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Intertidal Zone Study

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Preface

LITEHAUZ has undertaken an intertidal zone study upon request by A.P. Moller-Maersk A/S. The study was carried out as a desktop in the period from June to September. A number of ship recycling stakeholders were interviewed during the course of the study.

Revision No.	No. of pages
05	41

Executive Summary

Contamination of the environment in the intertidal zone ship recycling locations is well described in the peer-reviewed scientific literature and the public reports available to the present study. The main delimitations of the study are: Firstly, the study is confined to the emissions and discharges to the environment only, i.e. occupational health and safety issues are not covered here, and secondly, the study addresses those emissions and discharges that takes place at the yard, i.e. "within the fence". There are few or no monitoring data available in the countries employing intertidal zone recycling and the data are typically spot samples from research studies. Some data sets are 15 years old, but a considerable portion of data sets are less than five years old. The data are considered to representatively reflect the contemporary picture at the time of the studies and clearly shows that ship recycling in the intertidal zone have lead to pollution of the environment.

Environmental impacts and pollutants
The range of concentrations of pollutants reported from sediment, water and air of the intertidal zone vary considerable, but frequently exceed numerical international reference values for the environment where these exist (Box 1).

International reference values are not available for all contaminants and may not necessarily be applicable in the conditions of the local settings of the intertidal zone recycling area.

Box 1: Non-prioritised list of pollutants exceeding international reference values:

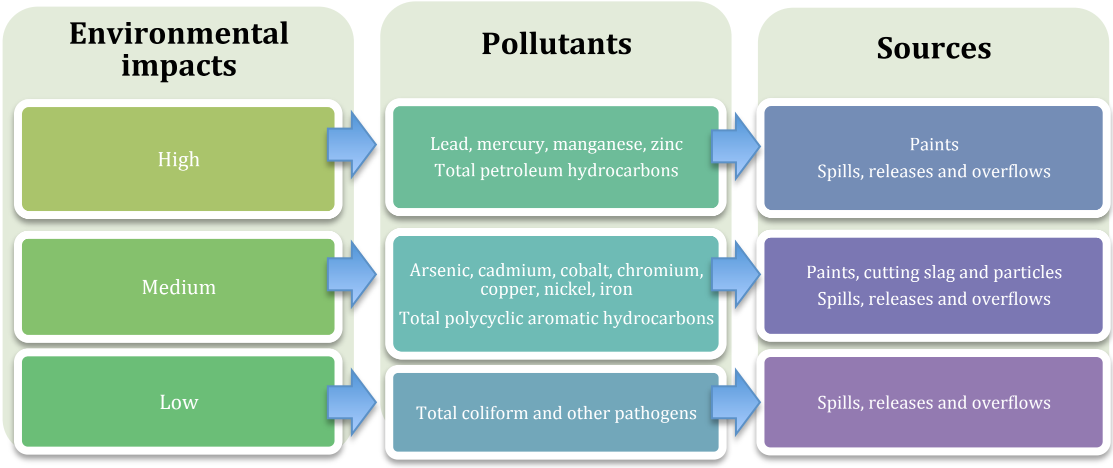
- ***Heavy metals***
  cadmium, chromium, copper, iron, lead, manganese, mercury, nickel and zinc
- ***Oil and oil residues***
  total petroleum hydrocarbons
- ***Pathogens***
  coliform bacteria and pathogens associated with sewage

The data were also compared to local background values, as found in the literature quoted or calculated in this study, showing that the heavy metals, oil and oil residues and pathogens repeatedly exceed local reference values (background or diffusely affected samples).

Key sources
This pollution may be caused by carelessness during past ship breaking, which may be better managed, or it may be inherent to the activities performed and the methods used when recycling ships in the intertidal zone and thus unavoidable. At the study's generic level it is not possible to assign a part of the impact to a particular source, e.g. identify a percentage of the lead pollution found in the environment to one activity among several that all generates lead emissions, and thus separate the manageable from unmanageable. A significant proportion of the observed impacts may be linked to many casual emissions in the intertidal zone recycling areas that are simply a consequence of rampant inadequate management of activities. During the recent years, yards employing intertidal zone ship recycling have emerged where more diligent environmental management takes place. How the improved operation of these yards impacts the environment is at this stage not clear.

Linking the impacts with activities is possible on a qualitative scale and in the following the impacts are ranked according to exceedence of local background values (Box 2). The high to low impact pollutants are aggregated across the sediment, water and air data and it is clear that activities not adequately managing the sources "Spills, releases and overflows", "Paints" and "Cutting slag and particles" may be the cause of the impacts. Aluminum as a conservative element has been omitted and mercury, which may still be found in a variety of locations associated with machinery and equipment, is included under "Spills, releases and overflow".

Box 2: Environmental impacts and their sources



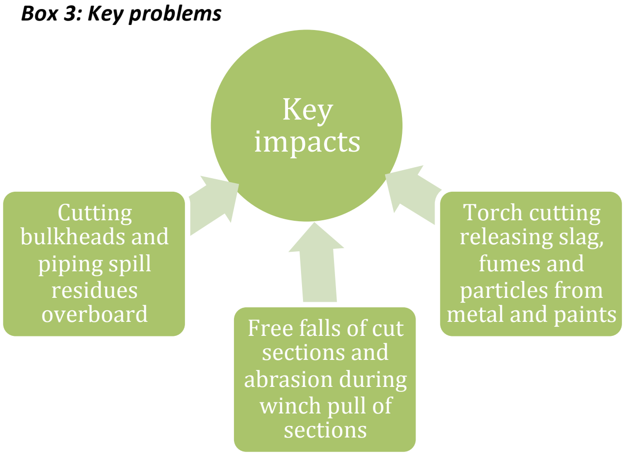
Activities and remediation technologies

The activities generating these sources of impact were assessed for the availability of feasible remediation technologies, and they are reported in three levels increasingly challenging:

1) A number of issues can with relative ease be solved,
2) some are more challenging, but technologies are available, and
3) a few issues represent key problems for recycling in an intertidal zone and for these feasible technical solutions have still not been presented or they may only just be emerging.

The latter category of key problems is governed by three main activities (Box 3).

Box 3: Key problems



1. Cutting bulkheads and piping

The key problem is caused by the lack of containment in the primary cutting zone, when the integrity of the vessel is compromised. In other recycling methods the hull is used as containment while the vessel is cut from the top (horizontal cutting) and when the bulkheads are cut the section of vessel or the entire vessel is situated in a dock or on a drained impermeable surface. Currently, in intertidal zone recycling the vessel is cut from the bow through piping and bulkheads at a time when no method for containment is provided. Bilge water, residues in pipes and tanks risk being spilled and/or flushed from the hull during high tide. Controlling spills, releases and overflow is crucial to sound environmental management and this activity is a key, if not the key issue to address for intertidal zone recycling.

Methods and technologies for remediation:

Simple methods such as oil booms cannot contain spilled oil when water retracts and seafloor is exposed during low tide. Avoiding the problem by cleaning all pipes before cutting does not appear feasible. More fundamental and costly changes to the intertidal zone recycling method would encompass the building of structures allowing the vessel to be lightened horizontally by cranes and the remaining still floating hull moved to a secure area with impermeable flooring.

The effort to develop and implement a feasible technology is estimated to be 1-3 years and considerably more than 100 kEUR.

2. Free falls of cut sections and abrasion during pulling of sections
The use of gravity method or free fall of cut sections represents an uncontrolled demolition method, but it is not in itself the key problem from an environmental point of view. It is the high energy impact with the seafloor of the intertidal zone, which may lead to the loss of paint chips and of liquids in broken pipes, tanks and canisters. Likewise, pulling cut sections onto shore over the seafloor lead to paint loss by abrasion and loss of flakes.

Methods and technologies for remediation:
In general, the moving of cut sections to the secondary cutting zone should be performed in a controlled manner achievable by using cranes, barges, pontoons, large rollers or any other method applicable in the intertidal zone. The same fundamental changes to the intertidal zone recycling method mentioned under 1. would lead to improved environmental management of cut sections. The effort to develop and implement a feasible technology is estimated to be 1-3 years and >100 kEUR.

3. Torch cutting releasing slag, fumes and particles from metal and paints
Although torch cutting is not specific for recycling in the intertidal zone the developed slag, fumes or particles are not contained in the primary cutting zone. For a 10,000 LDT vessel it is estimated that +120 tonnes steel is molten and lost, and 2-3 tonnes of paint is burned away from cutting lines.

Methods and technologies for remediation:
Collection of slag in the primary cutting zone may to some extent be achieved by cutting from appropriate sides and angles, and simple methods may be developed to contain slag to avoid contaminating seafloor. Avoiding the problem of fumes and airborne particles generated during cutting is possible by ventilation and filtration although challenging on the vessel. Finally, regarding paints several methods are already available for removing paint in cutting lines. The effort to develop and implement a feasible technology is estimated to be 1-3 years and 50-100 kEUR.

It is emphasized that some of these activities may in fact be remediated by more comprehensive infrastructure investments in intertidal zone ship recycling, in particular in structures allowing the sound management of the cutting onboard the vessel and the transport of sections to the shore. Jetties or other built structures would allow for mooring of vessels and cranes to operate at the vessel accessing the interior removing equipment for resale and installing equipment for safe and environmentally sound recycling. This also allow for top down or horizontal cutting of the ship avoiding cutting through bulkheads until the hull is on an impermeable floor. In essence, the beaching method would then mimic the along-side recycling method, but the feasibility, including the legal regime to build permanent structures in the intertidal zone areas, have not been tested.

