IMPACT OF SHIP BREAKING ACTIVITIES ON SOIL AND WATER QUALITY AT SITAKUNDA COASTAL AREA OF CHATTOGRAM

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A thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in Chemistry

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DECEMBER 2023

Declaration

I hereby declare that the work contained in this Thesis has not been previously submitted to meet requirements for an award at this or any other higher education institution. To the best of my knowledge and belief, the Thesis contains no material previously published or written by another person except where due reference is cited. Furthermore, the Thesis complies with PLAGIARISM and ACADEMIC INTEGRITY regulation of CUET.

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Dedication

To my beloved parents, infinitely supportive

List of Publications

Journal Article

- Ahasanul Karim, Ranjit K. Nath, Saswata Rabi, and Arup Kumer Roy, "Impact of Ship Breaking Activities on the Water Quality at the Coastal Area of Chattogram, Bangladesh." *Asian Journal of Chemistry*. Vol. 35, No. 10 (2023), Page; 2382-2388.
  DOI: https://doi.org/10.14233/ajchem.2023.28114
- Ahasanul Karim, Ranjit K. Nath, Arup Kumer Roy, and Saswata Rabi, "Impact and Environmental Risk Assessment for Hazardous Metal Pollution in the Sediment at Shipbreaking Yard Chattogram." Accepted for publication in *Journal of Water Chemistry and Technology*. Manuscript number: 2184(Accepted).

Conference

- Ahasanul Karim* and Ranjit K. Nath, "Ship-Breaking Activities: Impact on Pollution of Coastal Water at Chattogram" International Conference on Environmental Protection for Sustainable Development. University of Dhaka, Page; 318, 03 September 2022.

Approval/Declaration by the Supervisor

This is to certify that Ahasanul Karim has carried out this research work under my supervision, and that he has fulfilled the relevant Academic Ordinance of the Chittagong University of Engineering and Technology, so that he is qualified to submit the following Thesis in the application for the degree of Master of Science in Chemistry. Furthermore, the Thesis complies with the PLAGIARISM and ACADEMIC INTEGRITY regulation of CUET.

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Acknowledgement

All praise to Merciful and Almighty Allah, who has given me the strength and opportunity to complete the research and to submit this thesis for the degree of Master of Science (M.Sc.) in Chemistry.

The author expresses his heartfelt gratitude, wholehearted indebtedness, sincere appreciation, and profound regard to my honourable teacher and research supervisor, **Professor Dr. Ranjit Kumar Nath**, Department of Chemistry, Chittagong University of Engineering & Technology (CUET), Chattogram, for his academic guidance, constant untiring supervision, cordial support, endless encouragement, precious advice, guidance, enthusiasm and helpful discussion throughout the entire period of research work and preparation of this thesis.

The author feels proud to express his sincere appreciation and gratitude to Prof. Dr. Md. Rezaul Karim, Prof. Dr. M. K. M. Ziaul Hyder, Dr. Saswata Rabi, Dr. Arup Kumer Roy, & all teachers and staff of the Department of Chemistry, CUET for their cooperation, continuous inspiration, and encouragements.

I am also grateful to all of my friends in the Chemistry department, CUET for their valuable discussion and co-operation at all steps. The author is grateful to all of my friends and well-wishers, especially Muhammad Towhid Moula, A. H. M. Nur Uddin, Ibrahim, Eefan Md. Enamul Hud, Harun Rasid, Osman Gani, Noman Uddin, Md. Hosainul Karim, Shahed Alam, Shayaree and Shabib Taher Chowdhury. The author expresses gratitude to his parents, siblings, family members, and relatives for their unwavering support, encouragement, and sacrifices in his pursuit of higher education.

Authors are grateful to the Directorate of Planning & Development (P&D), Chittagong University of Engineering and Technology (CUET), Chattogram – 4349, for providing a scholarship for the present study.

Abstract

The Ship Breaking Area of Chattogram is one of the most ecologically effective regions in Bangladesh. It includes wealthy biodiversity that consists of numerous species that are endemic to this region. Physicochemical parameters and heavy metals in water and soil samples obtained from shipbreaking yards were measured to evaluate the potential ecological impact caused by these parameters. Here are the water quality parameters like temperature, EC, TDS, TSS, pH, DO, BOD, COD, salinity, oil, and turbidity. Temperature, pH, and BOD values were within the acceptable range, but TDS, EC, oil and grease, and turbidity were above the DoE's recommended standard level for surface water. Atomic absorption spectroscopy analysis was used to determine the presence of toxic metal contamination. Pb (avg. in Water: 0.46 mg/L; avg. in Soil: 52.55 mg/kg) > Cr(VI) (avg. in Water: 0.49 mg/L; avg. in Soil: 45.97 mg/kg) > As (avg. in Water: 0.205 mg/L; avg. in Soil: 6.99 mg/kg) > Cd (avg. in Water: 0.049 mg/L; avg. in Soil: 0.218 mg/kg). The levels of the harmful metals were higher than what was considered acceptable. Pb and Cr had no periodic effects, whereas As and Cd significantly varied (water and soil) with the times. The evaluation of the heavy metal pollution index showed that the study area had a critical score of water quality (HPI > 100). The average geo-accumulation index (Igeo) readings showed that the study area was very slightly polluted overall, with the exception of Cd. Also, all the ship-breaking region's sampling locations had pollution load indices ranging from 1.91 to 3.10, indicating that the soil there was heavily contaminated with heavy metals (PLI > 1). High levels of metal pollution in the study area suggest that it faces a high potential ecological risk index. According to this study, the shipbreaking site was moderately polluted with heavy metals and posed a risk to the ecosystem.

বিমূর্ত

চট্টগ্রামের জাহাজ ভাঙা এলাকাটি বাংলাদেশের সবচেয়ে পরিবেশগতভাবে কার্যকর অঞ্চলগুলির মধ্যে একটি। এতে সমৃদ্ধ জীববৈচিত্র্য রয়েছে যা এই অঞ্চলে স্থানীয় অনেক প্রজাতি নিয়ে গঠিত। শিপব্রেকিং ইয়ার্ড থেকে প্রাপ্ত পানি এবং মাটির নমুনায় ভৌত রাসায়নিক প্যারামিটার এবং ভারী ধাতুগুলি এই প্যারামিটারগুলির কারণে সৃষ্ট সম্ভাব্য পরিবেশগত প্রভাব মূল্যায়ন করার জন্য পরিমাপ করা হয়েছিল। এখানে তাপমাত্রা, EC, TDS, TSS, pH, DO, BOD, COD, লবণাক্ততা, তেল এবং গ্রীস এবং টার্বিডিটির মতো পানির মানের প্যারামিটার রয়েছে। তাপমাত্রা, pH, এবং BOD মানগুলি গ্রহণযোগ্য সীমার মধ্যে রয়েছে, কিন্তু TDS, EC, তেল এবং টার্বিডিটি ভূপৃষ্ঠের পানির জন্য (DoE)-এর প্রস্তাবিত মান স্তরের উপরে রয়েছে। বিষাক্ত ধাতব দূষণের উপস্থিতি নির্ধারণ করতে পারমাণবিক শোষণ বর্ণালী বিশ্লেষণ ব্যবহার করা হয়েছিল। Pb (পানিতে গড়: ০.৪৬ mg/L; মাটিতে গড়: ৫২.৫৫ mg/kg) > Cr(VI) (পানিতে গড়: ০.৪৯ mg/L; মাটিতে গড়: ৪৫.৯৭ mg/kg) > As (পানিতে গড়: ০.২০৫ মাটিতে গড়: ০.২১৮ mg/kg)। ক্ষতিকারক ধাতুগুলির মাত্রা গ্রহণযোগ্য হিসাবে বিবেচিত হওয়ার চেয়ে বেশি রয়েছে। Pb এবং Cr-এর কোনো পর্যায়ক্রমিক প্রভাব পাওয়া যায়নি, যেখানে সময়ের সাথে As এবং Cd উল্লেখযোগ্যভাবে পরিবর্তিত হয়েছে (পানি এবং মাটি)। ভারী ধাতু দূষণ সূচক এর মূল্যায়ন দেখায় যে অধ্যয়ন এলাকায় পানির গুণমানের একটি সমালোচনামূলক স্কোর রয়েছে (HPI > ১০০)। গড় জিও-অ্যাকুমুলেশন ইনডেক্স (আইজিও) রিডিং দেখায় যে সিডি বাদে অধ্যয়নের এলাকাটি সামগ্রিকভাবে খুব সামান্য দূষিত রয়েছে। এছাড়াও, সমস্ত জাহাজ ভাঙা অঞ্চলের নমুনা স্থানগুলিতে ১.৯১ থেকে ৩.১০ পর্যন্ত দূষণ লোড সূচক রয়েছে, যা নির্দেশ করে যে সেখানকার মাটি ভারী ধাতু (PLI > ১) দ্বারা ব্যাপকভাবে দূষিত রয়েছে। অধ্যয়নের এলাকায় উচ্চ মাত্রার ধাতব দূষণ থেকে বোঝা যায় যে এটি একটি উচ্চ সম্ভাবনাময় পরিবেশগত ঝুঁকি সূচক এর সম্মুখীন। এই সমীক্ষা অনুসারে, জাহাজ ভাঙার স্থানটি ভারী ধাতু দ্বারা মাঝারিভাবে দূষিত রয়েছে এবং বাস্তুতন্ত্রের জন্য ঝুঁকি তৈরি করেছিল।

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Nomenclature

Symbols

Symbols	Elaborations
e.g.	for example
etc.	Etcetera
et al	And Others
Fig.	Figure
E. coli	*Escherichia coli*
$	US dollar
Min	Minimum
Max	Maximum
ppm	Parts per million
nm	nanometer
λ	Wavelength
V	Volt
Sp	Sampling Position
^{o}C	Degree Celsius
$\mu S/cm$	Micro Siemens/centimeter
ppt	Parts Per Thousand

Acronyms and Abbreviations

AAS	Atomic Absorption Spectroscopy
ANOVA	Analysis of variance
APHA	American Public Health Association
BCSIR	Bangladesh Council of Scientific and Industrial Research
BOD	Biochemical Oxygen Demand
BWDB	Bangladesh Water Development Board
COD	Chemical Oxygen Demand
CUFL	Chattogram Urea Fertilizer Limited
DO	Dissolved Oxygen
DoE	Department of Environment
EC	Electrical Conductivity
ECCs	Environmental Clearance Certificates
ECR	Environment Conservation Rules
EQS	Environmental Quality Standard
ETP	Effluent Treatment Plant
GEMS	Global Environmental Monitoring System
GPS	Global Positioning System
ICP-MS	Inductively coupled plasma mass spectrometry
IWM	Integrated Watershed Management
NGO	Non-Governmental Organizations
NTU	Nephelometric Turbidity Unit
ORP	Oxidation-Reduction Potential
PAHs	Polycyclic Aromatic Hydrocarbons
SBRI	Ship Breaking and Recycling Industry
SBSRB	Ship Building and Ship Recycling Board
SoE	State of the Environment
TDS	Total Dissolved Solid
TSS	Total Suspended Solid
UEM	Urban Environmental Management
WHO	World Health Organization

Chapter 1: INTRODUCTION

1.1 GENERAL OUTLINE

The shipbreaking industry in Bangladesh is booming as the country sees the lucrative potential in this sector. It began operations in 1969 in Bangladesh and has since earned a profit by providing affordable steel and jobs to the local population. Shipbreaking accounts for 2.2–2.5 million tons of annual steel output in the country. There are at least 40 operational shipbreaking yards and between 250 and 350 re-rolling mills in Bangladesh (Ali et al., 2022; Azad et al., 2009; Sarraf et al., 2010). Since 2009, the number of people directly engaged in shipbreaking has grown to around 22,000, while the number of people indirectly engaged through ancillary employment has grown to almost 200,000. The coast of Bangladesh is home to almost 30 million people and is a vital resource for many different kinds of wildlife (Abdullah et al., 2013; Ali et al., 2022).

In Bangladesh, heavy metal contamination in water and soil has increased due to growing industrialization and urbanization, particularly in the areas surrounding river deltas that empty into the marine (Ahmed et al., 2022; Ali et al., 2018; Bhuyan et al., 2019). Agricultural runoff, chemical fertilizers and pesticides used improperly, municipal sewage disposal, and other sources all contribute to the release of harmful metals into the coastal aquatic environment (Ding et al., 2018; Jiang et al., 2018). The aquatic ecosystem may be subjected to toxic metals from natural processes such as geological weathering, atmospheric precipitation, water erosion, and bioturbation, in addition to human activities (Guan et al., 2018; Proshad et al., 2022). Their persistence, long-term abundance, toxicity, bioaccumulation potential, and environmental impact are all reasons to be concerned (Jolly et al., 2022; Shirani et al., 2020). The majority of shipbreaking yards are situated in South Asian countries because of the cheaper labor costs and less stringent disposal regulations, which are a result of bad design, management, and legislation (Demaria, 2010). Recent years have seen the publication of studies that synthesize data on the contamination of different habitat types in Bangladesh's water and soil by hazardous elements. The majority of coastal water and soil (Ali et al., 2022; Yuksel et al., 2022). However, a deeper look at the study reviews on the contaminated metals in soil shows that the writers typically integrate information from unrelated studies. There is a pressing need for a comprehensive national assessment of HM pollution in Bangladesh's shipbreaking coastal regions. However, studies published in Bangladeshi journals are not being fully utilized. Statistics on the levels of contaminated metals in the water and soil at the shipbreaking site are scarce, and Bangladesh lacks the proper management procedures to address the issue (Ali et al., 2020; Rani et al., 2021).

1.2 CONCEPT OF COASTAL AREA POLLUTION

Most researchers adhere to the GESAMP-developed definition (Azad et al., 2009). Define marine pollution as "the introduction by person, either or both, of pollutants or energy into the marine ecosystem (including coastal waters) resulting in such adverse effects as harm to ecosystems and biodiversity, hazards to public health, hindrance to marine operation, such as fishing, impairment of performance for use of sea water, and decrease in amenities (Abdullah et al., 2010)." According to the United Nations Convention on the Law of the Sea, "pollution in the marine environment" (DoE, 1997; ESCAP/UN, 1987) refers to the introduction by man of materials or energy into the marine environment, including estuaries, that result in or is likely to result in such negative effects.

a) As harmful effects on marine life and appropriate uses of the water (like fishing).

b) There have been cuts in infrastructure and a decline in the quality of seawater use.

The concept implies that there is a distinction between pollution and contamination, where the quantity of a substance is increased beyond natural levels but has no obvious effect (Siddiquee et al., 2014). When will the ocean's ability to absorb toxins without being harmed be at risk? How poisonous the waste is to different species, how much of it is released, and what kind of ecosystem it ends up in all have a direct bearing on the answer. In actuality, it's up to each nation to determine their own procedures for determining what kinds of trash are acceptable for sea disposal. No matter the cost or the environmental damage, some people are adamant that trash should never be dumped into waterways and that all waste should be processed on land. The environmental capacity is assessed in other countries, and permits are issued for discharges that are much below the threshold. Because of this, sea disposal is a viable option for general waste management (Talukder et al., 2016).

1.2.1 Shipbreaking Sites

Today, the most proficient ship breakers employ the strategy of driving the ship at full speed toward the shore. The ships are disassembled by hand using portable cutting torches. Steel from the wrecked ship is rapidly hauled ashore. As scrap steel is continuously cut, pounded, and hammered at a shipbreaking site before it is shipped for processing, metal shards and rust, especially iron rust, accumulate along the shore. During this procedure, many different types of garbage and disposable goods are dropped or leaked into the water or the sand.

