5'648'931**	**6'273'347**

Table 27: Break-down of calculated landfillable waste - asbestos and asbestos containing materials (ACMs) (kg/year)

Landfillable waste break-down – Asbestos + ACMs	**Low estimate**	**High estimate**
General Cargo	114'970	147'015
Bulk carrier	1'128'771	1'443'384
Oil & Chemical tanker	607'139	861'528
Container	192'414	246'043
Refrigerator Ship	976	4'383
Passenger Ship	3'113	6'295
Other	46'010	58'834
Total	**2'093'393**	**2'767'482**

Table 28: Break-down of calculated landfillable waste - Glasswool (kg/year)

Landfillable waste break-down – Glasswool	**Low estimate**	**High estimate**
General Cargo	71'856	85'759
Bulk carrier	705'482	841'974
Oil & Chemical tanker	273'213	394'867
Container	120'258	143'525
Refrigerator Ship	15'453	58'445
Passenger Ship	54'474	114'097
Other	28'756	34'320
Total	**1'269'493**	**1'672'986**

Table 29: Break-down of calculated landfillable waste – Other landfillable waste (kg/year)

Landfillable waste break-down – Other landfillable waste	**Low estimate**	**High estimate**
General Cargo	287'425	367'537
Bulk carrier	2'821'928	3'608'460
Oil & Chemical tanker	303'569	861'528
Container	481'034	615'108
Refrigerator Ship	4'880	23'378
Passenger Ship	98'572	188'850
Other	115'026	147'086
Total	**4'112'435**	**5'811'947**

10.6 Indian Treatment / Disposal allocation

Treatment / disposal options for schedule -1 waste

(Maharashtra Pollution Control Board,
Government of India)

SN	Processes		Waste Streams	Treatment disposal/options			
				Ch/ph treatment	Incineration	Landfill	Recycle
1	Petrochemical processes and paralytic operations	1.1	Furnace / reactor residue and debris*	*	*	1	*
		1.2	Tannery residue	*	1	*	*
		1.3	Oily sludge emulsion	*	1	*	1
		1.4	Organic residue	*	1	*	*
		1.5	Residue from alkali wash of fuels	1	*	1	*
		1.6	Still bottoms from distillation process	*	1	*	2
		1.7	Spent catalyst and molecular sieves	2	*	3	1
		1.8	Slop oil from waste water	*	1	*	1
		1.9	ETP sludge containing hazardous constituents	1	*	2	*
2	Drilling operation for oil and gas productions	2.1	Drill cuttings containing oil	1	*	2	1
		2.2	Sludge containing oil	1	1	2	*
		2.3	Drilling mud and other drilling waste*	1	*	2	*
3	Cleaning, emptying and maintenance of petroleum oil storage tanks including ships	3.1	Oil containing cargo residue and sludge	1	1	2	1
		3.2	Chemical containing cargo residue and sludge	*	1	*	1
		3.3	Sludge and filters Contaminated withh oil	*	1	*	1
		3.4	Ballast water containing oil from ships	1	1	*	1
4	Petroleum refining / refining of used oil/recycling of wastee oil	4.1	Oily sludge / emulsion	*	1	*	1
		4.2	Spent catalyst	2	*	3	1
		4.3	Slop oil	*	1	*	1
		4.4	Organic residue from process	*	1	*	1
		4.5	Chemical sludge from waste water treatment	1	*	2	*
		4.6	Spent clay containing oil	1	2	2	*
5	Industrial operations using mineral / synthetic oil as lubricant in hydraulic system or other applications	5.1	Used / spent oil	*	*	*	1
		5.2	Wastes / residue containing oil	1	3	*	3
6	Secondary production and / or use of zinc	6.1	Sludge and filter press cake arising out of zinc sulphate production	2	*	3	1
		6.2	Zinc fines/dust/ash/skimming (dispersible form)	2	*	3	1
		6.3	Other residues from processing of zinc ash / skimming	2	*	3	1
		6.4	Flue gas dust and other particulates*	*	*	2	1