The report is a desk-top study based on publically available information, interviews and expert knowledge. Several data gaps on emissions and loss to the environment of hazardous materials were identified, and the existence and volume of these substances potentially impact on the choice and dimensioning of systems for managing their risk.

Table of Contents

Abbreviations and acronyms

APMM	A. P. Møller-Mærsk
IAEA	International Atomic Energy Agency
GESAMP	Joint Group of Experts on Scientific Aspects of Marine Pollution
WHO	World Health Organization
US EPA	US Environmental Protection Agency
IMO	International Maritime Organization
TBT	Tributyltin
ODS	Ozone Depleting Substances
PCB	Polychlorinated Biphenyl
PAH	Polycyclic Aromatic Hydrocarbon
DNV	Det Norske Veritas
PFOS	Perfluorooctane sulfonate
BFRs	Brominated Flame Retardants
ISO	International Standardization Organization
OSHAS	Occupational Health and Safety Assessment Series
GT	Gross Tonnage
MARPOL	Marine Pollution Protocol 73/78
DIVEST	Dismantling of Vessels with Enhanced Safety and Technology
LDT	Lightweight Displacement Tonnes

1 Objective

The main objective of the Intertidal Zone Study is to provide A.P. Moller-Maersk (APMM) with a science-based answer on the actual environmental impacts of the activities conducted in the intertidal zone, assessed against international environmental standards. The study is envisioned to function as a dialog starter amongst stakeholders involved in ship recycling issues and it is not to be regarded as an exhaustive comparative study.

2 Methodology

The IMO Hong Kong Convention does not define different methods of ship breaking. While all ship recycling takes place at the shore and as such if occurring between the high and low tide marks will take place in the "intertidal zone", only the beaching method as applied in India, Pakistan and Bangladesh is commonly understood as being carried out in the intertidal zone. This method of ship recycling is in the present study understood as recycling where the body of a vessel is not floating at low tide but resting on the exposed seafloor.

The most significant impacts and their sources in the yards are outlined and the technologies allowing the key activities to be remediated are reviewed. As part of the study a few of the actors engaged in recycling (appendix A.3) were approached for an interview regarding their experiences and their knowledge of recent datasets or technological developments. The information supplied is quoted in its original form. The oldest datasets included are from 1999 and it may be argued that increased attention to environmentally sound management in the yards have reduced the emissions since then. However, this cannot be an *a priori* conclusion and there are no time-series of monitoring data to support it.

The study aims at clarifying the data available regarding ship recycling in the intertidal zone irrespective of the location of such activities and it is not an objective to identify impacts potentially specific to the activities of the sites in India, Pakistan and Bangladesh.

Since the study aims to compare the findings to recognized numerical standards, the environmental impacts are understood here as the pollutant concentrations underlying the loss of fish, mussels et cetera, e.g. concentrations of metals in sediments. These monitoring data are compared to international acceptance criteria.

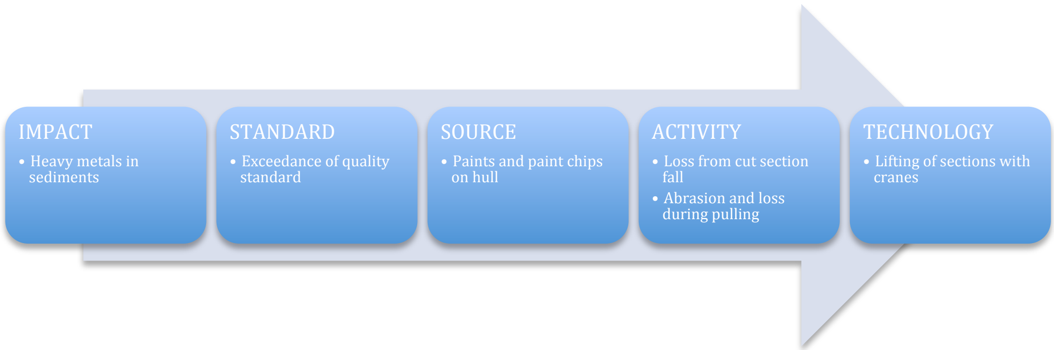


Figure 1 The assessment process of impacts to remediation technology with illustrative example of heavy metals

There are a few important delimitations to the present study: Firstly, it is confined to the emissions and discharges to the **environment** and secondly, the study addresses those emissions and discharges taking place at the yard, i.e. **"within the fence".** It is recognized that a potential for emissions to the environment is associated with off-site transported equipment, waste and hazardous waste not managed in an environmentally sound manner[1]. Likewise, those issues to be managed in relation to safety and occupational health including mooring, emergency access, asbestos, hot work and safe entry are important in their own right and may lead to secondary emissions to the environment, if not managed properly.

It was chosen to emphasize the emissions and impacts for which international numerical standards may be available, e.g. of organics and inorganic pollutants, which are associated with more or less continuous emissions over a longer term. The international standards are found as scientifically consensus background values (e.g. GESAMP 1984), but in the absence of international standards, references to Indian standards have been used.

There are few data on impacts caused by occasional or discrete events, e.g. number of oil spills or the area of habitat lost to the establishment or expansion of yards. The limited data have not been included, although it is recognised that such environmental impacts are found.

3 Introduction

3.1 The beaching countries

India, Pakistan and Bangladesh employ the beaching method in ship recycling where taking advantage of a significant tidal gauge and gently sloping shores allow for even large vessels to be run aground near the shore and accessed without any noteworthy infrastructure development. Despite the commonality suggested by the "beaching methodology" substantial natural and technological differences do exist between the sites: In particular, the slope of the beach ranges from a nearly level beach approach in Chittagong (Bangladesh) to the steeper but still gentle slope in Alang (India) and Gadani (Pakistan). Both of the latter also features more compact and sandy sediments while the Sitakunda site in Chittagong is an extensive mud flat. This also leads to differences in the vessels appreciated locally, since the flat bottomed bulkers and tankers are preferred in Bangladesh, while a broader range of vessels find their final resting place in Alang and Gadani.

3.1.1 India

The main ship breaking site is in the Gulf of Khambhat (Cambay) where the Alang-Sosiya ship recycling area occupies approx. 14 km of beach in the State of Gujarat[2]. The Alang-Sosiya area lies in the tropical region typically with hot summers (>35 C) and mild winters (>15 C) .The area is semi arid with the principle precipitation (>85%) occurring during the monsoon period June-September where the winds are also strongest. The tidally submerged sediment is sandy silt with a gentle slope, and the tidal gauge is massive, up to 12-13 m.

The Alang-Sosiya site is relatively developed and displays fundamental infrastructure. Approx. 180 plots employ some 40-50,000 workers when fully operational. IMO statistics over 2004-2013 India see ranked number 1 with regards to scrapped tonnage (maximum 12 mio. GT/annually).

India has a ship breaking regulation were several ministries hold individual responsibilities for different elements of the regulation. Key to the regulation India is the Angolan Saxon legal regime with the Supreme Court playing an active role in creating customary law by its rulings.

[1] Assessments of selected waste fractions in ship recycling facilities have been carried out in India although the data are not in a form that currently would allow assessment of their impacts (Hiremeth et al 2015).

[2] There are other and smaller ship breaking sites in India e.g. in Mumbai (beaching type) and Kolkata (along side). These sites are less dominated by international vessels. Some data from Mumbai are available and included.

Furthermore, India is in the process of implementing the requirements of the Hong Kong Convention.

The Gujarat Maritime Board is the implementing authority and it leases the plots to the yards, and the Gujarat Pollution Control Board is responsible for the environmental monitoring in the area including the yards. Many yards boast ISO 9000, ISO 14000, ISO 30000 and/or OSHA 18000.

3.1.2 Bangladesh

The Sitakunda ship breaking site is located on a 13 km beach stretching north of Chittagong and is an area formerly forested by mangroves. The area is tropical with mild winters (October to March) and hot, humid summers (March to June). The warm and humid monsoon last from June to October. From April to October the predominant wind is south-southeasterly, turning to the northerly and north easterly directions from November to January. The tidal gauge is 6 m.

The Sitakunda site is underdeveloped and is short of fundamental infrastructure. Approx. 40-50 plots employ some 22-30,000 workers when fully operational. Bangladesh is ranked number 2 at 8.8 mio ton GT/year with regards to maximum scrapped tonnage during 2004-2013., according to IMO.

Recently, ship recycling was formally recognized as an industry in Bangladesh, and several different ministries and departments holds responsibility for different areas of the industry. A national regulation implementing the Hong Kong Convention was issued in 2012 (GOB 2012), but not all regulatory mechanisms are yet in place. Additionally, other international regulation has so far seen limited incorporation in local legislation (Alam & Faruque, 2014). Also, on the local level the the city of Chittagong as the administrative centre of Chittagong District (Chittagong Division), performs very little monitoring of the industry and the result is weak environmental protection, with limited threat of sanctioning of non-compliance.

3.1.3 Pakistan

The ship breaking in Pakistan takes place on a 10 km beach in the Gadani area on the south western shore of the Balochistan region some 70 km from the city of Karachi. The climate is subtropical hot and arid with the majority of the limited rainfall occurring during the monsoon season June-September. The tidal range is relatively small compared to Alang and Chittagong (up 3.5 m) and the beach is sandy and sufficiently compact to allow heavy duty vehicles, stackers and cranes to operate.