While there are a wide variety of compounds that can make up ship steel, the soil around shipbreaking sites is often contaminated with nickel and Pb compounds. Cr pollution from paint has a connection to the deterioration of metals at the beach.

Human and mechanical activity along the coast of Chattogram has degraded the binding characteristics of beach soil, according to a 1986 study (Islam & Hossain, 1986). Once the soil's binding qualities are gone, the rate and volume of erosion along the beach will increase regardless of the turbidity of the seawater within the shipbreaking site. This could affect the local aquatic ecosystem by reducing DO and increasing biological oxygen demand. Throughout the process of scrapping the ship, it will always be full of substances that cannot be sold or handled. Common methods of disposal for such pollutants include combustion and ocean disposal.

1.2.2 Water Contamination

Pollution is the process of making something smell bad or look dirty. Water contamination occurs when large quantities of harmful substances are introduced into an aquatic environment. When water cannot be used for its intended purpose, it is considered contaminated. To degrade or otherwise negatively damage the quality of the environment as a result of interaction with or presence in that environment is to engage in pollution. As the population of the universe rises, so does the rate at which human activity must increase to keep up with it.

Shipbreaking activity poses a severe hazard to the coastal aquatic environment and its ecology as a result of the uncontrolled expansion of the sector (Jiang et al., 2018). Ammonia, oils, and lubricants can all increase the pH of soil and the ocean (Allafta & Opp, 2020). Shoreline erosion and saltwater turbidity are both accelerated by a variety of human and machine-made factors. It's possible that the severe turbidity of the water will cause the DO concentration to drop while the BOD level rises dramatically. Acute toxicity, a reduction in light intensity, and a blockage of oxygen and carbon dioxide exchange across the air-sea water interface are all potential outcomes of an oil spill, all of which suggest that this pollution poses a serious threat to the development and population of marine organisms, especially plankton and fish (Dai et al., 2018).

The shipbreaking yard was a major source of pollution due to the presence of heavy metals, petroleum hydrocarbons, and other poisons. Heavy metals and petroleum hydrocarbons were the most significant of all these contaminants due to their toxicity and longevity. Heavy metals like Fe, Zn, and Cu are essential for both human and aquatic life. If they are subjected to high concentrations of these metals over a lengthy period of time, they may become toxic. Asbestos, Cd, and Pb are examples of harmful metals found in the environment that have no known human health advantages (Panda et al., 2023). The physical, chemical, and biological features of the area have degraded severely. The removal processes necessitated by this problem pose risks to both the environment and human health due to the pollutants and debris they generate (Muhibbullah, 2013).

There are costs to the economy and, presumably, the marine environment that are associated with the shipping business. There is not yet an adequate integrated system for the recycling or reusing of ship-related materials. Multiple heavy metals, such as Cd, Pb, Hg, Ni, Fe, Co, Zn, and asbestos, are released into a marine water body during the recycling process of ships. Toxic metals are a major cause of water and marine habitat pollution. The concentration of shipbreaking yards in the Sitakunda region has made water contamination there a growing concern. The purpose of this research was to determine the levels of heavy metals and other water quality indicators in the surface water near the ship-breaking yard in the Chittagong, Bangladesh, neighborhoods of Kumira to Sitakunda (Soner et al., 2021).

1.2.3 Soil Contamination

When they reach the end of their 20- to 30-year service life, most ocean-going vessels are broken up in India, Bangladesh, Pakistan, or China. Shipbreaking has boomed in Bangladesh because of the country's inexpensive labor force, its lengthy, homogeneous coastline intertidal zone, and its low environmental rules. This has led to a 25-year increase from around 3 km in 1989 to over 15 km in 2016 in the longitudinal extent of the shore used for shipbreaking yards (Feng et al., 2017; Panda et al., 2023). Scrapping, on the other hand, poses a number of risks to coastal and marine ecosystems due to the release of a wide variety of pollutants into the water, seabed/ground, and air (Hasan et al., 2013). These include toxic waste, harmful chemicals, such as poly-chlorinated biphenyls (PCBs), polyvinyl chloride (PVC), polycyclic aromatic hydrocarbons (PAHs), tin-organic compounds, oils, gas, asbestos, heavy metals (i Many ship components, including paints, coatings, anodes, and electrical equipment, include heavy metals (Mohiuddin et al., 2012).Because they may travel considerable distances in air, mercury, Pb , and Cd are metals of primary concern. Heavy metal concentrations in sediments around ship-breaking zones have been shown to be higher in several studies (Ali et al., 2022).

1.3 WATER AND SOIL RELATIONSHIP

The suspended particles in the water column can act as carriers for nutrients, metals, and biocides. The end result could lessen or increase the materials' biological availability to phytoplankton and other aquatic organisms. Getting bacterial phytoplankton cells and suspended particles to stick together has also been shown to be an effective way to lower the levels of both chemicals in water (Raknuzzaman et al., 2016). Increased organic turbidity in water can harm larger creatures; reduce visibility, and negatively impact irrigation efficiency and recreational water bodies' aesthetic appeal. Soil turbidity, particularly in shallow lakes and ponds, can be influenced by wind and fish churning up the bottom soil (Lian & Lee, 2021; Zhang et al., 2017). Water and soil are crucial in the process of nutrient and material addition to ponds and lakes, with Cyprinus carpio playing a significant role in this process (Yi et al., 2011). Organic and inorganic particles contribute to the natural process of silt and organic material deposition on water bodies, affecting lake development and biological systems. Soil erosion accelerates this process, causing increased turbidity and Lake Basin siltation (Xiao et al., 2015).

1.4 HAZARDS INVOLVED IN SHIP BREAKING ACTIVITIES

Shipbreaking poses the fewest problems in terms of environmental damage and human health. Unloaded scrap ship weights vary from 5,000 to 40,000 tons (13,000 on average), with 95% of that weight being steel and the remaining weight made up of 10 to 100 tons of paint, including Pb, Cd, organotins, As, zinc, and Cr. Oil (oil for engines, bilge, hydraulics, lubrication, and grease), PCB-containing sealants, and up to 7.5 tons of asbestos are only a few of the numerous dangerous pollutants carried by ships. Up to one thousand cubic meters of unused oil can be transported via tanker. The Basel Agreement has previously designated most of these chemicals as hazardous waste (Haarstad et al., 2012).

1.5 OBJECTIVES OF THE STUDY

This study focuses on the following specific objectives

I. To investigate the physico-chemical changes in water and soil quality parameters of Chattogram ship breaking area.

II. To evaluate the effect of ship breaking pollutants in the coastal area of Chattogram and to find out some remedial measures.

1.6 SCOPE OF THE STUDY

This research will contribute to the knowledge of future researchers on the ship recycling industry in Bangladesh and the hazardous metal and environmental issues it deals with. This research will provide an outline of the countries in South Asia and analyze the current situation of Bangladesh's shipbreaking sector. Both Bangladesh and India have shipbreaking operations, and their locations can be compared. The research can also be used to calculate the amount of harm that shipbreaking does to the environment (in terms of both soil and water quality). The study's final phase will involve the development of strategies and a sustainable strategy for the shipbreaking industries; this will be a novel contribution for Bangladesh and the countries participating in shipbreaking.

Chapter 2: LITERATURE REVIEW

2.1 BACKGROUND HISTORY OF THE INDUSTRY

Shipbreaking developed an industry in the United States, the United Kingdom, and Japan during World War II as a result of the high volume of war-damaged ships and the subsequent urgent demand for steel (Scott Frey, 2015). The United Kingdom was responsible for half of the shipbreaking business in Scotland in order to run the largest shipbreaking operation in the world (Devault et al., 2017). In the 1960s, it traveled to Spain, Italy, and Turkey, three of Europe's less developed countries (Mearns et al., 2020). In the 1970s, it left Europe for Asia, first settling in Taiwan and South Korea (Siddique et al., 2021). By the 1980s, it had also established itself in China, Bangladesh, India, Pakistan, the Philippines, and Vietnam (Hiremath et al., 2016). Because of vast tidal ranges, soft slopes, and rocky bottom beaches, South Asian countries have been able to benefit from beaching their battleships (Demaria, 2010). This has transformed a highly mechanical enterprise into one that requires a lot of work (Alam & Xiangmin, 2019; Lucia & Iavicoli, 2018). Shipbreaking yards reportedly employ over 100,000 workers around the world. However, in recent years, yards in Asia have recycled ships from 79 different countries (Rights et al., 2002).

Ship recycling in Chittagong began in earnest when the Greek ship M.D. Alpine washed ashore at Fauzdarhat during a storm in the 1960s (Siddiquee et al., 2014). In 1965, it was demolished by Chittagong Steel House. In 1974, Karnafully Metal Works salvaged the Pakistani ship Al Abbas, beached it at Fauzdarhat, and began dismantling it (Hossain et al., 2016). These occurrences highlight the beachgoing potential of the coastline close to Fauzdarhat

(Abdullah et al., 2010). Chittagong's ship recycling sector has weathered both bad and good times, eventually becoming the largest in the world in 2015. More than 18 kilometers of shoreline in the Bhatoary- Fauzdarhat- Baroiyawlia areas are currently used by the ship breaking and recycling industry (SBRI) (Hiremath et al., 2016). After Bangladesh gained its independence in 1980, shipbreaking became a legitimate industry there for the first time. The Prime Minister of Bangladesh recently made the decision to legalize shipbreaking in the country (Muhibbullah, 2013). Only about 65% of the SBRI's registered ship recycling yards (out of a total of 200) are really active at any given time. Providing half of Bangladesh's steel products, the industry employs over 200,000 people directly. An estimated one million people rely on this sector as their main source of income, as stated by (Alam & Faruque, 2014).

However, there is a long list of problems with SBRI. Poor waste management, environmental damage from improper hazardous waste handling, coastal contamination, air pollution, the spread of hazardous materials into the environment, forest destruction, etc. (Scott, 2015) are the primary problems, along with ineffective labor management due to hazardous working conditions for manual laborers, a lack of protective clothing and equipment, the prevalence of manual processes, and a high accident rate. In 2008, the Bangladesh Environmental Lawyers Association (BELA) filed a suit with the High Court on these concerns. As a result, the Bangladesh High Court issued a directive requiring the evacuation of ships carrying potentially dangerous goods prior to their destruction by qualified personnel (Hossain, 2018). It also required the Department of Environment (DoE) to provide Environmental Clearance Certificates (ECCs) to ship recycling yards so that they could import ships, and it required the government to draft regulations to regulate SBRI. In 2010, a ruling from Bangladesh's High Court prohibited the country's government from importing or disassembling ships. When the

Ministry of Industry (MoI) established the Ship Breaking Waste Management Rules later that year, recycling efforts were resumed. As it stands, the SBRI is bound by the Ship Breaking and Ship Recycling Rules 2011 issued by the MoI, the Environmental Protection Act 1995 issued by the MOEF, and the Environmental Protection Rules 1997 issued by the DoE. After implementing these measures, there has been a noticeable uptick in the local yards' commitment to worker and environmental safety (Gregson et al., 2011).

In a 2005 report titled "Sustainability in the Management of Shipbreaking Operations and Their Effects on the Chittagong Coastal Zone, Bangladesh," the Young Professionals in the Solid Waste Industry (YPSA) examined the effects of shipbreaking on aquatic biodiversity, human health, and other resources, as well as its history, national and international status, and the hazardous and toxic substances involved. Studies show that shipbreaking causes pollution in coastal areas by releasing toxic chemicals into the water and soil. The emission of ammonia, spilled burnt oil, floating grease balls, metal rust (iron), and a wide variety of other single-use goods, as well as excessive levels of turbidity in the ocean, are mostly to blame for the problem.

To facilitate the implementation of the MoI, the government of Bangladesh has established a one-stop shop known as the "Ship Building and Ship Recycling Board" (SBSRB). After launching, it will provide integrated services, such as providing required licenses and certificates for shipbreaking, recycling, and other related activities in coordination with other relevant departments and ministries. The DoE was founded in 1989 as the technical arm of the MOEF in order to ensure the lawful implementation of the Environmental Conservation Act of 1995. The Department of Energy (DoE) is working to guarantee environmentally responsible policies in order to reduce pollution. Any ship recycling yards or other industrial units in Bangladesh require an ECC from this specific department before construction can begin. In addition, it offers permits for the handling of hazardous waste generated during ship recycling (Salazar et al., 2015).

The NGO Ship Breaking Platform is an international coalition of groups fighting to prevent abandoned ships from being broken up on the shores of underdeveloped countries. It has been in operation since 2005, and its member companies include ship owners and recyclers from Bangladesh (Hiremath et al., 2016). Public advocacy group BELA has attacked the ship recycling sector for its activities, saying they are destructive to the environment and human rights. In 2009, the Supreme Court of Bangladesh banned all ship recycling activities that did not comply with sufficient environmental regulations in one of its lawsuits. In contrast, the Bangladeshi organization BSBA has been representing ship recyclers and yards since its founding in 2003. This business group is dedicated to advancing environmentally sound ship recycling practices and protecting the legal rights of its members (Scott, 2015).

2.2 THE RECYCLED MATERIALS

The ship makes extensive use of previously existing components. Ship breakers can make a lot of money off of the ferrous and non-ferrous scrap on board, but they can also recoup some of their expenses through the sale of other machinery. Shipbreaking mostly results in the production of iron scrap. Pieces of the ship's steel that need to be reprocessed are sent to the steel company. Re-rolling ferrous scrap into reinforcement bars for low-stress building construction or using it as a melting charge in the manufacturing of steel and iron are common practices, but the former depends on the nature and quality of the scrap.

The ship's propeller, aluminum framework, copper piping, and electrical wire are all examples of non-ferrous metals that are painstakingly separated and sold locally. The typical end users of these products are American shipyards close to shipbreaking yards. Everything from the ship's diesel engines and pumps to its winches and electronic navigational systems falls under this category. The ship's supplies are mostly made out of repurposed materials. Tools, drums, and furniture drums are also available for purchase. Due to the lack of trash recycling facilities, shipbrokers must resort to the most basic of methods when disposing of unwanted goods. Any remaining materials that can't be sold are incinerated.

2.3 THE SHIP RECYCLING INDUSTRY IN CHATTOGRAM

Sitakunda, a coastal location in Bangladesh located to the northwest of Chattogram, had the first beaching activity 40 years ago. Like its Indian counterpart, Alang, it is the largest shipbreaking yard in the world. Nearly forty thousand people are employed by the yards in this area. The majority of workers in the country are migrants from northwest Bangladesh (Pearce, 2020). Mishaps are common and are typically meticulously documented. At more than one death per month on average (shipbreaking BD), 90 workers lost their lives between 2005 and 2012. Another study (The Daily Star, 2016) found that between 2011 and 2015, 53 workers were killed and 78 others were injured at the Chattogram shipbreaking yards. Tank explosions injured five workers in 2014, while gas cylinder explosions injured four, caused five deaths, and injured three more. In addition, three individuals were killed by falling metal plates or cables; three more were killed by falling; two more were killed; and one was injured in mysterious circumstances (Platform, 2010). Data from 2015 indicates 16 deaths and 22 injuries on the job. According to the NGO Shipbreaking Platform, 2016 saw seven fatal accidents and at least four people seriously injured. As reported by The Daily Star (2016), on January 19, 2016, a worker was killed instantaneously when he was hit by an iron plate. Workers in Bangladesh have a median life expectancy of 40 years, 20 years lower than men in Bangladesh generally (Platform, 2010).

There was apparently one incident where a yard owner hid the death of a worker. On July 25, 2013, an accident occurred, but the yard's management declined to cover any associated medical costs. The shipbreaking yard denied the deceased worker's employment and refused to pay his family any damages (Rahman et al., 2019).