SN	Processes		Waste Streams	Treatment disposal/options			
				Ch/ph treatment	Incineration	Landfill	Recycle
7	Primary production of zinc/lead copper and other non ferrous metals except aluminum	7.1	Flue gas dust from roasting*	2	*	3	1
		7.2	Process residue	1	*	2	*
		7.3	Arsenic-bearing sludge	1	*	2	*
		7.4	Metal bearing sludge and residue	1	*	2	*
		7.5	Sludge from ETP and scrubbers	1	*	2	*
8	Secondary production of copper	8.1	Spent electrolytic solutions	1	*	2	*
		8.2	Sludge's and filter cakes	1	*	2	*
		8.3	Flue gas dust and other particulates*	2	*	3	1
9	Secondary production of lead	9.1	Lead slag / lead bearing residue	1	*	2	*
		9.2	Lead ash / particulate from flue gas	2	*	3	1
10	Production and /or use of cadmium and arsenic and their compounds	10.1	Residues containing cadmium and arsenic	1	*	2	*
11	Production of primary and secondary aluminum	11.1	Sludge's from gas treatment	1	*	2	*
		11.2	Catch residue including pot lining wastes	1	*	2	*
		11.3	Tar containing wastes	*	1	2	*
		11.4	Flue gas dust and other Particulates*	2	*	3	1
		11.5	Wastes from treatments of salt slag's and black dross's*	1	*	2	*
12	Metal surface treatment such as etching, staining, polishing, galvanizing, cleaning, degreasing, plating etc.	12.1	Acid residue	1	*	2	*
		12.2	Alkali residue	1	*	2	*
		12.3	Spent bath / sludge containing, sulphide, cyanide and toxic metals	1	*	2	*
		12.4	Sludge from bath containing organic solvents	*	1	2	*
		12.5	Phosphate sludge	1	*	2	*
		12.6	Sludge from staining bath	1	*	2	*
		12.7	Copper etching residue	1	*	2	*
		12.8	Plating metal sludge	1	*	2	*
		12.9	Chemical sludge from waste water treatment	1	*	2	*
13	production of iron and steel including other ferrous alloys (electric rolling and finishing mills, coke oven and product plant)	13.1	Process dust*	1	*	2	*
		13.2	Sludge from acid recovery unit	1	*	2	*
		13.3	Benzol and sludge	*	1	*	*
		13.4	Decanter tank tar sludge	*	1	*	*
		13.5	Tar storage tank residue	*	1	*	*
14	Handling of steel	14.1	Cyanide-nitrate-or nitrate containing sludge	1	*	2	*
		14.2	Spent hardening salt	1	*	2	*
15	Production of asbestos containing materials	15.1	Asbestos containing residue	*	*	1	*
		15.2	Discarded asbestos	*	*	1	*
		15.3	Dust/particulates from exhaust gas treatment	*	*	2	1
16	Production of caustic soda and chlorine	16.1	Mercury bearing sludge	1	*	2	*
		16.2	Residue / sludge's and filter cake's*	*	*	1	*
		16.3	Brine sludge containing	1	*	2	*

SN	Processes		Waste Streams	Treatment disposal/options			
				Ch/ph treatment	Incineration	Landfill	Recycle
			mercury				
17	Production of acids	17.1	Residues, dusts or filter cakes*	1	*	2	*
		17.2	Spent catalyst*	2	*	3	1
18	Production of nitrogenous and complex fertilizers	18.1	Spent catalyst*	*	*	2	1
		18.2	Spent carbon*	*	1	2	*
		18.3	Sludge / residue containing arsenic	1	*	2	*
		18.4	Chromium sludge from water cooling tower	1	*	2	*
		18.5	Chemical sludge from waste water treatment	1	*	2	*
19	Production of phenols	19.1	Residue / sludge containing phenol	*	1	*	*
20	Production and/or industrial use of solvents	20.1	Contaminated aromatic, aliphatic or naphthenic solvents not fit for originally intended use	*		*	*
		20.2	Spent solvents	*	1	*	1
		20.3	Distillation solvents	*	1	*	*
21	Production and/or industrial use of paints, pigments, lacquers, varnishes, plastics and inks	21.1	Wastes and residue	*	1	*	*
		21.2	Filters residues	*	1	*	*
22	Production of plastic raw material	22.1	Residues of additives used in plastic manufacture like dyestuffs, stabilizers, flame retardants etc.	1	*	2	*
		22.2	Residue of plasticizers	*	1	*	*
		22.3	Residues from vinyl chloride monomer production	*	1	*	*
		22.4	Residues from acrylonitrile production	*	1	*	*
		22.5	Non-polymerized residue	*	1	*	*
23	Production and/or industrial use glue s, cements, adhesive and resins	23.1	Wastes / residue (not made with vegetable or animal materials)*	*	1	*	*
24	Production of canvas and textiles	24.1	Textile chemical residue*	1	*	1	*
		24.2	Chemical sludge from waste water treatment	1	*	2	*
25	Industrial product ion and formulation of wood preservatives	25.1	Chemical sludge from waste water treatment	1	*	1	*
		25.2	Residues from wood alkali bath	1	*	1	*
26	Production or industrial use of synthetic dyes, dye-intermediates and pigments	26.1	Process waste sludge / residue containing acid or other toxic metals or organic complexes	1	1	2	*
		26.2	Chemical sludge from waste water treatment	1	*	2	*
		26.3	Dust from air filtration system	*	*	1	1
27	Production or industrial use of materials made with organ silicone compounds	27.1	Silicone containing residues	*	1	1	*
		27.2	Silicone oil residue	*	1	*	*
28	Productionion / formulation of	28.1	Residue and wastes*	1	1	2	*
		28.2	Spent catalst / spent carbon	2	*	3	1