The Gadani site has few amenities and lacks fundamental infrastructure (SDPI & NGO Platform 2013). Approx. 68 plots employ some 12-15,000 workers when fully operational. Pakistan is ranked number 4 at 5.5 mio ton GT/year with regards to maximum scrapped tonnage during 2004-2013.

The regulatory framework for ship recycling in Pakistan is limited. The main requirement for beaching and breaking is a No Objection Certificate issued by the provincial authority (SDPI & NGO Platform 2013).

The Gadani shipbreaking area falls under the governance of the Province of Balochistan, which leases plots to the breakers, and various Balochistan authorities perform certain site inspections although reportedly not to any great extent (SPDI and NGO Shipbreaking Platform 2013).

Table 1: Conditions in the intertidal zone ship recycling areas of the study

Region	Geophysical properties	Meteorology	Environmental conditions	Ref.
Alang-Sosiya, Gulf of Cambay, India	• Ship breaking yards about 14 km along the north-south, impacted area approx. 67 km2 with a bifurcating small creek • A mud-free coast, gentle slope with a firm bottom • Semi- arid, drought prone, coastal zone of saline soils • Average highest tide is around 13 m	• Average annual rainfall of 55.8 cm • The monsoon season is June to September • The mean highest and lowest temperatures are 34.2 and 21.9 °C, respectively • Relative humidity (%): 30 – 67	• Villages • The District, originally based on farming and fishing, is under rapid industrialization and urbanization	Basha et al., 2007 Reddy et al., 2004 Reddy et al., 2005 Reddy et al., 2006 Demaria, 2010
Sitakunda, Chittagong, Bangladesh	• Ship breaking yards about 13 km, impacted area approx. 11 km2 • A long and uniform intertidal zone with a limited slope (mud flats) • An extended beach with tidal difference of 6 m	• Annual rainfall of 2,687 mm • Pre-monsson season April to May • Monsoon season June to October • Annual average temperature 32.5 and 13.5 °C • Frequent cyclones, storm surges and floods	• Settlements in proximity • Near main road Chittagong-Dhaka • Steel mill and reprocessing industry • Agriculture, forest	Hossain et al., 2006 Abdullah et al., 2013
Gadani Beach, Balochistan, Pakistan	• Ship breaking yards 10 km • Moderate slope with a firm sandy bottom • Tidal gauge approx. 3.5 m	• Average annual rainfall of 420 mm • The monsoon season is July to September • The mean highest and lowest temperatures are 35.2 and 10.4 °C (for Karachi), respectively	• Steel mill and related reprocessing industry • Arid environment with little infrastructure	Hossain et al., 2006

4 Ship recycling impacts

Data on environmental contamination from a number of publications primarily from Alang in India and Chittagong in Bangladesh have been compiled and the full dataset can be found in Appendix section A.1. The majority of datasets are on heavy metal concentrations in sediment, which are also the medium with the most potential for displaying long-term effects in the dynamic environment of an intertidal zone. There are data sets available for seawater, freshwater and air. In Table 2 (overleaf) a consolidation of the data is shown demonstrating the wide range of concentrations found in sediments, water and air.

Table 2: Low and high range of heavy metals from the areas in India, Bangladesh and Pakistan

Parameter	Range Lower	Range Higher	Medium
Metals			
	(µg/g dw)	(µg/g dw)	Sediment
Aluminum (%)	8.61±0.58	12.04±0.99	
Arsenic	-	163	
Cadmium	n.d.	45.85±6	
Chromium	2.42	776	
Cobalt	52.55±14	145.00 ± 12	
Copper	7.56 ± 0.9	888	
Iron	282	162189±72537	
Lead	11.3	898	
Manganese	0.015	12979±4324	
Mercury	n.d.	8.25	
Nickel	23.12	347	
Zinc	50.60 ± 2.1	2112	
	µg/L	µg/L	Water
Cadmium	314±14	561±17	
Chromium	621±26	765±24	
Cobalt	1226±45	1665±43	
Copper	3122±113	3939±123	
Iron	2889±142	3662±132	
Lead	1570±146	2036±167	
Manganese	4015±221	4920±232	
Nickel	522±126	944±132	
Zink	4271±136	5832±123	
	$\mu g/m^3$	$\mu g/m^3$	Air
Cadmium	n.d.	3.7	
Chromium	0.11	0.42	
Cobalt	n.d	1.4	
Copper	0.85	4.32	
Iron	20.78	41.88	
Lead	n.d.	1.13	
Manganese	1.12	3.75	
Nickel	n.d.	0.65	
Zink	2.15	6.15	
Other substances			
Radioactive materials	Bq/kg	Bq/kg	Sediment
^{226}Ra	9.88±0.86	86.95±3.47	
^{232}Th	24.07±1.69	178.07±6.57	
^{40}K	68.01±4.80	792.68±29.80	
^{17}Cs	n.d.	n.d.	
Oil and oil residues			
Oil and oil residues	mg/kg	mg/kg	Sediment
	0.32	4300	
Oil and oil residues	mg/L	mg/L	Water
	52.5	10800	
Pathogens			
		no/g dw	Sediment
Escherichia coli		15.79	
Vibrio cholera		10.14	
		no/mL	Water
Escherichia coli		15.18	
Vibrio cholera		5.93	

5 International regulation, background values and conditions in other ship recycling locations

5.1 International regulation

Although no international standard for sediment is available for oil and oil residues, the background concentrations of oil and oil residues are typically considered to be zero and the concentrations encountered in the intertidal zone from oil ranges from 0.3 mg to 4.3 grams per kg of sediment[3]. In analyses of seawater impacts were less pronounced, but comparison to discharge standards 5 mg/L from the oil and gas sector and 15 mg/L from shipping (MARPOL) reveals that oil and oil residues may even reach these levels in water. International standards given by IAEA, GESAMP, WHO, IMO and MARPOL are shown in Table 3.

Table 3: International standards and reference values.

Parameter	International Standard (IS)		
Metals	**Sediment**	Water	Air
	(µg/g dw)	mg/L	µg/m^3
Aluminum (%)	No IS	No IS	No IS
Arsenic	No IS	No IS	No IS
Cadmium	0.115 a,b	2.0 c	0.005 d
Chromium	77.2 a	2.0 c	1.1 d
Cobalt	No IS	No IS	No IS
Copper	33.0 b	30 c	No IS
Iron	27000 a	3 c	No IS
Lead	22.8 b	2.0 c	0.5 d; 1.5 e
Manganese	1.17 b	2 c	0.15 d
Mercury	0.02 a	No IS	No IS
Nickel	56.1 a	50 c	0.00038 d
Zinc	95.0 b	15 c	No IS
Other substances			
Radioactive materials	Bq/g	-	-
^{226}Ra	10		
^{232}Th	10		
^{40}K	100		
^{17}Cs	10		
Oil and oil residues			-
Oil and oil residues	No IS	No IS, 15 mg/L accepted in discharges under MARPOL	
Pathogens			
		CFU/100 mL	
Escherichia coli		250 f	
Vibrio cholera		1 f	

Legend: a: IAEA(190); b: International background values from GESAMP (1982); c: Indian Standards (general standards for discharge of environmental pollutants); d: WHO; e: Indian standard (Ambient air, industrial area); f: IMO BWM/CONF/36;

5.2 Background values

For many contaminants international standards are not available. In most studies quantitative data from control sites were given and used as background contamination. Both the international standards and the local background data were compared to the corresponding pollution data and used to categorize each pollutant as shown in Appendix section A.2. A short overview over the exceedence of the local background is given in Table 4.

3 Operational oil spills from the ship breaking activities in Sitakunda are estimated at 500 tons/year (Hussein 2010).

Table 4: Summarized exceedence of local background values in sediment, water and air compiled from India, Bangladesh and Pakistan

Pollutant	Pollutants exceeded the background values by
In sediment	
Heavy Metals: Aluminum, Cobalt, Manganese **Pathogens:** Total coliform and other species	up to 10 times
Heavy metals: Arsenic, Cadmium, Chromium, Copper, Iron, Nickel, Zinc	up to 100 times
Heavy metals: Lead, Mercury	over 100 times
In water	
Heavy metals: Cadmium **Hydrocarbons:** Total petroleum hydrocarbons, Oil, **Pathogens:** Total coliform and other species	up to 10 times
Heavy metals: Chromium, Cobalt, Copper, Iron, Lead, Nickel **Hydrocarbons:** Total polycyclic aromatic hydrocarbons	up to 100 times
Heavy metals: Manganese, Zinc **Oil**: Total petroleum hydrocarbons	over 100 times
In air	
Heavy metals: Cadmium, Chromium, Nickel	up to 10 times
Heavy metals: Cobalt, Copper, Iron, Lead, Manganese	up to 100 times
Heavy metals: Zinc	over 100 times

5.3 Other ship recycling locations

Ship recycling in several locations in China and in Aliaga in Turkey has also been under the scrutiny of international stakeholders, but in particular during the last five years action has been taken through the national and local authorities and in collaboration with the organisations of the ship recycling industry. The two countries are number three and five on the IMO list of ship recycling nations with respect to maximum scrapped tonnage.