Shipbreaking has been damaging the environment in Chattogram since at least the year 2000. Det Norske Veritas collected samples of many different kinds of contamination from the environment, including air, water, sludge, soil, paint, electrical lines, and intertidal zone silt. There was oil found in the ground and in the water. PCBs were found in extremely high concentrations in paint, an electrical cable, and the soil. In the report, it is stated that "asbestos was found and was largely present throughout the shipbreaking yards." Furthermore, "there were no precautions or actions enforced at any level in order to control this substance" (International Law and Policy Institute, 2016). Chattogram ecology has been negatively impacted by shipbreaking for the past 15 years. Chattogram water samples conducted in 2015 "clearly indicated the environmental degradation" (Hossain et al., 2016) due to the shipbreaking yards. In 2010, methods for the responsible management of hazardous waste were described as "virtually non-existent" (Sarraf et al., 2010), indicating that environmental protection at shipbreaking yards is, at best, inadequate. Illegal logging is also a major issue. Mangrove trees are planted to defend coastal communities from cyclones, but in 2014, officials destroyed two yards for illegally cutting them down (Voss et al., 2003).

2.4 SHIPBREAKING AND BANGLADESH'S ENVIRONMENTAL CONSERVATION ACT

There is a wide range in the implementation and enforcement of the many rules governing the shipping and shipbreaking industries. Production of PCBs was halted in the United States and much of Europe between 1978 and 1982.

There is an international movement to ban the use of PCBs, and the Rotterdam and Stockholm Conventions regulate their commerce. Refrigerants and cleaning solutions often include chlorofluorocarbons (CFCs), another prevalent source of harm. An international treaty restricting the use of CFCs and other substances that damage the ozone layer has been in effect since 1987. Once ratified by at least 25 countries that represent at least 25% of global merchant tonnage, a newly defined international treaty prohibiting the use of harmful drugs like TBT will enter into force (Ref). However, in Europe, anti-fouling measures must adhere to Regulation 782/2003.

The Bangladesh Environment Conservation Act of 1995 is still the country's primary environmental law, with the stated goals of protecting and improving environmental standards and decreasing environmental pollution. Shipbreaking is a targeted industry under Section 6(D) of the Act. Shipowners, importers, and anyone who uses shipbreaking yards must comply with regulations aimed at preventing environmental and human health hazards caused by the release of hazardous waste during the scrapping process. If there is an excessive discharge of environmental pollutants, the party at fault and the person in charge of the incident site must take measures to limit or mitigate the pollution as outlined in Section 9. Every industry, including shipbreaking, is required to get an "Environmental Clearance Certificate" from the Department of the Environment, Ministry of the Environment, per a requirement of the Environmental Law of 1995. The Bangladesh Environment Conservation Act of 1995 is still the country's primary environmental law, with the stated goals of protecting and improving environmental standards and decreasing environmental pollution. Shipbreaking is a targeted industry under Section 6(D) of the Act. It requires ship importers, ship owners, and shipbreaking yards to prevent the release of hazardous waste during scrapping to protect local communities and marine ecosystems. If there is an excessive discharge of environmental pollutants, the party at fault and the person in charge of the incident site must take measures to limit or mitigate the pollution as outlined in Section 9. The Environmental Law of 1995 mandates that all industries, including shipbreaking, obtain an "Environmental Clearance Certificate" from the Department of the Environment, Ministry of Forest and Environment. An EMP (Environmental Management Plan) has to be developed by the shipbreaker to achieve this goal. The government has the authority to adopt environmental legislation under Section 13 that deals with the prevention, reduction, and remediation of environmental contamination. The most recent development is the 2011 publication of the "Ship Breaking and Recycling Rules" by the Ministry of Industry. However, due to a lack of political will, these rules are still just recommendations rather than actual law. According to the Ship Breaking and Recycling Rules, 2011 (Alam & Faruque, 2014), the Ship Building and Ship Recycling Board (SBSRB) is a one-stop service under the Ministry of Industry that incorporates all necessary procedures and permissions while collaborating with other relevant departments and ministries (Jannat et al., 2023).

Chapter 3: METHODOLOGY

3.1 INTRODUCTION

Every study consists of a sequence of tasks whose logical and practical connections enable research to be viable in terms of outcomes and cost- and time-effectiveness. The methodology of a study, thus, includes the methods, instruments, and processes used to conduct a certain study or research in order to attain a predetermined set of objectives. This chapter will give an overview of the study's approach, equipment, and methods. Along with warnings, it will also detail how to gather samples.

This study has chosen the following methodology, which is listed below:

3.1.1 Topic Selection

Globally and particularly in emerging nations like Bangladesh, India, and Pakistan, shipbreaking is a significant industry. However, Bangladesh is increasingly overtaking India as the leading nation for shipbreaking. The shipbreaking and recycling rules from 2011 in Bangladesh state that the activity is now regarded as a sector of the economy. Both the local economy and the national economy depend heavily on the industry. The entire amount of steel used in our nation is 5 million metric tons (MT), although only 2.5 million MT of steel is produced, with up to 1.5 million MT (30% of total consumption) coming from ship recycling yards (source: World Bank statistics, Dhaka office, September 2010). A total of 1 lac jobs and 50,000 direct jobs are also provided by the industry. Through import duties, yard taxes, and other taxes, the government receives 1000,000,000 Taka in revenue each year from the shipbreaking sector (YPSA, 2012). The sector does, however, have some negative effects on the environment and worker health. However, only a few studies on this subject have been done to date. Thus, we chose "Impact of Ship Breaking Industry on Environmental Pollution Condition of Bangladesh: A Case Study of Sitakunda Ship Breaking Yard, Chittagong" as our thesis topic, which is undoubtedly difficult work for us.

3.1.2 Fixation of Study Area

Once the topic and study areas have been chosen, the study's goal and objectives have been established. The Bhatiary, Kadamrasul, Joramtal, Shitolpur, and Kumirar Ship Breaking Yard study areas are located in Sitakunda, Chattogram. To "identify the environmental and socioeconomic impact of the shipbreaking industry in Sitakunda, Chattogram, and provide some guidelines for sustainable shipbreaking activities," according to the study's objectives.

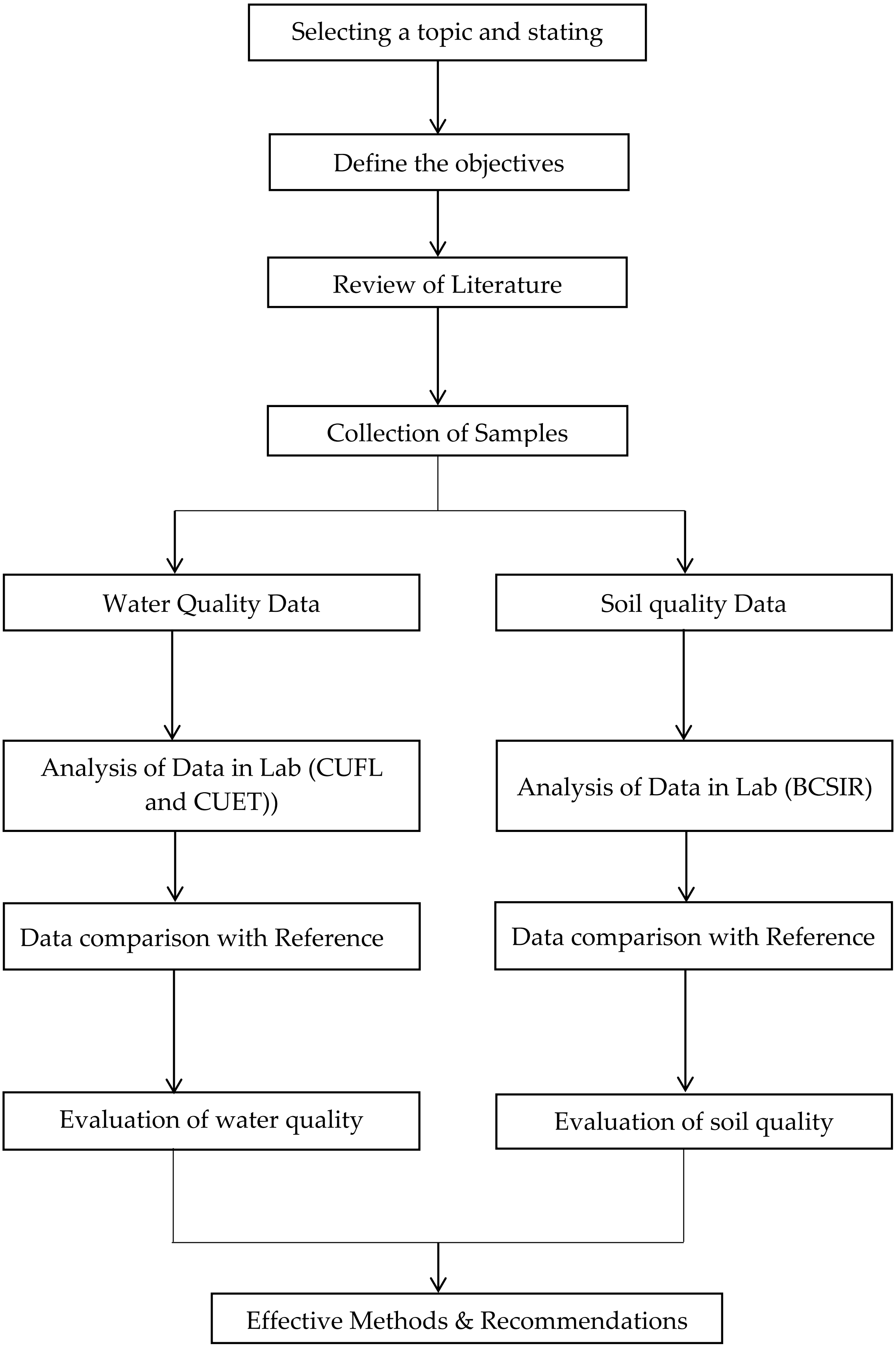

Figure 3.1 Flowchart of this study.

3.2 MATERIALS

Analytical research-grade chemicals are collected from different scientific stores in Bangladesh.

3.3 SAMPLING

Samples were collected using statistical sampling techniques. The important elements for any sampling program are

- the frequency of sample collection,
- the total number of samples,
- the size of the sample,
- the locations where the sample collection will take place,
- the method of sample collection,
- the data to be collected with each sample, and
- the transportation and handling of the samples before analysis.

3.3.1 Types of Samples

Three main types of sample methodologies are used for natural and wastewater analysis:

a. **Grab samples**: Grab samples are one-time collections made during a brief period of time (usually a few seconds or minutes) at a specified location on a site. They thus serve as a spatial and temporal snapshot of a sample region (APHA, 2017).

b. **Composite samples**: Composite samples need to offer a more accurate representation of heterogeneous matrices, where the concentration of the relevant analyzers may fluctuate over brief intervals of time and/or place (APHA, 2017).

c. **Integrated (discharge-weighed) samples**: It is advantageous to analyze combinations of grab samples acquired from several sites simultaneously, or as nearly simultaneously as feasible, employing discharge-weighted methods (such as equal-width increment) for some applications (APHA, 2017).

One could argue that analyzing several diverse samples collected at various times and locations are more insightful than finishing and analyzing a single representative sample. Grab sampling was used in this study to get samples for the DO, and composite samples were used for the other parameters.

3.4 COLLECTION OF SAMPLES

According to APHA, BS, and Bangladesh Standards, surface water and soil samples from the shipbreaking yard's various locations were gathered for examination. In (Figure 3.2) the complete sampling locations are displayed.

3.5 LOCATION OF THE STUDY AREA

The Shipbreaking Yard in Chattogram, the second-largest shipbreaking hub in the world, is confined to an area of 18 km^2 extending along Sitakund Upazilla's coastline, particularly from Bhatiary to Kumira inside the Chattogram district, which is in Bangladesh's southeast. This district is where the majority of the shipbreaking or ship recycling industry sectors is found. Shipbreaking is now a method of ship waste in which ships are dismantled for recycling into scrap, with the bodies being dumped at ship graveyards. When ships are demolished, a variety of reusable and disposable items are released and filled, and these materials frequently mingle with the sand and water on the beach. The industry produced a wide range of soluble and insoluble water wastes when dismantling the ships, which collected over the soil first, moved progressively to the coastal region, sub-tidal zone, and eventually to the deep saltwater and into the corresponding soil. The research region is located outside of the city of Chattogram between latitudes 22°48′78″N and longitudes 91°70′26″E. The sampling points' locations were as follows:

Yard-1 (Latitudes: 22°24′ 05″ N and Longitudes: 91°44′45″ E),

Yard-2 (Latitudes: 22°25′31″ N and Longitudes: 91°44′18″ E),

Yard-3 (Latitudes: 22°26′15″ N and Longitudes: 91°43′58″ E),

Yard-4 (Latitudes: 22°26′42″ N and Longitudes: 91°43′52″ E),

Yard-5 (Latitudes: 22°27′58″ N and Longitudes: 91°43′23″ E), and

Yard-6 (Latitudes: 22°29′31″N and Longitudes: 91°42′21″E).

3.5.1 Water Sampling

About 1 liter of water using plastic containers with a pair of stoppers was randomly gathered from the area to be tested for water quality. The bottles were cleaned, rinsed, and treated using 5% HNO_3 for an overnight period prior to sampling. After drying, deionized water was used to rinse the bottles. The bottles were carefully screwed after sampling, and the corresponding identification number was written on them. All water samples had their collection sites tested for temperature, pH, EC, and TDS. Again BOD, COD, DO, TSS, Salinity, Total Hardness, and Turbidity were measured at the laboratory of Chattogram Uria Fertilizer Limited (CUFL); heavy metals were studied at the Institute's BCSIR (Bangladesh Council of Scientific and Industrial Research) Laboratories in Chattogram, Bangladesh, and by the Department of Chemistry, Chittagong University of Engineering & Technology (CUET).

3.5.2 Soil Sampling

A mobile for sample collection An Ekman grab sampler was utilized in the coastal surface soil at a thickness of 0 to 5 cm. Three composite samples totaling roughly 200 g were collected at each station. In the field, mixed soil samples were gathered into airtight polyethylene bags, which were then taken to the lab for pre-treatment. In order to reach a uniform weight, the samples have been dried and heated for 48 hours at 45°C in the oven. After being dried, samples were broken up with a mortar and pestle, sieved through 106 micrometers, and then placed in high-density polyethylene (HDPE) bottles with labels to be kept due to chemical examination. The complete set of processed samples was delivered to the BCSIR (Bangladesh Council of Scientific and Industrial Research) Laboratories in Chattogram, Bangladesh.

3.6 GEOGRAPHICAL DETAILS OF THE RESEARCH AREA

The world's greatest industry for shipbreaking is located in Sitakunda, which is predominantly an agricultural region (Sarraf et al., 2010). There is a ship-breaking facility at Sitakunda Upazila. For example, by contaminating soil, it has been accused of causing environmental harm. The ecosystems of the Sitakunda are at risk from biodiversity loss, overfishing, and water pollution. Natural calamities, including earthquakes, hurricanes, and storm surges, pose a threat to the Upazila. It is situated near the Sitakunda-Teknaf earthquake, the fault in Bangladesh with the most seismic activity.

The geomorphological layout of Sitakunda, which would be 70 kimlometers (43 miles) large and 10 kimlometers (6 miles) large and is among the Chattogram Hill Tracts' westernmost systems in Bangladesh, is defined as north of the Feni River, within the south the Karnaphuli River, within the east the Halda River, and the Sandwip Channel towards the west as well (Ali et al., 2022). The Sandwip Channel and the Halda Valley are separated from one another by the Sitakunda Range. The Halda is one of the six banks of the Karnafuli, the same principal river in the region, and it flows approximately 88 kilometers (55 miles) through Khagrachari to the Gulf of Bengal (Ali et al., 2022). The Sandwip Channel turns up the northern terminus of the Chattogram-Tripura Folded Belt (Islam et al., 2018).