SN	Processes		Waste Streams	Treatment disposal/options			
				Ch/ph treatment	Incineration	Landfill	Recycle
	drugs / pharmaceuticals	28.3	Off specification products	1	*	2	*
		28.4	Date expired, discarded and off-specification drugs / medicines	1	*	2	*
		28.5	Spent mother liquor	*	1	*	*
		28.6	Spent organic solvents	*	2	*	1
29	Production, use and formulation of pesticides including stockpiles	29.1	Waste / residues containing pesticides	*	1	*	*
		29.2	Chemicals sludge from waste water treatment	*	1	2	*
		29.3	Date expired and off-specification pesticides	*	1	*	*
30	Leather tanneries	30.1	Chromium bearing residue and sludge	1	*	2	*
		30.2	Chemicals sludge from waste water treatment	1	*	2	*
31	Electronic industry	31.1	Residue and wastes*	1	1	2	*
		31.2	Spent etching chemicals and solvents	*	1	2	*
32	Pulp and paper industry	32.1	Spent chemicals	1	*	2	*
		32.2	Corrosive wastes arising from use of strong acid and bases	1	*	2	*
		32.3	Sludge containing adsorb able organic halides	*	1	*	*
33	Disposal of barrels / containers used for handling of hazardous wastes / chemicals	33.1	Chemical contaiming residue from decontamination and disposal	*	1	*	*
		33.2	Sludge from treatment of waste water arising out of cleaning/disposal of barrels / containers	1	1	2	*
		33.3	Discarded containers / barrels / liners used for hazardous wastes / chemicals	1	1	2	*
34	Purification process for air and water	34.1	Flue gas cleaning residue*	1	*	2	*
		34.2	Toxic metal containing residue from used ion exchange materials in water purification	1	*	2	*
		34.3	Chemical sludge from waste water treatment	1	*	2	*
		34.4	Chemical sludge, oil and grease skimming residues from common industrial effluent treatment plants (CETP's) and industry specific effluent treatment plant (ETP's)	1	1	2	*
		34.5	Chromium sludge from cooling water treatment	1	*	2	*
35	Purification process for organic compounds / solvents	35.1	Filters and filter material which have organic liquids in them e.g. mineral oil, synthetic oil and organic chlorine compounds	*	1	*	*
		35.2	Spent catalysts*	2	*	3	1
		35.3	Spent Carbon*	*	1	2	*
36	Waste ttreatment processes e.g. incineration, distillation, separation and	36.1	Sludge from wet scrubbers	*	*	1	*
		36.2	Ash from incineration of hazardous waste, flue gas cleaning residue	*	*	1	*
		36.3	Spent acid from batteries	1	*	2	*

SN	Processes		Waste Streams	Treatment disposal/options			
				Ch/ph treatment	Incineration	Landfill	Recycle
	concentration techniques	36.4	Distillation residue from contaminated organic solvents	*	1	*	*

1, 2, 3 indicates Order of preference for the Treatment/Disposal option.

☐ A number appearing twice indicates possible treatment by both options depending up on merits.

☐ Sign '*' Indicates Not possible to treat by this option.

10.7 Current disposal options of main industrial hazardous waste

Table 30 Most common waste management practices in the industries surveyed. CCC : Chittagong City Corporation. DoE : Department of Environment

Waste stream	**Most common practices in the industries surveyed**
APC dust	Sold to third party
Asbestos	DoE instructed to bury in tanks
Bleaching earth	Sold to third party
Contaminated packaging	Sold to third party/sent to cement plant or to incinerator
Contaminated plastic waste	Sold to third party
Contaminated solid waste	Sold to third party/landfilled on own premises/burnt in own incinerator
ETP sludge	Landfilled at own premises/Given to third party/thrown to CCC dustbin/sent to cement plant
Fabric waste	Sold to third party
Flesh	Sold to third party
Maintenance Scrap	Sold to third party
Oily crude tank sediment	Sold to DoE Designated third part/ sold to third party
Raw Hides Cutting	Sold to third party
Shaving dust	Sold to third party
Spent lubricant	Sold to third party/thrown to CCC dustbin/incinerated
Trimming dust	Sold to third party
Tundish lining	Storage & earth filling
Waste oil and grease	Collected and reprocessed/sold to third party