The method used in Turkey is referred to as "landing" where the vessels are moored with the bow or the cut bulkhead resting on the shore and the vessel is lightened by cutting and lifting sections onto the shore with cranes. The vessel is then moved forward. There is very little tide at the ship recycling site in Aliaga (<0.5 m). Ship recycling in Turkey tend to focus on medium sized vessels, but large vessels can be accommodated as was the case with the British navy aircraft carriers with draughts of 5.8 meters (de-stocked and de-armed) and steel weight of the ships of approx. 16,000 ldt.

DIVEST showed in 2009-2010 that sediment samples of coastal transects from the recycling yards were polluted with heavy metals and oil residues (Neser et al. 2012a, Neser et al. 2012b). Soil contamination in the dismantling zone was widespread. The concentrations of the oil residues, PAH, in sediments were still comparable to the levels reported by Greenpeace (2002). The PAHs were not petrogenic (from spills of oil), but rather pyrolitic (from combustion processes).

In China a number of ship recycling locations exist all employing the along-side recycling where sections are cut from the top of the vessel and lifted directly onto the quay with impermeable flooring. In the early report series "Ships for Scrap" Greenpeace (2001) also found high concentrations of pollutants in the proximity of Chinese recycling yards. Little solid information is available in the public domain on the state of environment in ship recycling yards, but yards and local authorities may hold such information.

In both countries significant improvements have taken place during the last decade. In Turkey, the adoption of regulation to implement EU laws on waste etc. has led to industry-wide application of environmentally sound management, and in China private and government initiatives has brought about a similar change. Both in China and Turkey environmental monitoring is mandatory and reported to authorities.

6 Technical solutions to avoid or mitigate environmental impacts in intertidal ship recycling

This section identifies technical solutions to key recycling activities that lead to significant planned or unplanned discharges of the materials or substances causing the environmental impacts. The reader is reminded that the focus is on environmental issues “within the fence”, and general, but important issues related to safety and occupational health such as mooring, emergency access, hot work and entry, and those of final treatment and disposal are not within the scope of the study.

There are many environmental issues associated with the current practices of beaching facilities, but a considerable number of these challenges are not inherent to the intertidal zone recycling, but arise from inadequate attention to sound environmental management. These oversights are also addressed here, but amongst the key environmental issues currently specific to intertidal zone recycling are 1) the uncontrolled releases of liquids contained in equipment, piping and tanks when cutting these and the bilges released when cutting through bulkheads in an uncontained environment, and 2) the loss of materials from the dismantling process itself, e.g. the loss during torch cutting, and the loss of paints and litter during the free fall of cut sections and the dragging over seafloor towards the beach.

This section introduces briefly more comprehensive and investment-heavy methodologies, but does not intend to present the exhaustive picture of such projects, proposals and ideas that stakeholders of the industry have put forward over the years. The examples are illustrative of projects that provide solutions under a transformation of the industry, e.g. the proposals to provide docking facilities or large scale jetties and mooring facilities in Alang or Chittagong[4]. Most of these project attempts to address the specific issues while also providing sound environmental management remediating the general challenges.

The more comprehensive methodologies will typically comply with the recent requirements from the European Union for “built structures” and “.....demonstration of the control of any leakage, in particular in intertidal zones” as laid out by the European Union regulation on ship recycling in article 13 (c) and (f).

However, it is emphasized that certain impacts and potential impacts to the environment in particular in the primary cutting zone in some stakeholder’s views are simply not avoidable when conducting ship recycling under a beaching regime, and these include (based on interviews, ISRA and NGO Platform information):

> **Spills and emissions while dismantling engine room some distance from shore facilities**
> While the hull is quickly broken and recycled in sections pulled to the beach, the engine room is often left some distance from the beach and is recycled as the last item

[4] The feasibility of such large infrastructure projects may be affected, not only by costs, but also land ownership issues as permissions to built on sea territory may not necessarily be generously granted.

of the vessel. It is stripped of easy accessible equipment to be resold, but the heavy engine equipment and piping containing fuel, oil residues, lubricants et cetera are cut without access to proper waste management facilities and may be spilled while lifted over open water or sand.

Spills and emissions while cutting through bulkheads and piping
The bilge water and other residues in the bottom of the vessels, pipes and tanks cannot be guaranteed to be in a self-contained condition when cutting through bulkheads while vessel is resting on the sand/mud of the intertidal zone. The interior of the opened vessel will be flushed during tides.

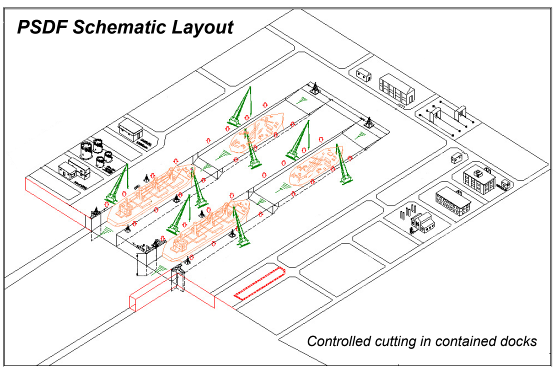
Spills, losses and littering using the gravity method and wire pulled sections
The free fall and high energy impact of cut sections of the vessel into water or dry surface of the intertidal zone lead to the loss of paint from the surface, of liquids in pipes, tanks and canisters broken, of loose waste material et cetera.

Other actors maintain that the beaching method is not worse than other accepted methods, e.g. the along-side ship recycling, and provided a suitable upgrading is carried out the above challenges can be managed at least in Alang, India (GSR 2014). To that end, the Japan International Cooperation Agency has recently agreed a 180 million USD loan to India specifically for upgrading the Alang ship recycling beaches. The planned upgrades will include the construction of a pre-treatment facility for the removal and treatment of those hazardous materials from ships that raise 'special concerns', expansion of the current treatment storage disposal facility such that it will be possible for 25 tonnes of waste to be incinerated daily, and housing projects for labourers (Recycling International 2015). Part of this activity is aimed at achieving compliance of the upgraded yards with the Hong Kong Convention thus allowing certification, a process the Japanese classification society ClassNK is undertaking.

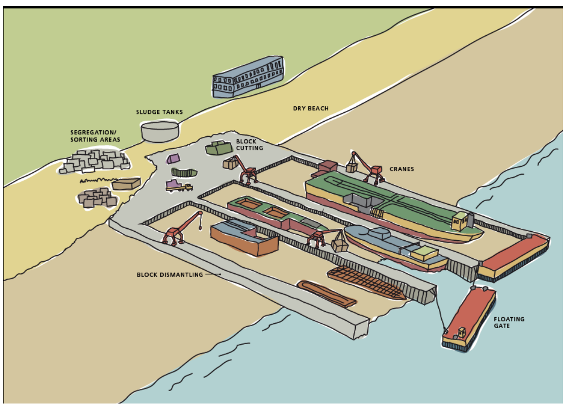
6.1 Comprehensive methodologies for beaching

6.1.1 "Docks on the beach" infrastructure

In the early 00's a project for a dismantling facility in Pipavav, Gujarat (India), some 70 km from Alang, was presented to the IMO (PSEL 2002). The facility was intended to dismantle up to four vessels at a time in a twin dock design. The project facility was constructed, but has not dismantled vessels. A related design was developed by DNV as a model yard for the Chittagong ship recycling area in Bangladesh (DNV 2011).



Design in Pipavav, India (PSEL 2002)



Design in Chittagong, Bangladesh (DNV2011)

6.1.2 Floating dock and jetties

A method for the cutting of engine room sections in floating docks and a concept of common jetties for separating deckhouses and engine rooms were proposed by Winjgarten (2004). In the proposed approaches the steel hulls are still broken in beachside yards. All of these concepts address the current lack of firm and compacted surface allowing the vessel to be dismantled horizontally, thus avoiding the cutting of bulkheads until the lightened hull is pulled onto an impermeable and drained surface. The structures also allow the use of cranes to lift and transport cut sections off the vessels rather than allowing them to fall into the intertidal flat or sea. The use of built structures, which is a part of the requirements of the EU regulation, allows not only (smaller) cut sections to be lifted directly to a proper impermeable surface but also avoids pulling the sections across the intertidal zone.

6.2 Combining key sources, activities and remediation technologies

In the following the impacts found earlier in intertidal zone recycling areas are combined with their origin in the ship recycling process in terms of their source in e.g. paints or oil and the activity that brought their releases about.

While steel alloys and other solid constructive elements onboard a ship will include metals they are as such not a key source of mobile heavy metals. These metals are however released from the cutting operation as slag and particles; and will also be found in the paint and paint chips. The following list of key source of hazardous substance is based on the findings of the DIVEST study as published in the Position Paper from University of Strathclyde (McKenna et al. 2013):

> Loose Paint Chips: hazardous paint falling off the hull naturally or after disturbance by external force
>
> Beaching/Ramp Abrasion on Ships Hull: paint chips being scrapped off the ship's hull by abrasion of materials on the coast, beach and ramp.
>
> Cutting Slag and Particles: slag from oxy-fuel cutting operation falling directly into the environment during cutting, and particles in the cutting fumes from oxy-fuel cutting settling on surrounding environment
>
> Spills, releases and overflows: materials discharged into the environment on purpose or by accident, including poorly managed waste. Such discharges release a range of substances and materials and are associated with many activities, e.g.:
>
> - Dismounting equipment, canisters, containers etcetera for re-use;
> - Disconnecting piping and cutting through bulkheads;
> - Bilge, ballast and sewage water discharged;
> - Allowing bilge water to accumulate in hull and overflow while ship is broken;

These key sources of pollution are broad and apply to a range of specific contaminants that may require specialized approaches, e.g. the specific issues of PCBs in cables, ODS in insulation materials, or other substances not yet included in the IHM of the Hong Kong Convention (the refractive PFOS and BFR). Environmentally sound management of these materials may not be simple, but is certainly possible through application of suitable procedures, tools and equipment that are already available commercially and for which personnel can be trained to operate.