Figure 3.2 Map of the study area (ship Breaking Yard, Sitakunda, Chattogram, Bangladesh).

The formation is a complex geographical history of stone, gas, and sandstone. Moreover, because the Chattogram Hill Tracts are located between Chattogram, there is little difference in the general lithology of the exposed layers of sandstone, which are 6500 meters (21,325 feet) thick and devoid of limestone. The length of the Sitakunda fold is an irregular double plunge anticline container. Both the anticline's higher western slope and gently declining eastern slope are abruptly terminated by the Feni River alluvial plain. This anthill is one of the least frequently investigated structures in Bangladesh due to a lack of infrastructure. A syncline separates the Feni Structure's eastern end from Sitakunda, which is located on the folding bank of the Bengal Region.

Along the Gulf of Bengal coast, the entire study area is situated. Ships are being disassembled along the coastline. As a result, the coastal Bay of Bengal is exposed to chemicals, industrial effluent, and other hazardous materials. On the beach, oil remnants and other trash spills occur and are mixed with the water and soil; however, it is unknown what will happen to the oil released into the coastal waters. A significant problem is how to dispose of the liquid waste that is produced by the various parts of the dyeing and finishing facilities. Another major problem with the finishing and dyeing procedures is the disposal of liquid waste, which raises the danger of hazardous pollution of the environment by metals. Among the most frequent causes of liquid release is floor cleaning. The majority of the wastewater from the source is made up of chemicals like oil and many other instrumental chemicals like salts, acids, paints, caustic agents, and some others, as was previously noted. It has been observed that in the majority of currently operating shipbreaking operations, oil loss is substantial (often around 20%) as a result of the technological process's insufficient maintenance and operation, leading to a toxicity level or water stream with color.

A few potential sources of polychlorinated biphenyl are bilge or ballast water, paint and coating, different ship equipment, high-capacity cathode lights with glass, laptops, freons, radios, TV apparatus, and plates with coatings. Hazardous substances like Fe, As, Cr, Cd, Pb, and Hg, among others, are connected to the shipbreaking industry. Particle hydrocarbons like carbon monoxide are generally regarded as causing more serious problems than nitrogen compounds because of the significance of hydrocarbons in the formation of smog. As a result, combustion efficiency is a factor in boiler emissions and can be decreased by employing boiler equipment that is well-designed. Condensed steam, stagnant, dirty water, and other liquids, such as valve and piping leaks that let the operational conditions of the ship be drained, make up bilge water.

3.7 ANALYSIS OF WATER QUALITY

Analyzing the quality of water involves assessing its physical, chemical, biological, and radiological properties for drinking, leisure, business, and ecological uses. For the protection of the environment and human health while upholding rules and standards, regular monitoring is essential. Visual observations, turbidity, chemical analysis, biological markers, microbiological analysis, and radiological analysis are important components.

3.7.1 Determination of the Heavy Metal Pollution Index

The level of water pollution was assessed for its fitness for human consumption, with a critical score of 100 applied to cases of contamination with heavy metals in drinking water. To determine the caliber of river water, the following formula was employed to determine the water pollution index (Venkata et al., 2008):

Heavy metal pollution Index formula constitute of two different parts:

1. Units Weight
2. Sub-Indwx Value

(1) Units Weight (Wi)

$$Wi\alpha\frac{1}{Si} \quad , \qquad (3.1)$$

$$Wi = \frac{K}{Si} \quad , \qquad (3.2)$$

Where,

K= Constant

Si= standard permissible limit value of the ith parameters

(2) Sub-Index Value (Qi) of the parameters is calculated by the following formula

$$Qi = \sum_{i=1}^{n} \frac{|Mi - Ii|}{(Si - Ii)} \times 100, \qquad (3.3)$$

Where,

Mi= Monitored Value of heavy metals of the i^{th} parameters

Ii= Ideal value of the i^{th} parameters

Si= Standard value of the i^{th}

$$HPI = \frac{\sum_{i=1}^{n} WiQi}{\sum_{i=1}^{n} Wi}, \qquad (3.4)$$

Where, Wi stands Unit weight of the ith parameters, Qi is the Sub-Index value of the parameters. Pb, As, Cr, and Cd each have tolerable limits of 0.01 (mg/L), 0.01 (mg/L), 0.05 (mg/L), and 0.003 (mg/L) respectively, according to (WHO, 2011).

3.8 SOIL QUALITY ASSESSMENT

Studies in the literature have suggested that the concentration of hazardous metals in soil and coastal sediment is higher than their background levels (Chandrasekaran et al., 2020; Pellinen et al., 2021). The calculation of the Geo-accumulation index (I_{geo}), the contamination factor (CF), the pollution load index (PLI), the enrichment factor (EF), and the potential ecological risk index was used to determine the level of heavy metal contamination (Zhang et al., 2017).

3.8.1 Determination of the Geo-accumulation Index

At six locations in the shipbreaking yard of Sitakund Upazila, Chattogram, the geo-accumulation index (I_{geo}) for hazardous metal pollution in aquatic soil was calculated using (Hasan et al., 2020; Hasan et al., 2013) formulation as well as regional backgrounds accessible for this area (Ahmed et al., 2022; Angelidis et al., 1995). I_{geo}, a device for measuring the extent of environmental contamination from hazardous metals, was originally described (Kusin et al., 2018). The I_{geo} value can be calculated using the equation below:

$$Igeo = \log 2\left[\frac{Cn}{1.5\,Bn}\right] \quad (3.5)$$

Where, Cn denotes the concentration of metal and Bn denotes the geochemical background metal concentration. An adjustment to the background matrix called factor 1.5 was made to lessen the impact of any potential changes in the reference values brought on by lithogenic processes. The I_{geo} value was used to classify the soil quality into seven categories, (Table 3.1).

Table 3.1. Classification of the geo-accumulation index

***Igeo* value**	**Class**	**Quality of soil**
<0	0	Unpolluted
0-1	1	Unpolluted to moderately polluted
1-2	2	Moderately polluted
2-3	3	Moderately to strongly polluted
3-4	4	Strongly polluted
4-5	5	Strongly to extremely polluted
>5	6	Extremely polluted

3.8.2 Determination of the Pollution Load Index and Contamination Factor

In order to determine soil quality, (Islam et al., 2015) developed a combination of methods using the index of pollutant load, such as (4) materials. The factor for metal contamination (CF) is the multiplier of the amount of time it has increased in number, and the result is the nth root, which is the definition of the Pollution Load Index (PLI).

$$CF = \frac{C_{metal}}{C_{background}} \quad (3.6)$$

Where, C_{metal} is the concentration of metal (mg/kg) in the sediment sample and $C_{background}$ is the background concentration of the metal (mg/kg).

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \ldots \times CF_n)^{\frac{1}{n}} \quad (3.7)$$

Where n is the number of pollutants analyzed and CF_1, CF_2, CF_3,...,CF_n are the contamination factors for each pollutant. In sediment, CF value represent the proportion compared to the level of each metal with the respective value for the background and the PLI value for the overall contamination status (Islam et al., 2021).

As, Cd, Cr, and Pb had background values of 14, 0.4, 95, and 25 mg/kg in average shale, respectively. A PLI score of 0 represents exceptional performance; a value of one implies that only baseline pollutants are present, as well as a number higher than one indicates deteriorating site or estuary value (Abrahim & Parker, 2008). A PLI evaluated a sample's overall toxic effect, as which another product each contribution made by the four metals. For tracking single metal pollution through time, the 4th grade categorization of the relationship between measurable concentration and the prevalence of a certain metal in nature was thought to represent the contamination factor (CF) (Islam et al., 2015): low degree ($CF < 1$), moderate degree ($1 \leq CF < 3$), considerable degree ($3 \leq CF < 6$), and very high degree ($CF \geq 6$). Hence, one can utilize CF values to monitor the gradual enrichment of a particular soil with metal.

Table 3.2. Classification of the Contamination Factor

Contamination Factor	Level of Contamination
Cf < 1	low contamination
1 Cf < 3	moderate contamination
3 Cf < 6	considerable contamination
Cf > 6	very high contamination

3.8.3 Determination of the Enrichment Factor of the Soil Samples Analysis

The enrichment factor (EF) is frequently used to distinguish between metals from natural and artificial sources. When comparing the level of metal pollution to the environment at large, the EF was utilized to make this determination. To determine whether a soil sample's metal content has enriched relative to the sample's surrounding environment, the concentrations of the sample metals are first normalized to proper materials (such as iron or aluminum) for data normalization purposes (Aprile & Bouvy, 2008). Iron (Fe) is usually used as the normalizing element to calculate EF values since it is a dominant trace metal absorbent stage and a quasi-conservative trace of the metal-bearing stages that naturally occur in the river and coastal soil (Giri & Singh, 2015). This means that EF may be computed as the proportion of the sample metal's concentration to the reference metal's concentration in iron, and it can be written as follows:

$$EF = \frac{Cn}{CR} \qquad (3.8)$$

where C_n is the concentration of metal (mg/kg) and C_R is the reference metal concentration (mg/kg)

Where, EF value indicates the proportion between the balanced metal concentration (C_n) and the reference metal concentration (C_R), which was reconstructed. Although it has been proposed that regional background values would be more appropriate, average crustal occurrence data can be utilized to choose reference metal values (Hu et al., 2013). Whereas EF levels of several orders suggest elements of anthropogenic origin, EF values of approximately unity denote elements that are naturally produced.

Table 3.3. Metal contamination based on seven classes of enrichment factor

EF value	Designation of soil quality
< 1	No enrichment
1-3	Minor enrichment
3-5	Moderate enrichment
5-10	Moderately severe enrichment
10-25	Severe enrichment
25-50	Very severe enrichment
> 50	Extremely severe enrichment

3.8.4 Determination of the Potential Ecological Risk Index

To quantify the degree of soil heavy metal contamination in connection to metal toxicity and the impact on the environment, (Tomlinson et al., 1980a) first created the Potential Ecological Risk Index (RI).Toxic metals' impact on the environment could be thoroughly assessed by RI. The following is a list of the RI calculation methods:

$$F_i = C_n^i / C_o^i \quad (3.9)$$

$$E_r^i = T_r^i \times F_i \quad (3.10)$$

$$RI = \sum_{i=1}^{n} = Ei \quad (3.11)$$

Where, Fi stands for the indicator of single metal contamination; C_n^i stands for a concentration of metal in the samples; C_o^i is the metal's background value. E_r^i Is one-sided ecological risk indicator; T_r^i is a component referred to as the metal toxic reaction. RI is the possible ecological risk resulting from pollution as a whole. Following are the four RI categories and five E_r^i categories:

Table 3.4. Potential ecological risk index

E_r^i Value	Grades of ecological risk	RI value	Grades of the environment
E_r^i < 40	Low risk	RI <110	Low risk
40 ≤ E_r^i <80	Moderate risk	110 ≤ RI < 200	Moderate
80≤ E_r^i <160	Considerable risk	200 ≤ RI < 400	Considerable risk
160 ≤ E_r^i <320	High risk	400 ≤ RI	Very high risk
320 ≤ E_r^i	Very high risk		

3.9 COASTAL WATER AND SOIL QUALITY TEST ANALYSIS AND PROCEDURES

Testing the quality of coastal water and soil is essential for understanding the state of coastal ecosystems. Researchers, environmentalists, and policymakers can better understand the effects of human activities on coastal environments and implement conservation and management practices thanks to the results of these tests. There is a specific set of scientific methodologies and measures that are used to determine the quality of coastal water and soil.

3.9.1 Parameters

The physical (Temperature, Electrical Conductivity, Salinity, Turbidity, TDS, and TSS, among other parameters) and chemical (pH, hardness, as well as concentrations of DO, BOD_5, and heavy metals like As, Cd, Cr, and Pb) water parameters that will be covered in this analysis for the research are listed below. Among the soil parameters are As, Cr, Cd, and Pb.

3.9.2 Analysis

Following established analytical procedures, water samples were sent to the Department of Chemistry at CUET or to the laboratory of Chattogram Uria Fertilizer Limited (CUFL), Anwara, Chattogram, as soon as they were collected. Soil testing was done in the labs of the Bangladesh Council of Scientific and Industrial Research (SCSIR) in Chattogram, Bangladesh. When water is sampled from study sites, temperature, pH, and DO will be measured. Data will be gathered via surveys, focus groups, key informant interviews, and direct observations to determine the sources and scenario of the contamination. Based on the advice of the appropriate resource person, the survey will be designed.

3.10 INSTRUMENTATION AND PROCEDURE

Proper instrumentation and systematic procedures are crucial for accurate data collection and reliable results in scientific research, and other fields.

3.10.1 Water Temperature

Instrument: IR thermometer or mercury-based thermometer.

Procedure:

The following procedures are used to measure temperature:

1) A beaker is first cleaned with distilled water.
2) A thermometer is inserted in the sample containing beaker.
3) The thermometer is read to determine the sample's temperature after around two and a half minutes.

3.10.2 pH

Instrument: Digital pH meters, pHep® Pocket-sized pH meters, and HACH sension™ 378 Multipara meter Meters are used to monitor pH.

Procedure: The following procedures are used to measure pH:

1. At first, the safety cap is taken off, and the meter is turned on.
2. The device is standardized at room temperature against a known buffer solution.
3. The electrodes are removed from the buffer solution following standardization.

4. The electrodes are cleaned with distilled water and then carefully and completely wiped with soft tissue paper.
5. The electrode is then placed on a 250 mL beaker that has 200 mL of sample in it.
6. On the keypad, the pH key is depressed. The pH value was then displayed by the device.
7. As soon as the readings stabilize, it is recorded in the logbook.

Figure 3.3 Pocket-sized pH meter by pHep ML0664

3.10.3 Electric Conductance

Instrument: Blackman conductivity meters, with a range of 0-1000 mhos/cm, or HACH® sension™378 multi-parameters are used to test conductivity.

Procedure: The following procedures are used to measure Conductivity:

1. At first, the safety cap is taken off, and the meter is turned on.
2. The electrode and the equipment are standardized at room temperature using a known buffer solution.
3. The electrode is removed from the buffer solution after standardization.
4. The electrode is cleaned with distilled water before being carefully and thoroughly wiped with soft tissue paper.
5. The electrode is then placed on a 250 mL beaker that has 200 mL of sample in it.

6. On the keypad, the conductivity key is depressed. When the conductivity value is reached, the instrument is then displayed.
7. It is recorded in the logbook as soon as the values stabilize.

Figure 3.4 Digital TDS and EC meter

3.10.4 Total Dissolved Solids

Instrumentation: The HACH® sension™ 378 multi parameters or TDS meter is used to measure total dissolvent solids (TDS).

Procedure: The following procedures are used to measure TDS:

1. At first, the protective cap of TDS meter is removed.
2. The apparatus and electrode are standardised at room temperature using a known buffer solution.
3. The electrode is removed from the buffer solution after standardisation.
4. The electrode is cleaned with distilled water before being carefully and thoroughly wiped with soft tissue paper.
5. The electeode is then placed on 200 mL of the sample, which has been poured into a 250 mL beaker.
6. On the keypad, the TDS key is depressed.
7. The instrument is then presented along with the TDS reading.

8. It is recorded in the logbook as soon as the values stabilize.

3.10.5 Dissolved Oxygen

Instrument: The HACH® Sension™378 or Azide Modification Method of Winkler, APHA 1995 is used to quantify DO.

Procedure: The following procedures are used to measure DO:

1. At first, the protective cap of meter is removed to turn on the meter.
2. After that, the instrument and electrode are compared to a known buffer solution at room temperature.
3. The electrode is taken out of the buffer solution following standardization.
4. The electrodes are properly and meticulously cleaned with soft tissue paper after being washed in a jar of distilled water.
5. The electrode is then placed on the 200 mL of the sample that has been poured into a 250 mL beaker.
6. The DO key on the keypad is depressed.
7. The instrument is then presented in relation to the DO value.
8. As soon as the readings stabilize, it is recorded in the logbook.

Figure 3.5 Digital DO and BOD meter

3.10.6 Biological Oxygen Demand

According to APHA, AWWA, and WPCF's 1998 analysis of biological oxygen demand

Apparatus: The HACH® sension™378 or Azide Modification Method of Winkler, APHA 1995 is used to quantify BOD.

Instrument: BOD bottles, a BOD incubator, and a DO meter

Procedure: Following the initial DO measurement, samples of water were placed in BOD bottles and then incubated at 20°C for five days in a dark area to calculate the biochemical oxygen demand.

Calculation: $BOD_5(mg/L) = (DO)_0 – (DO)_5$

Where, $(DO)_0$ = initial DO

$(DO)_5$ = DO after five days

3.10.7 Chemical oxygen demand

Analysis of COD was performed according to APHA-AWWA-WPCF, 1998 standards.

Materials/reagents:

01. COD reflux unit with a flat-bottomed flask with a ground glass mouth (250 mL) and a Liebig (straight tube, single surface) condenser (30 cm).

02. Heating mantle or hot water bath.

03. Sulphuric acid silver sulfate solution: Sulphuric acid silver sulphate solution was made by mixing 10g of $AgSO_4$ powder with 1000 mL of concentrated H_2SO_4. This solution was made 2 days before the study.

04. 0.025 N Standard solutions of potassium dichromate ($K_2Cr_2O_7$) were made. The sample was dried in an oven at 103°C for 2 hours,

and 2.259g was put in a 1000 mL volumetric flask. Distilled water was added to make the amount equal to the mark.

05. Ferroin indicator solution: To make Ferroin indicator solution, 1.485g of O-phenantholine ($C_{12}H_8N.H_2O$) and 0.695g of $FeSO_4.7H_2O$ were dissolved in water and then diluted to 100 mL.

06. Ferrous sulfate crystals ($FeSO_4.7H_2O$) were dissolved in distilled water in a 100 mL volumetric flask and the amount was brought up to the mark.

07. Standard 0.25 N ferrous ammonium sulfate: 98g of Fe $(NH_4)_3(SO_4)_2$. $6H_2O$ were dissolved in 98g of pure water. Then 20 mL of concentrated H_2SO_4 was added to the mixture. After letting it cool, the amount was brought up to the mark with distilled water. This solution was measured against potassium dichromate on the day of measurement.

08. Standardization of ferrous ammonium sulfate (FAS) solution: Exactly 10 mL of Standard $K_2Cr_2O_7$ solution was pipetted into a 250 mL conical flask. The amount was brought up to 100 mL with distilled water, and 30 mL of concentrated H_2SO_4 was added and cooled. With the substance, 3–4 drops of ferroin indicator were added and titrated against ferrous ammonium sulphate until the colour changed to a wine red.

09. Thus normally of Ferrous Ammonium Sulfate = 10 x normality of $K_2Cr_2O_7$ x volume (mL) of $Fe(NH_4)_2(SO_4)_2$ were added.

Procedure:

01. In a 500 mL refluxing flask, 50 mL of sample water, 1g of $HgSO_4$, and a few boiling chips were put in. Very slowly, 5 mL of sulfuric

acid solution was added while shaking the flask to dissolve the $HgSO_4$.

02. Then 25 mL of 0.025 N $K_2Cr_2O_7$ Solution was added and mixed.

03. The flask was hooked up to a condenser, which ran water through it to cool it down. Then, the 70 mL of sulfuric acid that was left was put through the condenser's open end. The sulfuric acid was added while the mixture was still being stirred and swirled.

04. Distilled water was put over the open end of the condenser.

05. The solution was cooled to room temperature and then titrated against $K_2Cr_2O_7$ with FAS and 2-3 drops of ferroin indicator.

Calculation: COD (mg/L) = (A-B) x N x 800/a

Where, a = Volume (mL) of sample taking in a bottle.

A= Volume (mL) of Fe $(NH_4)_2(SO_4)_2$ used for blank.

B= Volume (mL) of Fe $(NH_4)_2(SO_4)_2$

8000= Equation factor

N= Normality of Ferrous Ammonium Sulphate.

3.10.8 Total Suspended Solids

The analysis of Total Suspended Solids follows APHA-AWWA-WPCF, 1998.

Apparatus:

01. Whatman filter paper, 70 mm.
02. Conical flask.
03. Funnel
04. Drying in oven at $105^0 \pm 1\ ^oC$.
05. Desiccators provided with a desicant
06. Analytical Balance capable of weighing up to 0.1 mg.

Procedure:

01. The filter paper is numbered before being dried in an oven at $105^0 \pm 1\ ^oC$. After cooling in desiccators for roughly an hour, they were weighed.
02. The material is then filtered using a funnel.
03. The filter paper is once more weighted following titration.

Calculation:

Total Suspended Solid (mg/L) = (x-y) x 10^6/V

Where, x = wt of dried sample + dish

y = wt. of empty dish in g

V = volume of sample in mL

3.10.9 Turbidity

The idea at play is the particle scattering of the suspended particles remaining in the water samples as they pass through light from the bulbs built within the turbidity meter.

Instrument: With the aid of a Lovibond turbidity meter, turbidity may be measured between 0.00 and 1000 NTU.

Procedure:

01. At first, the electrical connection turned on the turbidity instrument.
02. After vigorous shaking, the sample is inserted into the turbidity meter's cell holder.
03. The knob is cranked and positioned correctly to bring the volume within the acceptable range, and the digital result is flushed into the turbidity meter's flashing region.
04. The outcome is then noted.

3.10.10 Salinity

Instrument: Salinity was measured with the HACH® sension™378 Multiparameter Meter.

Procedure:

The following procedures are used to measure Salinity:

01. After removing the protective cap, the meter was turned on.
02. At room temperature, the equipment and electrode were standardized against a known buffer solution.
03. The electrode was removed from the buffer solution when standardization was complete.
04. The electrode was gently and completely cleaned with soft tissue paper after being washed with distilled water.
05. The electrode was then placed on the 200 mL of sample that had been poured into the 250 mL beaker.
06. The keypad was pressed on the salinity key. The gadget then showed the salinity reading.
07. It was recorded in the logbook as soon as the readings stabilized.

Figure 3.6 Digital Salinity meter

3.10.11 Oil and Grease

Apparatus:

1. Separating funnel,
2. Beaker,
3. Measuring cylinder,
4. Funnel.

Reagent: Petroleum Ether (40^o– 60^o) C, Conc. HCl, Methyl orange indicator.

Procedure:

01. At first 150 mL of the sample is taken in the separating funnel.
02. Then 2 to 3 mL of concentrated HCl and 30 mL of petroleum ether solvent were added.
03. A couple of drops of indicator methyl orange are added.
04. Puted a stopper on the separating funnel and give it a good shake.
05. Released the gas produced when HCl reacts concurrently with metals and organic materials.
06. Waited until there is a clear separation of the two layers (organic and aqueous phases).
07. Removed the aqueous layer.
08. To get rid of any excess acid, washed with distilled water.
09. Utilized the methyl orange indicator to test. Filter the organic solvent comprising oil and grease using standard filter paper through a funnel containing 10 g of previously moistened solvent-containing Na_2SO_4.
10. In a beaker that has already been weighted, collected the filtrate.
11. Kept it in a hot water bath to help the solvent evaporate.
12. Weigh once the beaker has cooled.
13. Calculated the difference between the final weighed beaker and the empty beaker.
14. Measured the appropriate amount of oil and grease.

Calculations:

Oil and Grease in ppm = (A-B) x10^6/mL of sample taken.

3.10.12 Arsenic

Instrument: Arsenic (As) was measured using spectrophotometer (Model DR/4000 by HACH)

Reagent: As test reagents (e.g., Hach As Test Kit)

Procedure:

1. At first, turn on the Hach DR/4000 spectrophotometer and allow it to warm up if necessary.
2. Set the wavelength to the appropriate value for the As analysis. As is typically measured at a specific wavelength (λ), 660 nm, so ensure that the instrument is set to this wavelength.
3. A cell was filled with 10 mL of sample.
4. The content of one As test reagents (e.g., Hach As Test Kit) was added to the sample cell (the prepared sample).
5. The cell was swirled to mix
6. After pressing the soft key under START TIMER in a few minute reaction periods start.
7. Another sample cell (the blank) was filled with 10 mL of sample.
8. When the timer beeped, the blank was placed into cell holder and closed the light shield.
9. After pressing the soft key under Zero the display showed: 0.000 mg/L As.

10. Within 30 minutes after the timer beeped, the prepared sample was placed into the holder and closed the light shield. The result in mg/L As was displayed.

3.10.13 Cadmium

Instrument: Cadmium was measured using spectrophotometer (Model DR/4000 by HACH)

Reagent: Dithi Ver Metals Reagent powder pillow

Procedure:

1. After pressing the soft key under HACH PROGRAM the stored program number for Cd was selected by pressing 1350 with the numeric keys.
2. After pressing ENTER the display will show HACH PROGRAM: 1350 Cd, the wavelength (λ) 515 nm was automatically selected.
3. A cell was filled with 10 mL of sample.
4. The contents of one Dithi Ver Metals Reagent powder pillow was added to the sample cell (the prepared sample).
5. The cell was swirled to mix
6. After pressing the soft key under START TIMER a-2 minute reaction period start.
7. Another sample cell (the blank) was filled with 10 mL of sample.
8. When the timer beeped, the blank was placed into cell holder and closed the light shield.
9. After pressing the soft key under Zero the display showed: 0.000 mg/L Cd.

10. Within 30 minutes after the timer beeped, the prepared sample was placed into the holder and closed the light shield. The result in mg/L Cd was displayed.

3.10.14 Lead

Instrument: Lead was measured using spectrophotometer (Model DR/4000 by HACH)

Reagent: Pb standard solution

Procedure:

1. At first, turn on the HACH DR/4000 spectrophotometer and allow it to warm up according to the manufacturer's instructions.
2. Ensured the instrument is properly calibrated for the wavelength (λ), 520 nm uses for Pb analysis.
3. A cell was filled with 10 mL of sample.
4. The content of one Pb standard solution was added to the sample cell (the prepared sample).
5. The cell was swirled to mix
6. After pressing the soft key under START TIMER in a few minute reaction periods start.
7. Another sample cell (the blank) was filled with 10 mL of sample.
8. When the timer beeped, the blank was placed into cell holder and closed the light shield.
9. After pressing the soft key under Zero the display showed: 0.000 mg/L Pb.

10. Within 30 minutes after the timer beeped, the prepared sample was placed into the holder and closed the light shield. The result in mg/L Pb was displayed.

3.10.15 Chromium

Instrument: Chromium (Cr^{6+}) was measured using spectrophotometer (Model DR/4000 by HACH)

Reagent: Chroma Ver-3 (1,5-DIPHENYLCARBOHYDRAZIDE) POWDER PILLOW.

Procedure:

1. After pressing the soft key under HACH PROGRAM. The stored program number for hexavalent Cr^{6+} was selected by pressing 1560 with the numeric keys.
2. After pressing ENTER the display showed: HACH PROGRAM: 1560 Cr, Hex. The wavelength (λ), 540 nm, was automatically selected.
3. A cell was filled with 10 mL of sample.
4. The contents of one Chroma ver-3 Reagent Pillow were added to the sample cell (the prepared sample). The cell was swirled to mix.
5. After pressing the soft key under START TIMER an 8- minute reaction period began.
6. Another sample cell (the blank) was filled with 10 mL of sample.
7. When the timer beeped the blank was placed into the cell holder and closed the light shield.
8. After pressing the soft key under ZERO the display showed: 0.000 mg/L Cr^{6+}

9. Within eight minutes after the timer beeped, the prepared sample was placed into the cell holder and closed the light shield. The result in mg/L hexavalent Cr^{6+} was displayed.

3.11 DATA PROCESSING AND STATISTICAL ANALYSES

3.11.1 Data Processing

By applying the criteria proposed by the WHO, we were able to determine how many samples failed to meet the recommended levels for both drinking water quality and water pollution status. The data was analyzed by looking at the range of values for each source type and each statistic using the standard deviation, minimum, maximum, mean, and median. We next used principal component analysis (PCA) in Stat Box 6.6 (Stat Box logiciels, Grimmersoft, France) to find the degree of overlap between the samples. In this approach, the results from the analysis of water samples were supplemented by data from statistical tests.

3.11.2 **Statistical Analysis:**

In order to tabulate and process the data, MS Excel 2010 was utilized. The acquired data were then analyzed and displayed using techniques from statistics, such as descriptive statistics, column charts, line charts and error bars. Determine whether there has been a notable shift in the concentration of hazardous metals in the water near the shipbreaking site, an ANOVA was conducted. Using ArcGIS (v.10.1), we modified the study site map and created a counter graph to display the distribution of data related to added metals.

Chapter 4: RESULTS AND DISCUSSION

4.1 PHYSICOCHEMICAL PARAMETERS

The term "physicochemical" is used to describe the behavior and interactions of matter that involve both physical and chemical features and processes. These characteristics may include elements like temperature, pH, EC, TDS, salinity, and others.

4.1.1 Temperature

In water bodies, the temperature of the water has a profoundly significant effect on the biological, chemical, and physical activities that take place. The rate at which gases dissolve in water decreased as the water temperature rose, which led to an increase in oxygen consumption, which in turn accelerated decomposition (WHO, 2011). In this investigation, the average temperature was 29.65^{o}C (Figure 4.1) at yard-3, the temperature was at its highest point (31^{o}C), and at yatd-4, it was at its lowest point (28.44^{o}C). The overall value of temperature is given in Table 3 of Appendix C. The current study's temperature readings (DoE, 2001) all fell within the acceptable range (30.5^{o}C).

The environmental conditions and shipbreaking techniques at Shipbreaking Yard 3 all contribute to the higher water temperatures found at shipbreaking locations. Beached ships block water flow and trap warm waters, while shipbreaking yards soak up more heat in sunny climates. In addition to increasing water turbidity and disrupting coastal habitats, shipbreaking generates garbage and suspended particles. Some unintended consequences include pollution, habitat destruction, and workplace hazards (Vajravelu et al., 2018).