Table 5: Impacts, sources, activities and remediation technologies

Significant impact	Source/stream	Activity	Remediation technology
Heavy metals (incl. TBT and arsenic)	Paints	Torch cutting	Clean cutting lines with abrasive blasting or designated cutting line cleaner
		Paint chips	Avoid gravity fall. Risk reduction possible if section fall inside hull and is lifted out
		Abrasion during wire pull of sections	Currently, crane operation in intertidal zone is generally not applied. It is possible to lift smaller sections to barge or built structure for transport
	Steel and alloys	Torch cutting	Currently a method of containment is not available, although technically feasible Slag and particles are lost to seafloor. It has been proposed to apply ducted ventilation of cutting areas with filters.
Mercury (few data)	Equipment	Dismounting equipment, canisters, safety valves etcetera	Proper IHM. Collect and manage waste
Oil and oil residues	Bilge water	Allowing bilge water to accumulate in hull and overflow	Apply rain covers. Collect and manage waste
	Oil storage	Allowing rain water to accumulate in open oil storage and overflow	Apply rain covers and bunded area with impermeable flooring
	Fuel	Loss from hoses when pumping oil from tanks to transport (drums)	Sound management
	Oily water	Dumping of bilges, tank residues etcetera	Oily water separation unit
	Oil and oily water	Spills overboard	Currently a method of containment is not available for intertidal zone at low tide, although technically feasible
ODS (no data)	Fire extinguisher systems, HVAC	Gases escaping while equipment and canisters are disconnected	Proper equipment, and collect and manage waste
	Blowing agent in insulation for gas tanks and cooling	Release from insulation materials when dismantled	Apply proper management (collection, special treatment and disposal)
PCB (few data)	Cable wet paper insulation	Release when polymer insulation burned	Use mechanical stripping
	Cable wet paper insulation	Loss at mechanical stripping	Collect and manage waste
	Transformer oils	Liquid PCBs in transformers spilled	Collect and manage waste
Pathogens	Ship's bilge, ballast and sewage water	Emptying of ship's systems	Collect and manage waste
	Sewage from yard area	Open latrines and other inadequate sanitation	Install adequate amenities
Litter	Ship's garbage, unusable items, waste	Existing or generated waste during recycling	Avoid gravity fall. Remove only pre-cleaned sections. Collect and manage waste

The three main activities that give rise to impacts in the environment are identified as follows and a tentative costing of development is provided:

1. Cutting bulkheads and piping
The key problem is caused by the lack of containment in the primary cutting zone, when the integrity of the vessel is compromised. In other recycling methods the hull is used as containment while the vessel is cut from the top (horizontal cutting) and when the bulkheads are cut the section of vessel or the entire vessel is situated in a dock or in a drained impermeable surface. Currently, in intertidal zone recycling the vessel is cut from the bow through piping and bulkheads at a time when no method for containment is provided. Bilge water, residues in pipes and tanks may be spilled and/or flushed from the hull during high tide. Controlling spills, releases and overflow is crucial to sound environmental management and this activity is a key, if not the key issue for intertidal zone recycling.

Methods and technologies for remediation:
Simple methods such as oil booms cannot contain spilled oil when water retracts and seafloor is exposed during low tide. Avoiding the problem by cleaning all pipes before cutting does not appear feasible. More fundamental and costly changes to the intertidal zone recycling method would encompass the building of structures allowing the vessel to be lightened horizontally by cranes and the remaining still floating hull moved to a secure area with impermeable flooring. The effort to develop and implement a feasible technology is estimated to be 1-3 years and considerably more than 100 kEUR.

2. Free falls of cut sections and abrasion during pulling of sections
The use of gravity method or free fall of cut sections represents an uncontrolled demolition method, but it is not in itself the key problem from an environmental point. It is the high-energy impact with the seafloor of the intertidal zone, which may lead to the loss of paint chips and of liquids in broken pipes, tanks and canisters. Likewise, pulling cut sections onto shore over the seafloor lead to paint loss by abrasion and loss of flakes.

Methods and technologies for remediation:
In general, the moving of cut sections to the secondary cutting zone should be performed in a controlled manner achievable by using cranes, barges, pontoons, large rollers or any other method applicable in the intertidal zone. The same fundamental changes to the intertidal zone recycling method mentioned under 1. would lead to improved environmental management of cut sections. The effort to develop and implement a feasible technology is estimated to be 1-3 years and >100 kEUR.

3. Torch cutting releasing slag, fumes and particles from metal and paints
Although torch cutting is not specific for recycling in the intertidal zone the developed slag, fumes or particles are not contained in the primary cutting zone. For a 10,000 LDT vessel it is estimated that +120 tonnes steel is molten and lost, and 2-3 tonnes of paint is burned away from cutting lines[5].

Methods and technologies for remediation:
Collection of slag in the primary cutting zone may to some extent be achieved by cutting from appropriate sides and angles, and simple methods may be developed to contain slag to avoid contaminating seafloor. Avoiding the problem of fumes and airborne particles generated during cutting is possible by ventilation and filtration although challenging on the vessel. Finally, regarding paints several methods are already available for removing paint in cutting lines. The effort to develop and implement a feasible technology is estimated to be 1-3 years and 50-100 kEUR.

[5] Data on steel from Deshpande et 2013 and data on amount of paint recalculated from same paper.

Table 6: Activities and possible remediation (Capital investment – low: <50 kEUR, medium: 50-100 kEUR; High: >100 kEUR)

Activity	Gap of remediation	Possible action	Activity specific to intertidal zone	Innovation needed	Capital investment	Feasible time horizon for implementation
Identification of hazardous materials.	Inadequate identification of hazardous materials prior to dismantling.	**Identify and mark hazardous materials.** Use already available IHM or survey ship for hazardous materials. Experts/trained workers should undertake the ship survey. Use color code for clear identification and marking of materials and equipment on the ships suspected to contain hazardous materials.	No	No	Low	<1 year
Removal, handling and sorting of materials/equipment suspected of containing hazardous materials.	Inadequate procedures, facilities and equipment to ensure containment of hazardous materials.	**Collect and manage waste.** Remove all hazardous materials/equipment prior to dismantling based on prior identification and marking. Handling and sorting of HMs should only be conducted on impermeable surfaces with system to control drainage. Use a small team of trained workers for the process of pumping of bilge and oil and supervising the operation including monitoring of tank levels.[6]	No	No	Low	<1 year
Dismounting equipment/materials containing ozone depleting substances (ODS).	Improper identification and handling of ODS in refrigerants and firefighting equipment and in insulation.	**Recover ODS.** Reclaiming and/or handling materials with ODS require specialized equipment suitable for recycling on-site or for transport off-site to a ODS reclamation facility. Step by step procedures to recover, recycle and reclaim ODS and suitable equipment, as well as professional services to handle ODS issues are ready available.	No	No	Low	<1 year
Control of oily residues	Oily residues on and in materials, equipment and pipes are spilled during transport.	**Pre-clean and contain during transport** Machinery should be cleaned for oily residues as far as practical Oil and fuels in pipes should be permitted to drain under gravity back to the storage tanks prior to emptying of tanks.[7] Barge or other means of closed transport should be applied for moving items to secondary cutting area.	Yes	Yes	Low	<1 year

[6] DEFRA.
[7] DEFRA, App.3-1.

Activity	Gap of remediation	Possible action	Activity specific to intertidal zone	Innovation needed	Capital investment	Feasible time horizon for implementation
	Oily bilges is released to sea when cutting hull in smaller sections in the tidal zone.	**Suitably clean tanks and bottom of hull.** Clean tanks, engine room, and other spaces, which could create a flow of oily residues to the bottom of the ship. The bottom of hull should be emptied and cleaned using appropriate techniques, e.g. flushing or jet washing prior to opening hull section to the sea. Bilge should be collected and treated appropriately.[8]	Yes	No	Low	<1 year
Rainwater accumulates in hull or in temporary oil storage.	Inadequate protection of open spaces, which contains oil or oily residues.	**Protect.** Use rain covers on exposed lower section of hull to ensure that water accumulates in the bottom of the hull to avoid subsequent release of bilge when hull is cut into smaller sections. Temporary storages for oil should be roofed.	No	No	Low	<1 year
Oil spill	Oil spilled in water cannot be retained at low tide	**Fast response.** Spill of oil in the tidal zone, should be attended to rapidly and in any case before the seawater retracts and the seafloor is exposed. Use of oil spill booms and oil collection equipment, which are readily available close to the shore.	Yes	No	Low	<1 year
	Oil spilled on exposed seafloor are not collected	**Fast response.** Spill of oil in the tidal zone, should be attended rapidly and in any case before the tide returns. Use of oil absorbents and removal of contaminated mud/sand	Yes	No	Low	<1 year
Oily water treatment	Bilge is largely unmanaged.	**Oily water separation unit.** Oil-water separator can be installed in combination with storage tanks .	No	No	Low	<1 year
Emptying of ship's ballast water, sediments and waste water system	No control of release of pathogens.	**Collect and manage.** Transfer of ballast water and sediments to barge, onshore storage tanks, evaporation pits, or discharged directly overboard following the IMO D-1 exchange standard. Collection, containment and proper treatment of wastewater and any used solvents from the tank cleaning process.[9]	No	No	Low	<1 year
Worker accommodation	No control of discharge of pathogens from latrines and household	**Collect and treat.** Wastewater from worker accommodation areas should be treated prior to discharge to the sea.	Yes	No	Low-medium[10]	1-3 years

[8] DEFRA
[9] Basel Convention, 2003, p 50.
[10] Depending on level of structural logistics needed, i.e. construction of sewers, treatment facility etc.

Activity	Gap of remediation	Possible action	Activity specific to intertidal zone	Innovation needed	Capital investment	Feasible time horizon for implementation
Torch cutting	Flammable and/or toxic paints in the cutting lines are burned during cutting.	**Establish a cutting line.** A cutting line should be established at a distance of approx. 10 cm from the area to be cut. Methods available include: *Abrasive blasting:* The cutting line is blasted with abrasives using high-pressure equipment. *Chemical stripping:* The cutting line is stripped of paint using solvents. It should be noted that solvents in their own right usually are hazardous and special care should be taken with regards to exposure. *Mechanical removal:* The cutting line is stripped using power- or thermal tools. Thermal removal must not be used on paintwork containing PCB.[11]	No	No	Low	<1 year
	Slag and particles are not contained or collected in primary cutting zone.	**Gap.** Cutting is done from inside out and it is not possible to set up scaffolds on exterior of vessel to collect slag. No immediate solution to close gap is identified.	Yes	Yes	Medium (?)	1-3
	Slag and particles are not contained or collected in secondary cutting zone.	**Hydraulic shears for cold-cutting**. Can be mounted on machines to minimize the use of torch cutting and development of slag and particles. Machines are typically already available at the yard. The slag should be collected on a daily basis.	No	No	Medium-high[12]	< 1 year
Paint-removal	Paint chips and liquid wastes from the paint removal process are not collected and stored.	**Collect and manage.** Paint-removal operations at the yard should be conducted on impermeable floors allowing for easy collection of paint chips and any liquids used in stripping processes, if applied. Provide adequate storage/disposal facilities and storm water discharge facilities to avoid contamination of storm water runoff.[13]	No	No	Low	<1 year

[11] Basel Convention, 2003, p51 and 82.
[12] The investment is assumed high, if machinery has to be acquired.
[13] Basel Convention, 2003, p73.

Activity	Gap of remediation	Possible action	Activity specific to intertidal zone	Innovation needed	Capital investment	Feasible time horizon for implementation
High impact and abrasion during wire pull of sections	Cranes are not applied in the in primary cutting zone as the sandy/muddy seafloor is to soft to carry the weight of the crane.	**Permanent structure(s) extending into the primary cutting zone.** A structure, such as a jetty, for pre-cleaning and rapid first stage dismantling of deckhouses and engine rooms could be built in the tidal area. It can be constructed of relatively cheap materials such as concrete and/or flat-bottom steel pontoons.[14]	Yes	Yes	High	1-3 years
		Crane mounted on barge. There may be legal obstacles (e.g. leasing terms), which means that construction of permanent structures in is not possible. An alternative solution may be to apply a floating or jack up crane during cutting in the tidal zone.	Yes	No	High	<1 year
Burning of cables	PCB release from burning of polymer insulation to retrieve copper wire.	**Mechanical stripping of cables.** Cable burning for the recovery of copper wire is highly hazardous and must be prevented.	No	No	Low	<1 year
Temporary storage of hazardous materials	Insufficient/improper temporary storage of hazardous materials at the yard.	**Temporary storage facilities.** Hazardous materials must be stored in suitable containers, covered and labeled. Flooring must be able to prevent penetration of hazardous materials to soil with a curbing that provides sufficient containment of the volume stored in case of spill/overflow. Facility should be roofed and have walls that prevent rainwater from reaching the wastes, and no floor drains or other openings that would allow liquids to flow from the area.	No	No	Low	<1 year

[14] Wijngaarden, 2005.

7 Conclusions

Do we have scientific and quantifiable knowledge on environmental impacts from intertidal zone ship breaking?

The answer is partly yes. In the public domain enough information is available to draw the overall conclusion that impacts are prevalent. Individual yards may have information on more recent monitoring data and data for a broader range of pollutants.

Most available environmental data are from analysis of sediment samples. The conclusion drawn from these samples is clearly that there is a massive enrichment of metals both when compared to international standards and in comparison to the local background values. Several metals (iron, lead and manganese) exceed international standards in seawater. Few data are available for air, but lead, manganese and zinc is found to exceed ambient air quality criteria.

The background concentrations of oil and oil residues are typically considered to be close to zero in water and sediments. The oil concentrations encountered in the intertidal zone sediments from oil ranges from 0.3 mg to 4.3 grams per kg of sediment. In analyses of seawater impacts are less pronounced, but comparison to the discharge standard 15 mg/L from shipping (MARPOL) reveals that oil and oil residues may even reach this level in seawater.

Radioactive materials do not appear to cause impacts in the environment. These are presumably by and large contained in reused equipment.

Pathogens are found throughout the shipbreaking areas. These may have their source in discharges and spills from the ships or they originate in the amenities or lack thereof in the ship breaking areas is not clear.

> All in all, the data show that intertidal zone ship breaking do lead to impacts from heavy metals, oil and oil residues and pathogens in the environment.

Do current practices in intertidal zone ship breaking lead to impact higher than internationally accepted?

Although some data are 10-15 years old, new data does not suggest that the general patterns have changed, so the answer is: Yes, but with a caveat. The most frequently sampled media is sediment, which may change slowly, i.e. be historically conservative. It is emphasized that time series of monitoring data are generally not available, and the improvements in environmentally sound managements in certain sites are relatively recent. Thus, recent improvements may not be displayed in the data. Nevertheless, even in fast changing environmental compartments such as water and air residues related to paints (zinc) and spills of oil/oily water are prevalent, and signature to inadequate environmental management.

Are technologies and practices available that will allow the environmental impacts of intertidal zone ship breaking to be avoided?

With the current information level it is not possible to assign a portion of heavy metals lost to the environment or a certain part of petroleum hydrocarbons from oily water spills to specific sources and activities at the yards. It is however clear that in the intertidal zone ship recycling a substantial part of the spills, discharges and emissions can be completely avoided by adherence to basic sound environmental management.

Nevertheless, there are some activities that are the source of hazardous substances, which are difficult, unfeasible or perhaps even impossible to remediate, under the conditions of the intertidal zone. That would include how to contain slag, particles and fumes from torch cutting, how to avoid cut sections high energy impact and abrasion/loss during wire pulling, and how avoid and contain spills, discharges and emissions when cutting bulkheads.

The report is based on publically available information, interviews and expert knowledge. During the course of the study a number of data gaps regarding intertidal zone ship recycling emerged which is outlined in the table below.

Table 7: Data gaps and possible actions

Gap on data	Possible action
Hazardous substances and materials in the environment	
• **data on certain frequently named but rarely analysed contaminants arsenic, TBT, mercury, PCB;**	Generating new data by sampling and analysis of substances AND/OR collection of recent monitoring data from yards and authorities. Timeline for generating data would be expected 1-1.5 year, and costs may be 150-200k€ with 70% being costs for chemical analysis.
• **assessment of paint chips, slag and particles in soil and intertidal sediment;**	Generating new data by sampling and analysis of substances Timeline for generating data would be expected 0.5 year, and costs may be <50k€.
Frequency and volume of spills, discharges and other events	
• **oil, oily water and chemical spills**	Collection of recent monitoring data from yards and authorities Timeline immediately with limited costs
• **ballast and sewage water**	Collection of recent monitoring data from yards and authorities Timeline immediately with limited costs
Materials onboard	
• **determination of ODS in ships refrigerants and insulation**	Generating new data by sampling and analysis of substances Timeline for generating data would be expected 0.5 year, and costs may be <50k€.
• **knowledge on occurrence and amounts of hazardous materials in ships for recycling (Needs assessment)**	Collecting existing IHM from commercial shipping companies will allow estimate of capacity needed in yards. Timeline for generating data would be expected 1 year, and costs may be <50k€.