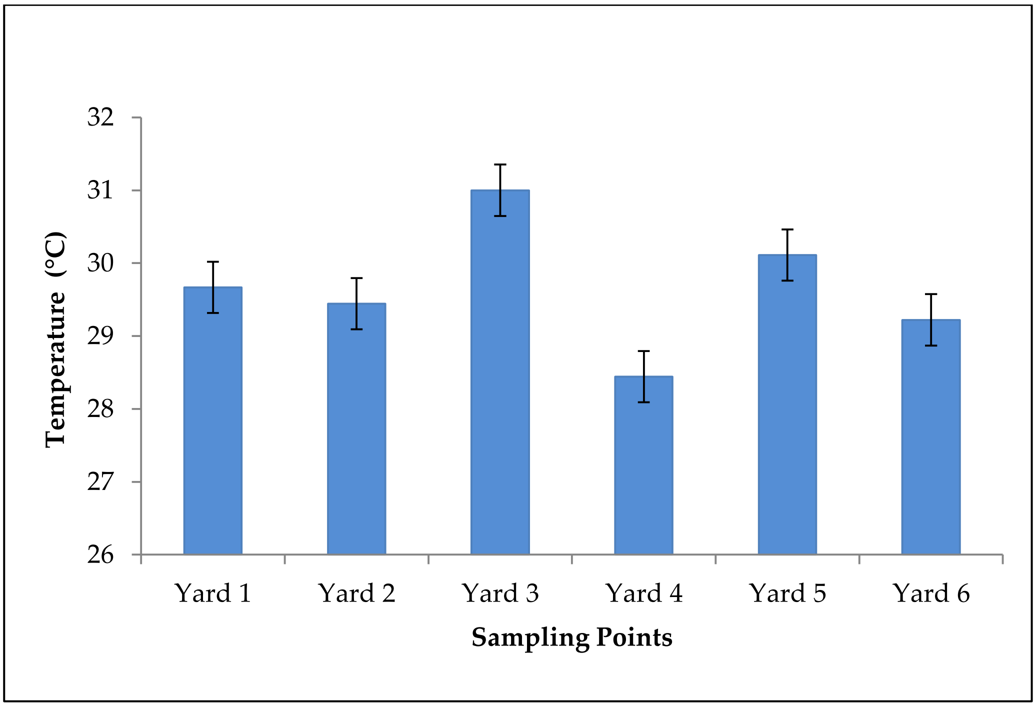

Figure 4.1 Temperature of water at different sampling points of Chattogram Shipbreaking Yard.

Water temperatures have dropped at Shipbreaking Yard 4 because of environmental changes caused by the shipbreaking process. Large metal constructions are exposed to the sea during shipbuilding, which entails dismantling and recycling old or retired ships. Heat is produced and absorbed during this process, which messes with water flow patterns. Minimizing adverse effects on seawater temperature and marine habitats requires appropriate regulation, safety precautions, and environmental concerns (Nithya et al., 2023).

4.1.2 Electrical Conductivity

The quantity of electrical current and the sum of all dissolved ions in a body of water are known as electrical conductivity (EC) (H. Hu et al., 2007). In the current investigation, the average EC value was 2028.87μS/cm (Figure 4.2). The lowest value was 1215.67μS/cm at yard-2, while the highest value was 3512.22μS/cm at yard-1. All of the results were above the 3000 μS/cm acceptable limit for surface water (WHO, 1993). Positive correlations between EC and transparency, salinity, and TDS; negative correlations between EC and DO, BOD, air temperature, and water temperature (Talukder et al., 2016). The water in a shipbreaking yard became extremely hard as EC levels rose, posing several health risks (Islam et al., 2017).

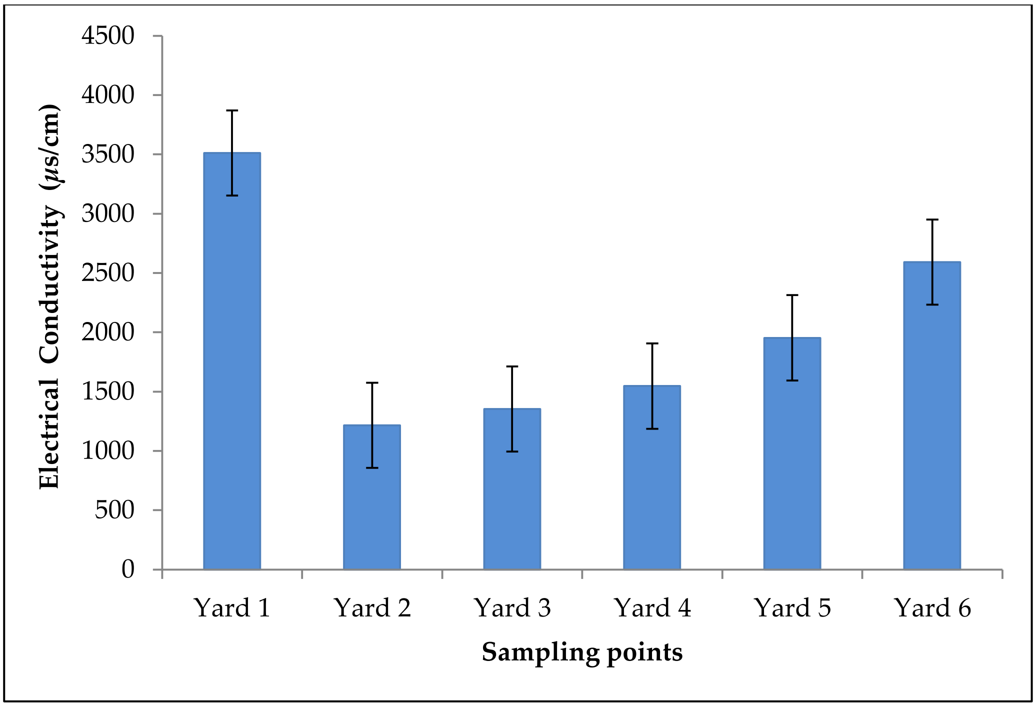

Figure 4.2 Electrical conductivity of water at different sampling points of Chattogram Shipbreaking Yard.

At Shipbreaking Yard 1, due to the leaching of metals and conductive materials from decommissioned ships, areas where ships are being broken up experience an increase in electrical conductivity. The seawater that these metal buildings are exposed to corrodes them and causes the release of conductive materials, including iron, copper, and aluminum. This raises electrical conductivity, which may have an impact on the environment since it affects the health of the marine environment and ecology. The detrimental environmental effects of increased EC and metal pollution in seawater must be minimized through good waste management and recycling procedures (Rashid et al., 2019).

Destroying old ships has been related to lower EC in the water at Shipbreaking Yard 2. Heavy metals, oils, and chemical releases all contribute to lower salinity and ion concentrations in the ocean. Ship corrosion and rust can also have an effect on electrical conductivity. Additionally, soil may be agitated during shipbreaking, leading to suspended particles that impede the flow of ions. Mixing in fresh water can reduce salinity and electrical conductivity. The degree to which EC drops in shipbreaking zones depends on factors such as the size and methods of the shipbreaking activities, applicable environmental rules, and the robustness of the local marine ecosystem (Afrin et al., 2021).

4.1.3 Total Dissolved Solid

The most important chemical component of water is total dissolved solid (TDS). TDS primarily shows the presence of several minerals, such as nitrite, nitrate, ammonia, phosphate, some acids, alkalis, metallic ions, and sulfates. Which contain dissolved and sticky particles in water (Alam et al., 2021). Elevated TDS levels may indicate the presence of waste-derived salts (Steve et al., 2014). The samples collected from all sites surpassed the machines' (HACH® 378 digital) TDS values. In contrast to the standard value (500 mg/L) recommended by (WHO, 1993), the detection limit is 10,000 mg/L. TDS's average value in the current study was 1014.89 mg/L (Figure 4.3). Yard-1 had the highest reading (1756.11 mg/L), whereas yard-2 had the lowest reading (607.78 mg/L). Seawater's physical and chemical characteristics in the ship-breaking yard are deteriorating, as evidenced by increasing TDS values, which are released and spilt off, scraped ships and frequently mix with the water (Hossain et al., 2006).

Shipbreaking activities at Shipbreaking Yard 1 increase the TDS in saltwater due to corrosion, exposure to harsh maritime conditions, and dissolved compounds. Chemicals on ships have the potential to destroy ecosystems and marine life. Improper waste management procedures may result in the direct dumping of ship parts and dangerous materials, further raising TDS levels. To reduce environmental effects and stop the TDS from rising, responsible shipbreaking techniques must be put into place (Afrin et al., 2021).

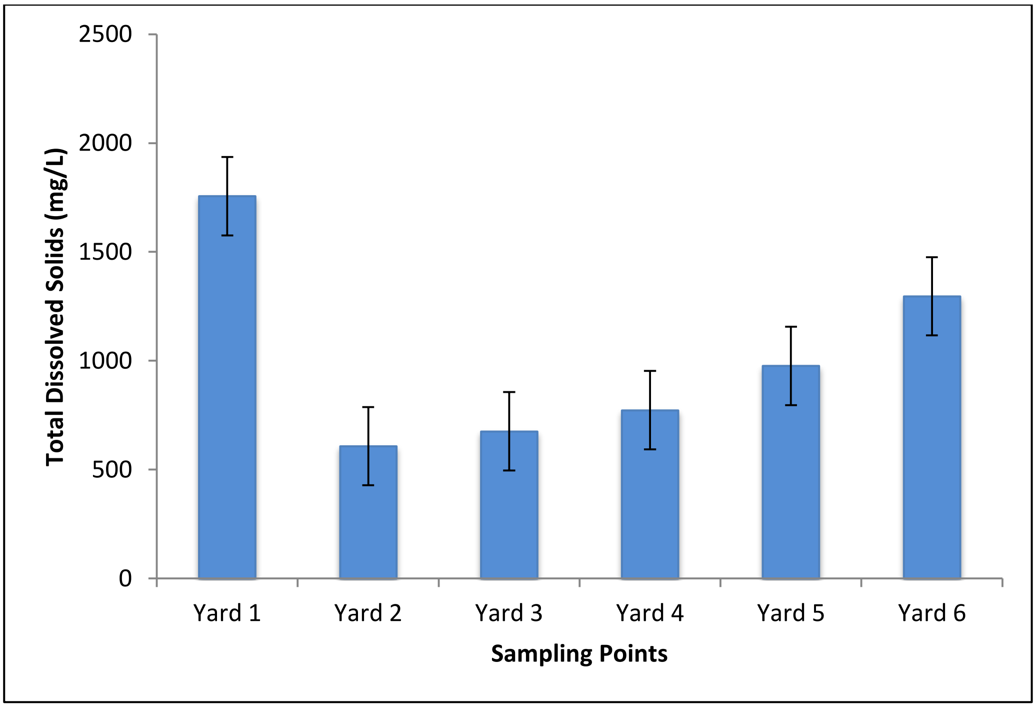

Figure 4.3 Total dissolved solid of water at different sampling points of Chattogram Shipbreaking Yard.

Due to pollution, precipitation, currents in the sea, chemical reactions, bioaccumulation, and other factors, Shipbreaking Yard 2's operations can reduce seawater total dissolved solid. However, environmental impacts are long-lasting and require proper regulations and monitoring. Implementing pollution control measures, waste management, and safe handling of hazardous materials can help minimize TDS levels (Meena et al., 2017).

4.1.4 Total Suspended Solids

The term "total suspended solids (TSS)" refers to solids that are suspended in water, both organic and inorganic. They might comprise plankton, silt, and industrial trash. By absorbing light, water quality can be affected by excessive suspended soil concentrations. The effect is that the water's capacity to maintain the oxygen necessary for aquatic life decreases as it warms up. The photosynthesis of aquatic plants slows, producing less oxygen, as they also receive less light (Hossain et al., 2006). Several types of life are rendered extinct by the interaction of warmer water, less light and lower oxygen levels. Moreover, suspended solids have various effects on life. They can obstruct fish gills, slow growth, weaken disease resistance, and stop the development of eggs and larvae. Suspended solids can be produced by industrial waste, sewage discharges, algae growth, bottom feeders, and erosion of the banks, as well as erosion from urban runoff and agricultural land. TSS's average value in the current study was 3792.42 mg/L (Figure 4.4). The lowest result was 2993.97 mg/L in yard-3 and the highest was 4515.69 mg/L in yard-4.

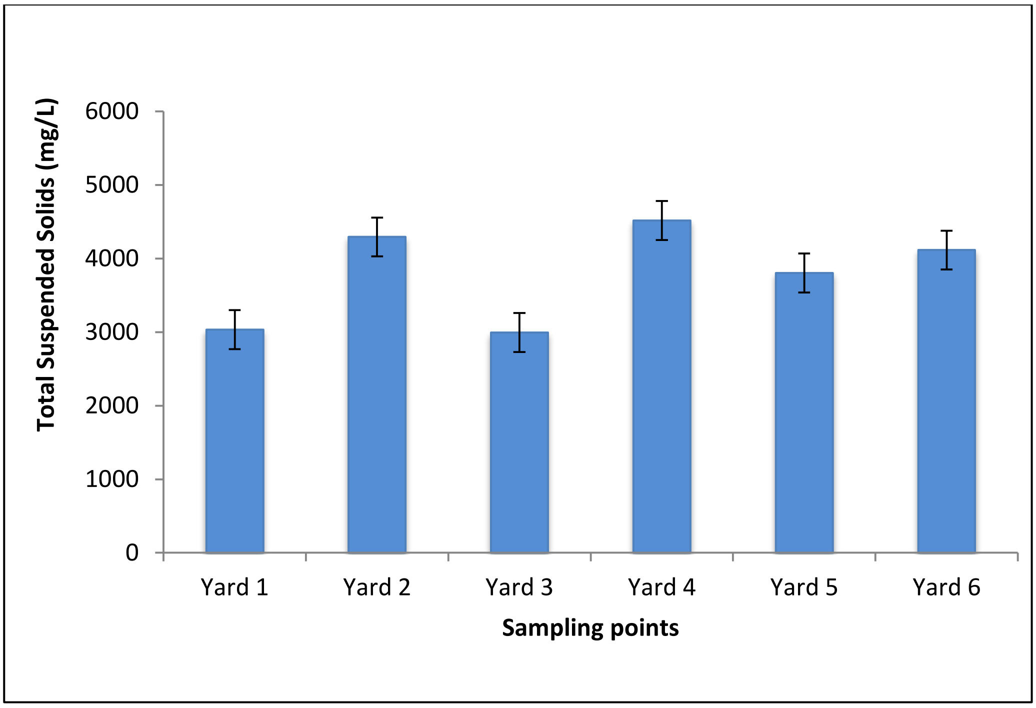

Figure 4.4 Total Suspended Solids of water at different sampling points of Chattogram Shipbreaking Yard.

At Shipbreaking Yard 4, due to variables like debris release, corrosion, and inadequate waste management techniques, shipbreaking regions can increase the total suspended solids in the water. Reduced light penetration and altered water quality are two potential environmental effects. In shipbreaking activities, proper environmental management and waste treatment are essential.

Total suspended solids levels in seawater can be lowered at shipbreaking facilities like Shipbreaking Yard 3 by removing large metal pieces and allowing them to settle on the seafloor. Water containment and management techniques help reduce total suspended solids levels. Reduced TSS levels do not necessarily indicate that pollution has been eliminated. To reduce their negative effects on maritime ecosystems and communities, shipbreaking yards must adhere to strict environmental standards and best practices (Vajravelu et al., 2018).

4.1.5 pH

pH is one of the key components of the water's quality that controls aquatic ecology. The water system's pH level, which measures the concentration of hydrogen ions, is closely related to all chemical and biological reactions (Hossain et al., 2011). The pH scale determines whether a liquid is acidic or alkaline by taking the negative logarithm of the hydrogen ion concentration in the solution. The pH balance had a range of 0 (very acidic) to 14 (extremely alkaline) (Uribe et al., 2022). The average pH in the current study was 8.03 (Figure 4.5). The highest value, 8.64, was discovered in yard 1, and the lowest value, 7.72, was discovered in yard 2. The study's pH readings fell within the (WHO, 1993) acceptable limit (6 - 8.5). In the present study, pH changed as a result of lower photosynthetic activity. Photosynthetic activity was decreased as a result of shipbreaking activities, which profoundly affected aquatic species' life cycles (Islam et al., 2017).