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Appendices

A.1 Full tables of data on contamination in sediments, water and air

A. 2 Priority contaminants based on International standards or exceeding local background values

A.3 List of interviewed experts

A.1 Full tables of data on contamination in sediments, water and air

Table 8: Impacts of heavy metal contamination (color coded for sediment, water and air)

Environmental efffect	Medium	Heavy Metals	Concentration measured			Location	Ref.
Pollution of sediment – enrichment of heavy metals 89% reduction in total number of zooplankton 40% reduction in total number of zooplankton groups 32% reduction in group diversity	Intertidal sediment		(µg/g, dw)[1, a]	Bulk fraction 63 µm-2mm (µg/g dw)[2, a]	Fine fraction <63 µm (µg/g dw)[2, a]	Alang-Sosiya, Gulf of Cambay, India	[1] Tewari et al, 2001 [2] Reddy et al., 2004
			-	8.61±0.58(%)	12.04±0.99(%)		
		Aluminum	24.03 ±2.1	32.7±2	45.85±6		
		Cadmium	-	290.18±63.18	312.77±25		
		Chromium	145.00 ± 12	52.55±14	111.42±11		
		Cobalt	7.56 ± 0.9	214.41±53	312.87±98		
		Copper	75088 ± 1,655	137990±78753	162189±72537		
		Iron	220.00 ± 9	169.98±69	262.54±139		
		Lead	1,488 ± 24	4643.1±1769	12979±4324		
		Manganese	1.56 ± 0.5	-	-		
		Mercury	117.00 ± 4	172.53±47	221.5±22		
		Nickel	50.60 ± 2.1	1222.18±147	1483.43±161		
		Zinc					
Pollution of sediment – enrichment of heavy metals			(µg/g dw)[b]			Mumbai scrapping area, India	Kantahk et al., 1999
		Arsenic	163				
		Chromium	776				
		Copper	888				
		Iron	282				
		Lead	806				
		Nickel	347				
		Zink	2112				
			(µg/g dw)[h]			Sewri, Mumbai, India (Ship recycling activities were completely stopped 6-7 years before the investigation)	Asolekar, 2010
		Arsenic	24.03 – 41.95				
		Cadmium	10.77 – 61.12				
		Chromium	50.71 – 111.39				
		Cobalt	20.23 – 24.97				
		Cupper	91.00 – 406.28				
		Lead	47.10 – 158.05				
		Nickel	83.93 – 253.99				
		TiZink					

Environmental efffect	Medium	Heavy Metals	Concentration measured	Location	Ref.
			17.21 – 49.86		
			102.65 – 291.59		
Pollution of sediment – enrichment of heavy metals			(µg/g dw)[b]	Alang, Gulf of Cambay, India	Kantahk et al., 1999
		Arsenic	35		
		Chromium	77		
		Copper	112		
		Iron	90		
		Lead	<2		
		Nickel	108		
		Zink	74		
Biodiversity of biota in sediments and seawater Trace metals can threaten marine mammals and birds. Fish, mollusks, crustaceans and turtles that are nearshore, permanent residents or mi-gratory visitors are also vulnerable. Particularly sensitive are eggs, larvae and juveniles. Plants and algae are also at risk			(µg/g)[c]	Bhatiari-Kumira[3] and Sitakunda[4], Chittagong, Bangladesh	[3] Siddiquee, et al., 2009 [4] Abdullah et al., 2013
		Cadmium	0.57 – 0.94		
		Chromium	22.89 – 86.72		
		Copper	21.05 – 39.85		
		Iron	11932.61 – 41361.71		
		Lead	36.78 – 147.83		
		Manganese	0.015 – 0.117		
		Mercury	2.32 – 8.25		
		Nickel	23.12 – 48.96		
		Zink	83.78 – 142.85		
			(µg/g)	Gadani, Pakistan	The World Bank 2010
		Cadmium	n.d.		
		Chromium	2.42 – 22.12		
		Lead	11.3 – 197.7		
		Mercury	0.078 – 0.158		
			(µg/g)	Chittagong, Bangladesh	The World Bank 2010
		Cadmium	n.d. – 2.2		
		Chromium	66 – 238		
		Lead	151 – 898		
		Mercury	n.d. – 0.3		
			(µg/g)[a]	Chittagong, Bangladesh	DNV 2000
		Cadmium	n.d.		
		Chromium	41 – 66		
		Copper	27 – 93		

Environmental efffect	Medium	Heavy Metals	Concentration measured				Location	Ref.
		Iron	21803 – 30516					
		Lead	13 – 25					
		Manganese	499 – 738					
		Mercury	0.028 – 0.052					
		Nickel	41 – 63					
		Zink	67 - 172					
Accumulation by marine invertebrates Serious bioaccumulation atrophy	Seawater		(µg/L)[d]				Alang-Sosiya, Gulf of Cambay, India	Reddy et al., 2005
			Summer	Monsoon	Winter			
		Cadmium	314±14	435±12	561±17			
		Chromium	621±26	648±28	765±24			
		Cobalt	1226±45	1400±42	1665±43			
		Copper	3122±113	3552±118	3939±123			
		Iron	2889±142	3095±126	3662±132			
		Lead	1570±146	1700±136	2036±167			
		Manganese	4139±243	4015±221	4920±232			
		Nickel	522±126	621±127	944±132			
		Zink	4271±136	4940±231	5832±123			
Air pollution, Workers, people living in neighboring areas	Air		Pre monsoon (May) (µg/m3)[e]	Post monsoon (Sep) (µg/m3)[e]	Winter (Jan) (µg/m3)[e]	Mean Concentration (µg/m3)[e]	Alang-Sosiya, Gulf of Cambay, India	Basha et al., 2007
		Cadmium	n.d.- 3.7	1.11 – 3.55	0.95 - 2.55	1.669		
		Chromium	0.11 – 0.355	0.11- 0.32	0.135 – 0.42	0.246		
		Cobalt	n.d. – 0.37	n.d. - 1.4	0.15 – 0.75	0.414		
		Copper	1.35 – 4.32	1.3 – 3.75	0.85 – 3.8	2.56		
		Iron	20.78 – 41.88	28.35 – 35.02	26.27 – 35.06	31.02		
		Lead	n.d. – 0.8	0.12 – 1.05	0.21 – 1.13	0.509		
		Manganese	1.12 – 2.24	1.4 – 2.75	1.62 – 3.75	2.04		
		Nickel	n.d. – 0.65	0.1 – 0.45	0.35 – 0.51	0.306		
		Zink	3.3 – 5.2	2.15 – 5.6	2.9 – 6.15	3.97		
			µg/m^3 [g]				Chittagong, Bangladesh	DNV 2000
		Cadmium	n.d.					
		Chromium	n.d.					
		Copper	8.5					
		Iron	163					
		Lead	9					

Environmental efffect	Medium	Heavy Metals	Concentration measured	Location	Ref.
		Manganese	11.5		
		Mercury[f]	0.04		
		Nickel	1860		
		Zink	180		

Legend: a: Sampling location near shore of the ship breaking yard, b: scrapping site, c: inter-tidal zone of the ship breaking area during high tide, d: sampling location along the ship breaking yard at 1 m depth from the surface during high tides, e: sampling location along the ship breaking yard at a height of 3-5 m using glass fiber filters with High-Volume sampler (Envirotech-APM 415); f: Hg in gas is not measured and gives normally a greater contribution than Hg in dust; g: Sample location in the ship breaking area; h: Samples were collected at 0 - 10 cm depths during low tide. Two samples were taken from the sediment exposed during low tide, Ones ample from the intermediate zone, two samples from the sediment close to the shore. These three sets then were combined and homogenized to be considered as a single sediment sample.

Table 9:Impact of various contaminants

Environmental effects	Medium	Parameter	Concentration measured	Location	Ref.
Higher survival of pathogenic and non-pathogenic bacteria	Intertidal sediment		(no/g dw)[a]	Alang-Sosiya, Gulf of Cambay, India	Tewari et al, 2001
		Total coliform	216.43		
		Escherichia coli	15.79		
		Shigella	8.16		
		Salmonella	7.93		
		Proteus and Klebsiella	10.14		
		Vibrio cholera	3.14		
		Vibrio parahaemolyticus	12.11		
		Other Vibrio	7.82		
		Pseudomonas aeruginosa	-		
		Streptococcus faecalis	-		
		Plastic debris	81 mg of small plastics fragments per kg of sediment		Reddy et al., 2006
Mortality of coastal wild life Waste is dumped along the coast – tides carry the waste into the marine environment or open burning of waste leading to other environmental pollution		Type of waste:	Waste (kg)		Reddy et al., 2003
		Paper	61.25 ± 6.68		
		Metals	53.25 ± 5.67		
		Glass and ceramics	72.00 ± 6.08		
		Plastics	113.00 ± 6.98		
		Leather	53.45 ± 6.46		
		Textiles	126.66 ± 8.36		
		Wood	244.08 ± 12.5		
		Rubber	201.91 ± 7.91		
		Food waste	73.33 ± 6.60		
		Chemicals	26.36 ± 4.45		
		Ash	36.66 ± 5.06		
		Paint scrap	34.75 ± 2.13		
		Thermocol	88.15 ± 7.38		
		Oiled sponge	133.5 ± 8.07		
		Miscellaneous combustible	81.96 ± 8.63		
		Miscellaneous non-combustible	82.33 ± 11.26		

Environmental effects	Medium	Parameter	Concentration measured			Location	Ref.
		Radioactive materials	Activity Concentrations (Bq/kg)[b]			Sitakunda, Chittagong, Bangladesh	Hossain et al., 2010
			Minimum	Maximum	Average		
		^{226}Ra	9.88±0.86	86.95±3.47	31.39±1.77		
		^{232}Th	24.07±1.69	178.07±6.57	63.34±3.27		
		^{40}K	68.01±4.80	792.68±29.80	364.47±15.32		
		^{137}Cs	n.d.	n.d.	n.d.		
			mg/kg			Gadani, Pakistan	The World Bank 2010
		Oil	485 - 4300				
		PCB	0.01 – 11.52				
			mg/kg			Chittagong, Bangladesh	The World Bank 2010
		Oil	0.32 – 4.43				
		PCB	n.d.				
			mg/kg dw			Chittagong, Bangladesh	DNV 2000
		PAH	0.81 – 6.648				
		PCB	n.d.				
		TBT	n.d.				
Endangers all other marine animals, killing off oyster larvae, deforming shells, and causing deformations and infertility in different kinds of snails, and harmful changes in fish and crabs	Soil		µg Sn/kg dw			Mumbai scrapping yard, India	Kantahk et al., 1999
		MBT	145				
		DBT	349				
		TBT	1090				
		TTBT	67				
	Intertidal sediment		µg Sn/kg dw			Alang, scrapping yard, India	Kantahk et al., 1999
		MBT	11 - 22				
		DBT	25 - 33				
		TBT	119 - 184				
		TTBT	<1 - 4				
Higher survival of pathogenic and non-pathogenic bacteria	Seawater		(no/mL)[a]			Alang-Sosiya, Gulf of Cambay, India	Tewari et al, 2001
		Total coliform	156.11				
		Escherichia coli	15.18				
		Shigella	10.21				
		Salmonella	7.42				
		Proteus and Klebsiella	4.85				
		Vibrio cholera	5.93				
		Vibrio parahaemolyticus	7.36				
		Other Vibrio	8.19				