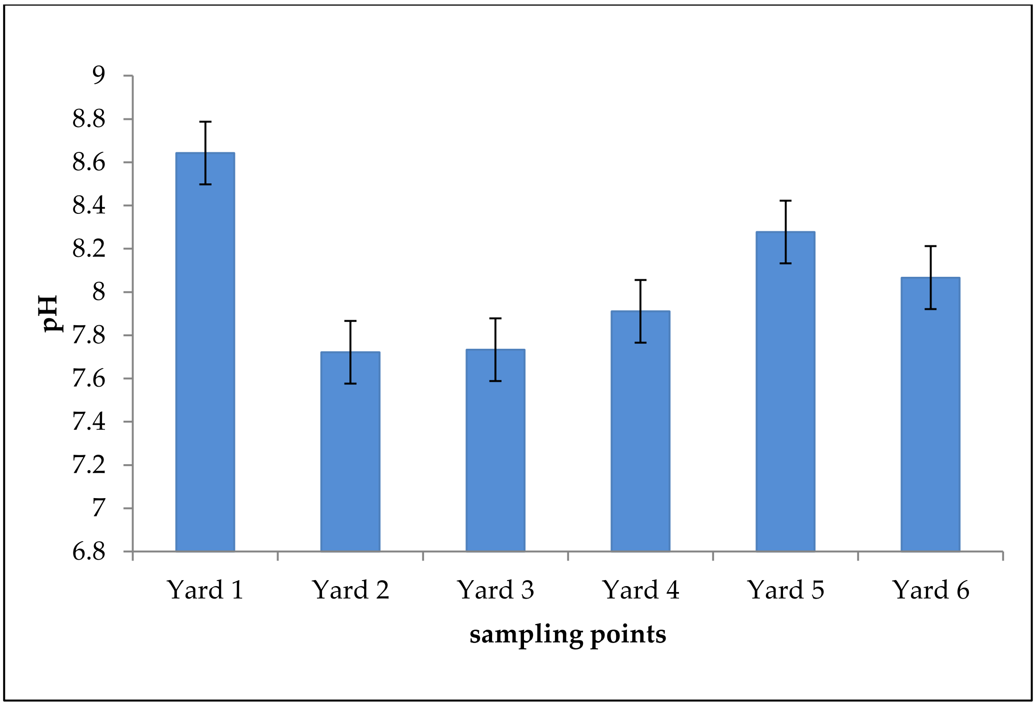

Figure 4.5 pH of water at different sampling points of Chattogram Shipbreaking Yard.

The pH of the water in places like Shipbreaking Yard 1 has increased, partly because alkaline materials like plaster and coatings were used during shipbuilding. These substances have the potential to leach alkaline chemicals, which would alter the surrounding water's chemistry. Changes in pH can have an adverse effect on marine habitats and water acidification. Environmental limitations, recycling methods, and efficient waste management are essential to reducing the impact on the environment. According to Vajravelu et al. (2018), it is crucial to monitor and assess the water quality in shipbreaking regions in order to protect marine ecosystems.

When ships are broken down in Shipbreaking Yard 2, the pH of the surrounding water drops as a result of pollution, chemical emissions, and natural processes. As ships disassemble and recycle, heavy metals, rust, corrosion, oil, gasoline, and hydrocarbons are released. To stop ocean acidification and save marine life and ecosystems, proper waste management and environmental laws are essential (Nithya et al., 2023).

4.1.6 Dissolved Oxygen

The level of dissolved oxygen (DO) is among the most crucial things signs of contamination in the aquatic environment. Oxygen gas that has dissolved in water is referred to as dissolved oxygen. DO in water is produced by photosynthetic planktons and atmospheric air (Kane et al., 2015). Any aquatic habitat with a healthy level of dissolved oxygen—around 5.0 mg/L—is considered to be free of pollution. Surface waters that are not contaminated typically have a high concentration of DO. Discharge of the wastes that require oxygen can quickly remove DO from the water. The amount of DO in water is also generally reduced by other inorganic compounds such hydrogen sulfide, nitrites, ammonia, ferrous iron, and other oxidizable chemicals. In general, high levels of organic matter contamination are correlated with low DO concentrations. The average DO in the current investigation was 7.28 mg/L (Figure 4.6). At the Yard-4 recorded the highest result (7.68 mg/L), while at Yard-5 recorded the lowest value (5.61 mg/L). The substantial amount of metallic waste present and a decline in the decomposition activities of a microorganism caused the DO values of all sampling stations to be greater than the average value (4-6 mg/L) provided by (WHO, 1993).

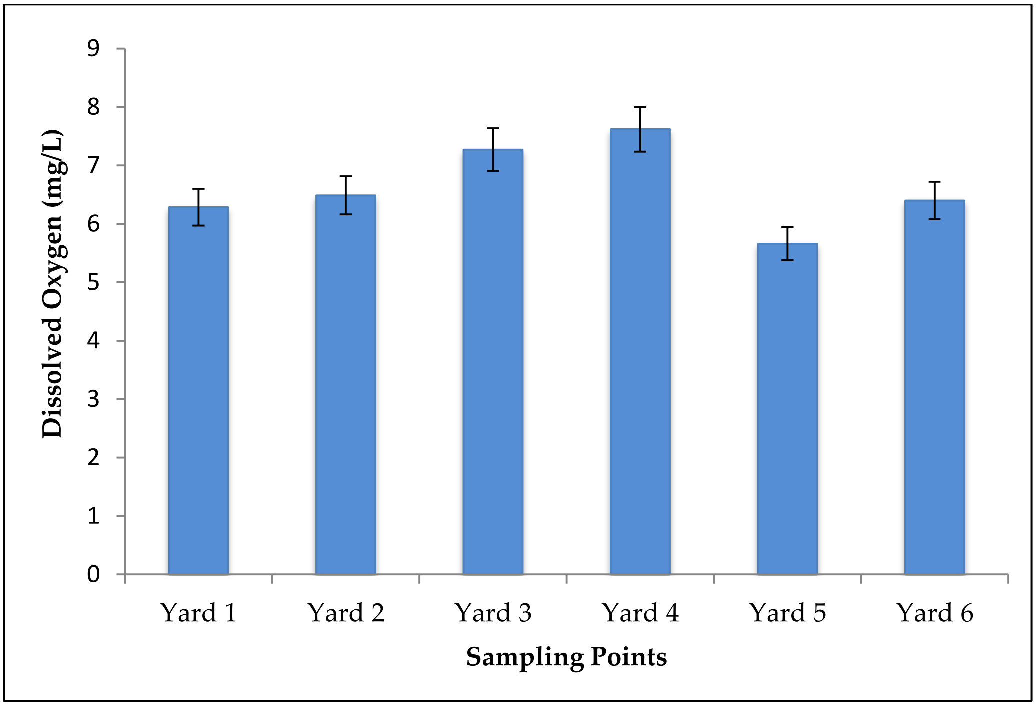

Figure 4.6 Dissolved oxygen of water at different sampling points of Chattogram Shipbreaking Yard.

Both natural and human-made processes can have an impact on the levels of DO in the water around Shipbreaking Yard 4. When ships are dismantled for their parts, the water is agitated, which increases the concentration of dissolved oxygen. This process is known as shipbreaking. In addition to being a source of oxygen-producing bacteria and a raw material for photosynthesis, the rust and paint chips generated during shipbreaking can also function as a food supply. Daytime exposure to these nutrients can aid marine plant growth, which boosts atmospheric oxygen levels. The effect that shipbreaking has on DO levels is context- and practice-specific. Shipbreaking activities must be monitored and regulated to ensure sustainable coastal and marine management (Rashid & Showva, 2019).

At Shipbreaking Yard 5, due to factors like biological decomposition, spills, soil suspension, hazardous compounds, and heat, shipbreaking, the process of dismantling old or decommissioned ships for valuable resources, can lower the amount of DO in seawater. These factors have the potential to affect local fisheries, marine ecosystems, and biodiversity. Environmental management strategies that are appropriate are essential to safeguarding the marine ecosystem (Vajravelu et al., 2018).

4.1.7 Biological Oxygen Demand

Biological oxygen demand (BOD) is among the most widely used techniques for counting the number of organic contaminants in water. The term "BOD" refers to a chemical process for calculating how much DO aerobic organisms in a body of water need to break down and decompose organic matter in a given water sample at a particular temperature for a defined period of time (Sawyer, 2003). A low BOD hence signifies clean water, whereas a high BOD suggests unclean water. Microorganisms consume DO when organic waste from sewage or other discharges is present in large amounts in the water. The exact amount of DO that is actually present in the water is known as DO. The life forms in the water become unable to function normally when the DO falls below a specific point. An essential part of pollution management efforts is the BOD test. It is a bioassay technique that calculates how much oxygen is consumed by living things. The average BOD value in the current study was 4.03 mg/L (Figure 4.7). Yard-2 recorded the highest reading of 7.04 mg/L, while yards 6 recorded the lowest reading of 2.44 mg/L. All BOD levels were below the average water quality limit (5 mg/L) for surface water set by the (WHO, 1993) as a result of the daily increase in inorganic and metallic wastes in the ship-breaking area.

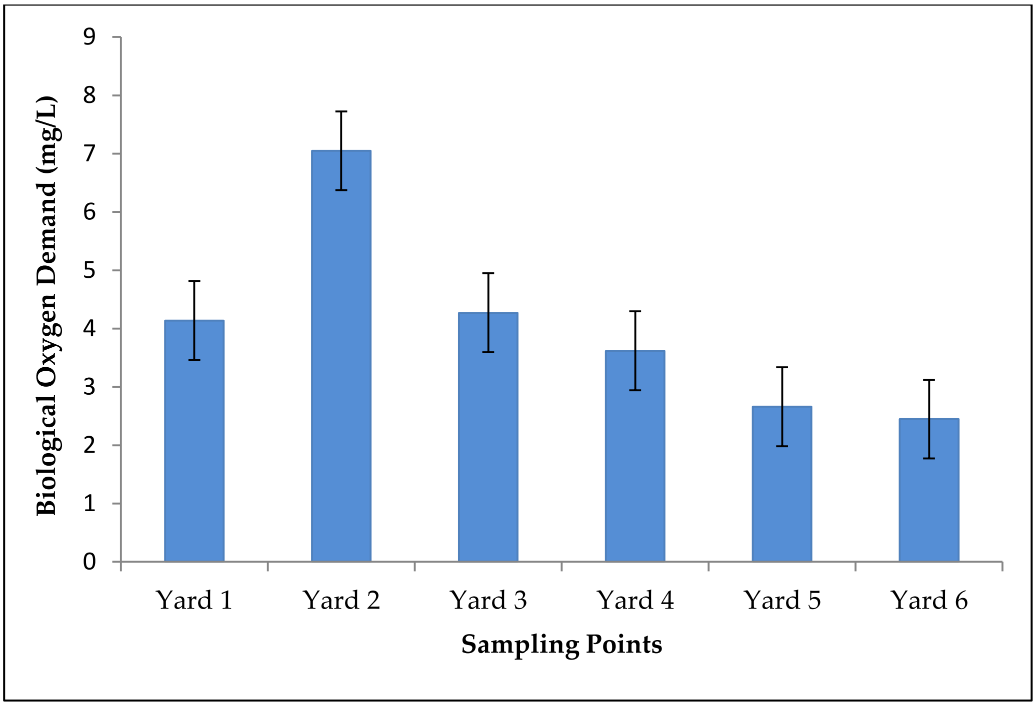

Figure 4.7 Biological oxygen demand of water at different sampling points of Chattogram Shipbreaking Yard.

Shipbreaking increases the BOD in the water at Shipbreaking Yard 2 as a result of factors including the removal of ship components, unintended spills, biofouling, biofilms, soil disturbance, and nutrient release. Additionally, shipbreaking disturbs the soil and produces a "dead zone," necessitating effective waste management and pollution control procedures to lessen adverse effects on the environment.

At Shipbreaking Yard 6, due to a number of reasons, including pollution, physical disturbances, soil, and modifications in water flow patterns, shipbreaking activities might result in a fall in BOD levels. As microorganisms prefer oxygen for microbial decomposition, this decline in organic matter breakdown and BOD levels may be harmful to marine ecosystems (Vajravelu et al., 2018).

4.1.8 Chemical oxygen demand

The amount of compounds in water that are oxidised from being reduced is known as the chemical oxygen demand (COD). The concentration of organic pollutants in surface water is often monitored using chemical oxygen demand. There is a correlation between the discharge of industrial effluent and an abundance of organic wastes, as measured by chemical oxygen demand, and a decline in water quality. As shown in (Figure 4.8), the mean COD concentration in this investigation was 82.54 mg/L. According to Rahman et al. (2021), the highest level was recorded at yard -6 with 93.45 mg/L, while the lowest level was recorded at yard -2 with 72.53 mg/L.

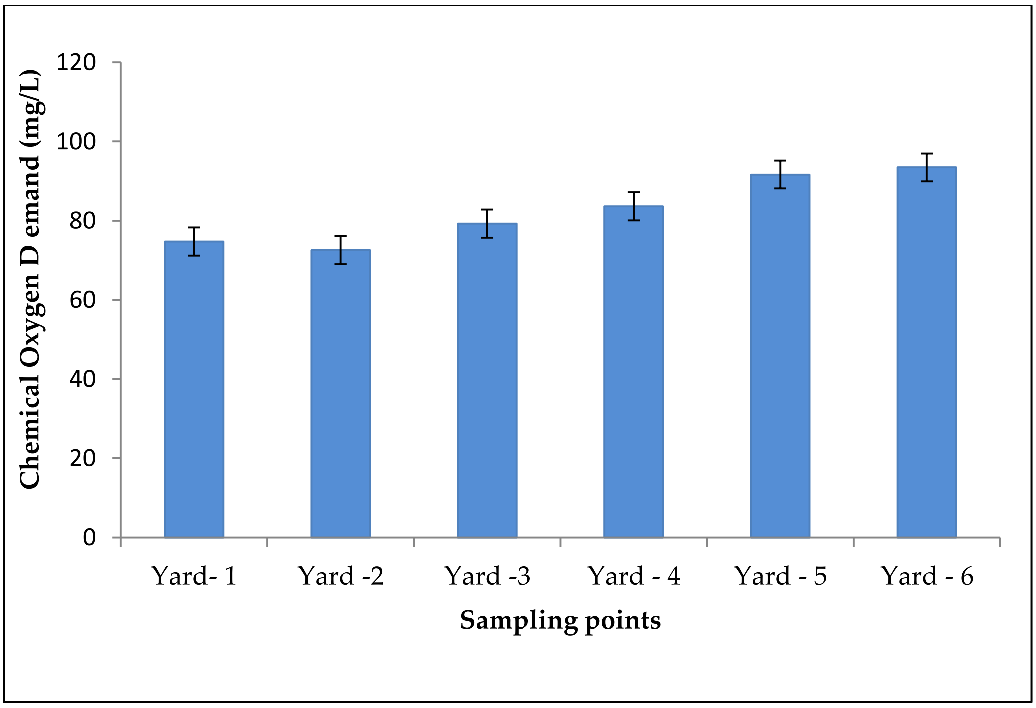

Figure 4.8 Chemical oxygen demand of water at different sampling points of Chattogram Shipbreaking Yard.

Due to a number of causes, the COD of the water in shipbreaking yard 6 tends to rise with time. Ships may have leftover lubricants, oils, and fuels when they are broken down for scrap. If these compounds were to leak or spill, the COD of the water would likely rise because of the higher concentration of organic matter. Paints and coatings used on ships can potentially be released into the environment when these structures are broken down. Incorrect waste management, chemical cleaning and degreasing practices and the redistribution of sediments from the seafloor are all contributors to rising COD concentrations.

To lessen the amount of oxygen needed to chemically oxidize organic and inorganic compounds, Shipbreaking Yard 2 is taking steps to lower the COD of the water used in the process. These yards are typically situated near water, which can dilute contaminants and lower COD levels in the water. The concentration of COD in water can be reduced through natural processes such as the biological decomposition of organic pollutants and the sinking of suspended solids. Water treatment procedures, such as chemical precipitation or coagulation of impurities, and containment measures to avoid pollutant release into the water are also possible at shipbreaking yard 2 (Gawle et al., 2021).