Environmental effects	Medium	Parameter	Concentration measured	Location	Ref.
		Pseudomonas aeruginosa *Streptococcus faecalis*	- 9.18		
Larvae, low motility organisms, filter feeders, benthic organisms - changes feeding and reproductive cycles, bioaccumulation, genetic mutations and cell atrophy		Total petroleum hydrocarbons (TPHCs)	657 to 3540 (±32 μg/L)[c] 1400±10.4		Reddy et al., 2005 Tewari et al, 2001
		Total polycyclic aromatic hydrocarbons (TPAHs)	336±12 to 1446±14 μg/L[c]		
Hamper the primary productivity by limiting sun-light penetration in the aquatic environment Inhibits photosynthesis; reduce exchange of oxygen and carbon dioxide, Damage of bird population, coating the feathers by oil, causes buoyancy and insulation losses.		Petroleum hydrocarbons PHC	n.d. [d]	Chittagong, Bangladesh	DNV 2000
		Oil	mg/L 9280 - 10800	Chittagong, Bangladesh	Hossain et al. 1986
		Total hydrocarbon	mg/L 52.5 – 123.5	Chittagong, Bangladesh	Hossain et al., 2010

Legend: a: Sampling location near shore of the ship breaking yard, b: sampling location at the ship breaking yard in 0-30cm depth, c: sampling location along the ship breaking yard at 1 m depth from the surface during high tides; d: Sample location in the intertidal zone area inside the ship breaking area, the sample was collected during a rising tide; n.d.: not detected

A.2 Priority contaminants based on International standards or exceeding local background values

Table 10: Priority list of contaminants based on Level of contamination in comparison with background values (BG): Low: 0 to 10 times higher than BG; Medium: 11-100 times higher than BG; High: over 100 times higher than BG. International Standard (IS): *Low: <100 % exceedence of BG/IS, Medium: 100-1000 % exceedence of BG/IS, High: >1000 % exceedence of BG/IS.

Parameter	Sediment/soil		Seawater		Air	
	Relative to background values	Relative to International Standards	Relative to background values	Relative to International Standards	Relative to background values	Relative to International Standards
Metals				No IS available		
Aluminum	Low	No IS available	No data	No IS available	No data	
Arsenic	Medium	No IS available	No data	No IS available	No data	
Cadmium	Low to Medium	High	Low	No IS available	Low	High
Chromium	Low to Medium	High	Medium	No IS available	Low	Low
Cobalt	Low	No IS available	Medium	No IS available	Medium	No IS available
Copper	Low to Medium	High	Medium to High	No IS available	Medium	No IS available
Iron	Low to Medium	High	Medium to High	No IS available	Medium	No IS available
Lead	Medium to High	High	Medium	No IS available	Medium	Low
Manganese	Low	High	Medium to High	No IS available	Low to Medium	High
Mercury	Medium to High	High	No data	No IS available	No data	
Nickel	Medium	High	Medium	No IS available	Low	High
Zinc	Medium	High	High	No IS available	High	
Other substances						
Total petroleum hydrocarbons (TPHCs)	No data		Low / High	No IS available	No data	
Total polycyclic aromatic hydrocarbons (TPAHs)	No data		Low to Medium	No IS available	No data	
Oil	No background data available	No IS available	Medium to High	No IS available	No data	
PCB	Low to Medium	No IS available	No data	No IS available	No data	
Radioactive materials			No data	No IS available	No data	
^{226}Ra	Low	Low				
^{232}Th	Low	Low				
^{40}K	Low	Low				
^{137}Cs	Low	Low				
Pathogens						

Parameter	Sediment/soil		Seawater		Air	
	Relative to background values	Relative to International Standards	Relative to background values	Relative to International Standards	Relative to background values	Relative to International Standards
Total coliform	Low*		Low*	No IS available	No data	
Escherichia coli	Medium*		Medium*	Medium		
Shigella	Medium*		Medium*	No IS available		
Salmonella	Medium*		Medium*	No IS available		
Proteus and *Klebsiella*	Low*		Low*	No IS available		
Vibrio cholera	Low*		Medium*	High		
Vibrio parahaemolyticus	Medium*		Medium*	No IS available		
Other Vibrio	Low*		Low*	No IS available		
Pseudomonas aeruginosa	Low*		No data	No IS available		
Streptococcus faecalis	Low*		Medium*	No IS available		

Legend: Level of contamination in comparison with background values (BG): Low: 0 to 10 times higher than BG; Medium: 11-100 times higher than BG; High: over 100 times higher than BG, *Low: 0 - 100%increase over control; Medium: 100 – 1000% over control; High: over 1000% increase over control.

Table 11: Low and high range of heavy metals from the areas in India, Bangladesh and Pakistan

Parameter	Range Lower	Range Higher	International Standard (IS)	Increase over Standard (%)	Medium
Metals					
	(µg/g dw)	(µg/g dw)	(µg/g dw)		Sediment
Aluminum (%)	8.61±0.58	12.04±0.99	No IS	-	
Arsenic	-	163	No IS	-	
Cadmium	n.d.	45.85±6	0.115 a,b	44987	
Chromium	2.42	776	77.2 a	905	
Cobalt	52.55±14	145.00 ± 12	No IS	-	
Copper	7.56 ± 0.9	888	33.0 b	2591	
Iron	282	162189±72537	27000 a	769	
Lead	11.3	898	22.8 b	3839	
Manganese	0.015	12979±4324	1.17 b	1478789	
Mercury	n.d.	8.25	0.02 a	41150	
Nickel	23.12	347	56.1 a	518	
Zinc	50.60 ± 2.1	2112	95.0 b	2123	
	µg/L	µg/L	mg/L		
Cadmium	314±14	561±17	2.0 c	n.e.	Water
Chromium	621±26	765±24	2.0 c	n.e.	
Cobalt	1226±45	1665±43	No IS	-	
Copper	3122±113	3939±123	30 c	n.e.	
Iron	2889±142	3662±132	3 c	26	
Lead	1570±146	2036±167	2.0 c	10	
Manganese	4015±221	4920±232	2 c	158	
Nickel	522±126	944±132	50 c	n.e.	
Zink	4271±136	5832±123	15 c	n.e.	
	µg/m^3	µg/m^3	µg/m^3		Air
Cadmium	n.d.	3.7	0.005 [d]	33280	
Chromium	0.11	0.42	1.1 [d]	n.e.	
Cobalt	n.d	1.4	No IS	-	
Copper	0.85	4.32	No IS	-	
Iron	20.78	41.88	No IS	-	
Lead	n.d.	1.13	0.5 d; 1.5 [e]	1.8; n.e.	
Manganese	1.12	3.75	0.15 [d]	1260	
Nickel	n.d.	0.65	0.00038 [d]	80426	
Zink	2.15	6.15	No IS	-	

Parameter	Range Lower	Range Higher	International Standard (IS)	Increase over Standard (%)	Medium
Other substances					
Radioactive materials ^{226}Ra ^{232}Th ^{40}K ^{17}Cs	Bq/kg 9.88±0.86 24.07±1.69 68.01±4.80 n.d.	Bq/kg 86.95±3.47 178.07±6.57 792.68±29.80 n.d.	Bq/g 10 10 100 10	n.e. n.e. n.e. n.e.	Sediment
Oil and oil residues					
Oil and oil residues	mg/kg 0.32	mg/kg 4300	No IS		
Oil and oil residues	mg/L 52.5	mg/L 10800	No IS, but 15 mg/L accepted under MARPOL		
Pathogens					
		no/g dw	CFU/100 mL		Sediment
Escherichia coli		15.79	250[f]		
Vibrio cholera		10.14	1[f]		
		no/mL	CFU/100 mL		Water
Escherichia coli		15.18	250[f]	507	
Vibrio cholera		5.93	1[f]	59200	

Legend: a: IAEA(190); b: International background values from GESAMP (1982); c: Indian Standards (general standards for discharge of environmental pollutants); d: WHO; e: Indian standard (Ambient air, industrial area); f: IMO BWM/CONF/36; n.d.: not detected; n.e.: not exceeded.

A.3 List of interviewed experts

Table 12: Interviews as outline in scope by APMM (telephone or email)

Affiliation	Person
University of Strathclyde	Stuart McKenna
NGO Shipbreaking Platform	Patrizia Heidegger (email)
ISRA	Arjen Uytendaal
Class NK	Junichi Hirata (=>Takeshi Naruse)
Lloyds Register	Jim Heath
Sea2cradle	Tom Peter Blankestijn
GSR	Henning Gramann
IMO Marine Environment Division	Jun Sun (email)