4.1.9 Salinity

The types of aquatic organisms that occur as an ecological component are greatly influenced by salinity. The world's ocean circulation is influenced by the salinity of the oceans, where density changes as a result of both salinity and temperature variations at the ocean's surface, which result in changes in buoyancy and cause water masses to sink and rise. Since more salinized waters become less soluble in carbon dioxide, changes in ocean salinity are believed to be involved in changes in the amount of carbon dioxide in the atmosphere. The average salinity in the current study was 12.83 ppt (Figure 4.9). The highest value, 17.79 ppt, was discovered in yard 6, and the lowest value, 3.59 ppt, was discovered in yard 1.

Shipbreaking activities at Shipbreaking Yard 6 can increase salinity in the water by altering regular water flow patterns and releasing ballast water with varying salt contents. Salinity changes may occur as a result of the discharge of chemicals, fuels, and contaminants during shipbreaking. Runoff and the disturbance of minerals in the water can also result in salinity changes. These considerations and measures to mitigate the negative effects on water quality, specifically salinity levels, are crucial in reducing the environmental impact of shipbreaking (Meena et al., 2017; Vajravelu et al., 2018).

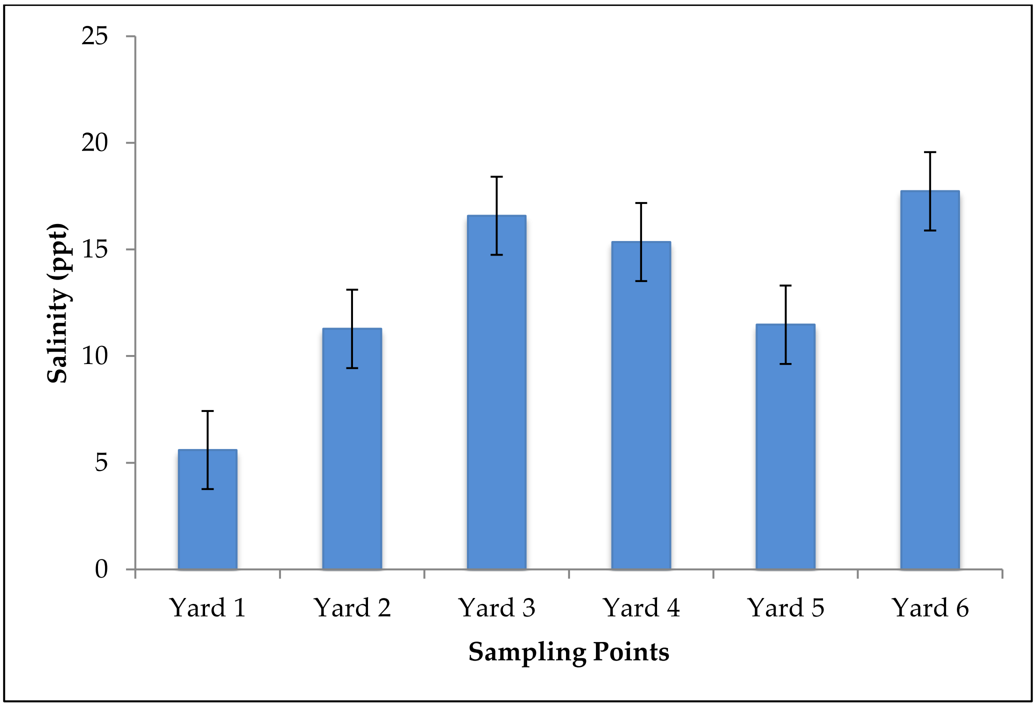

Figure 4.9 Salinity of water at different sampling points of Chattogram Shipbreaking Yard.

Salinity levels in the water have been proven to drop at Shipbreaking Yard 1 because of the use of chemicals, lubricants, particle emissions, and proximity to nearby sources of clean water. They interact with marine organisms and change the way the water flows. Maintaining the quality of the water requires proper waste management, environmental monitoring, and regulatory procedures (Nithya et al., 2023).

4.1.10 Oil and Grease

Grease and oil are major impediments to sunlight reaching the aquatic environment, which is one of the main factors regulating the marine aquatic ecosystem. Generally, it is challenging to reduce or eradicate grease and oil once they have spread out in an aquatic environment. When the level of oil and grease in the air is between 25.0 mg/L, it is deemed normal (Rashid & Showva, 2019).

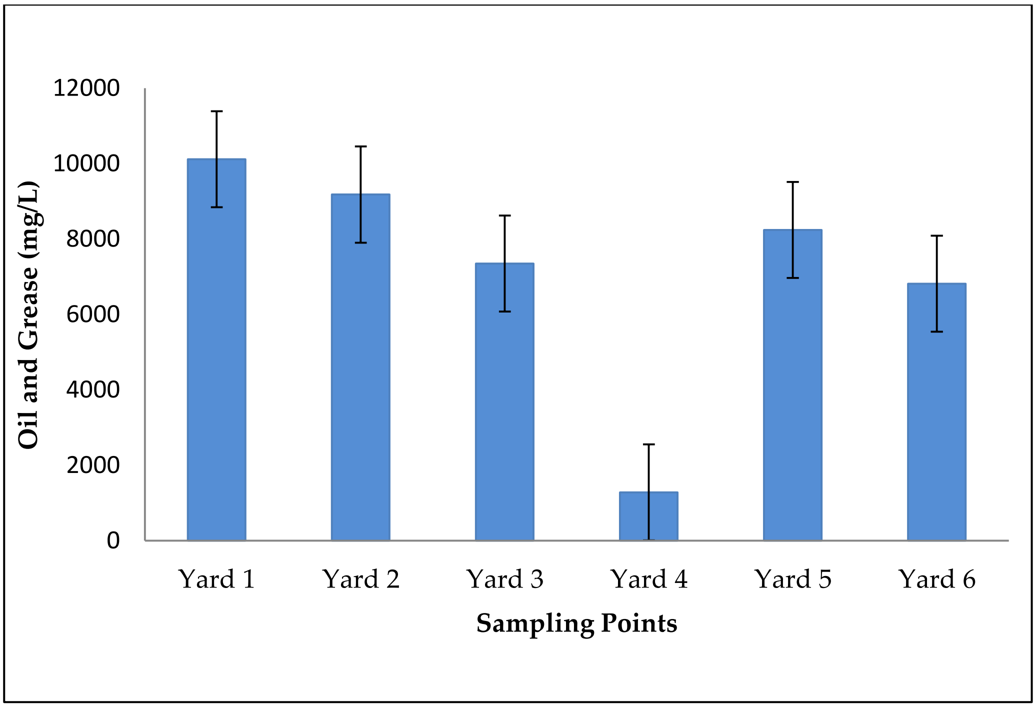

Figure 4.10 Oil and grease of water at different sampling points of Chattogram Shipbreaking Yard.

In the current investigation, the average oil and grease concentration was 7166.64 mg/L (Figure 4.10). At the Yard-1 had the highest reading (10120.09 mg/L), while yard-4 had the lowest reading (1284.46 mg/L).

Due to inappropriate treatment and disposal of hazardous materials at Shipbreaking Yard 1, the amount of oil and grease By lowering pollutants and supporting eco-friendly dismantling techniques, an effective waste management system can help reduce the negative environmental effects of shipbreaking.

Oil spills, ship mechanical leaks, and natural processes have all contributed to a drop in grease and oil in the waterways around Shipbreaking Yard 4. Water dilutes contaminants, whereas microbial communities break down organic contaminants. Grease and oil are removed with the aid of deposition. Environmental legislation and inspections can make practices better, but to reduce harmful environmental effects, competent waste management and shipbreaking procedures are essential (Mazzoccoli et al., 2020).

4.1.11 Turbidity

Environment monitoring, water quality assessment, and industrial activities are all impacted by the measurable cloudiness or haziness in water known as turbidity. The ability of aquatic organisms to access sunlight and engage in photosynthesis is negatively impacted at high concentrations. In order to preserve water quality and protect aquatic habitats, turbidity standards and restrictions have been put in place.

In the current investigation, the average turbidity concentration was 340.31 NTU (Figure 4.11). Yard-5 had the highest reading (676.97 NTU), while yard-3 had the lowest reading (103.69 NTU).

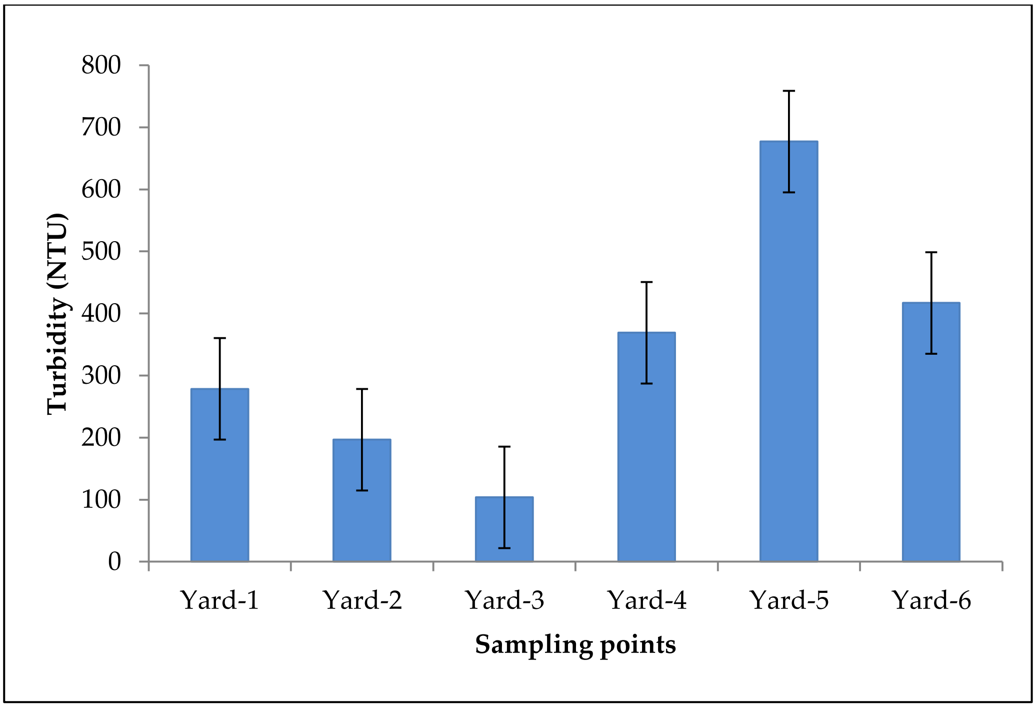

Figure 4.11 Turbidity of water at different sampling points of Chattogram Shipbreaking Yard.

Shipbreaking yards, large machinery, soil disturbance, and poor waste management are the main contributors to increasing turbidity at Shipbreaking Yard 5. Weather conditions and natural processes like currents and tides can also aid in material recovery. The detrimental impacts of turbidity on marine ecosystems can be mitigated through efficient waste management, particle control techniques, and adherence to environmental rules (Afrin et al., 2021).

At Shipbreaking Yard 3, due to activities like dismantling outdated or decommissioned ships, clearing debris, and putting containment measures in place, shipbreaking lowers turbidity in saltwater. This procedure eliminates heavy particles, lowers the amount of suspended matter, and lowers turbidity. Shipbreaking facilities also use booms and barriers to control oil (Meena et al., 2017).

4.2 THE CONCENTRATION OF HEAVY METALS IN WATER

The outcomes of high levels of hazardous metals in surface waters The normal concentrations there were metals found to decrease in a body of water in the following order: As > Pb > Cr> Cd. In the water samples under study, Cr concentration was greater than that of the other metals.

4.2.1 Arsenic

With a standard value of 0.002 mg/L, the deadly component as is found in fresh, the ocean's surface (Deng et al., 2018; Lindsay & Maathuis, 2017). This element is common that is harmful to both people and marine life at high concentrations (Absi et al., 2019).In addition to additional long-term problems such an abnormal birth, vascular and skin illnesses, and cancer, it also causes diarrhea, brain damage, stomach discomfort, and vomiting (Ali et al., 2022). Clean coastal and ocean waters typically have total levels of arsenic (As) between 0.001 and 0.003 mg/L, averaging around 0.002 mg/L (Bundschuh et al., 2021). The As that oceanic species collect originated in saltwater that retain within their bodies, particularly photosynthetic organisms, causes species changes in the As due to metabolic processes. Ocean water As biogeochemical cycles have a long history of research (Raab et al., 2005). Aquatic algae contain arenosugars (Kalia & Khambholja, 2015) as well as aquaculture uses for arsenobetaine are examples of organisms that are both inorganic and organic species that are present (Duncan et al., 2015). As levels in Maryland's estuary of the Patuxent River, the United States, reach a peak of the equivalent of 0.001 mg/L in July and August before gradually declining from January to April, to approximately 0.1 to 0.2 g/L (Hossain et al., 2021). The acutely lethal value of arsenate in Mysidopsis bahia is 2.32 mg/L. To change mature Crangon shrimp, concentrations of arsenate of more than 25 mg/L are required. Little people are more sensitive than people who are comparatively larger. When exposed for a brief time 10–50 mg/L arsenate, shrimp respiration rates decrease.

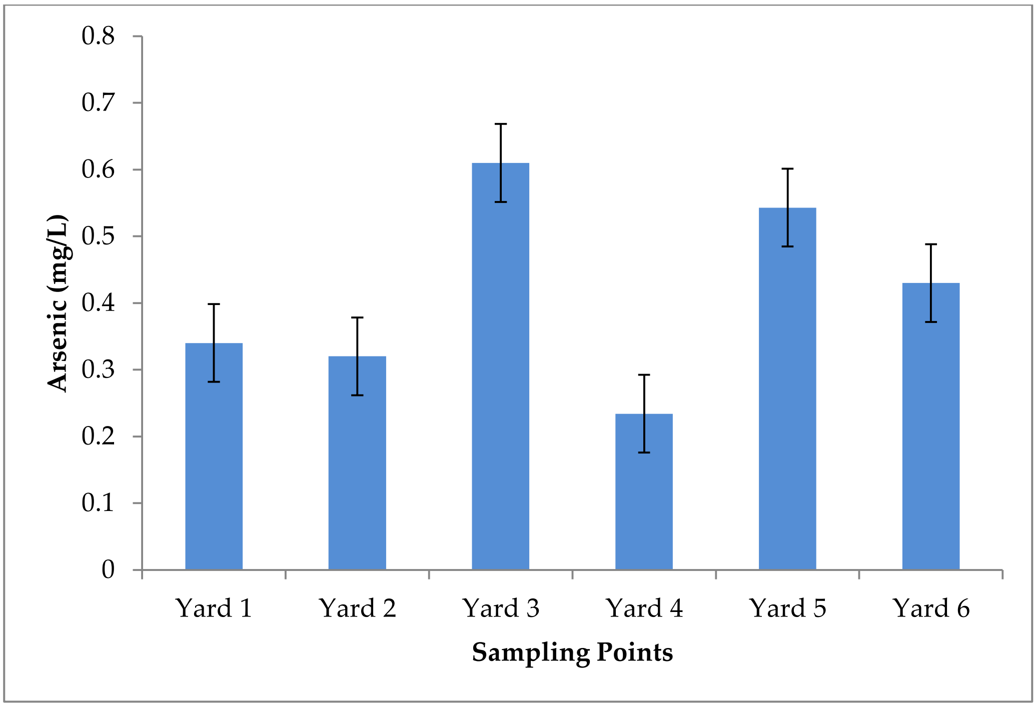

Figure 4.12 Arsenic of water at different sampling points of Chattogram Shipbreaking Yard.

As average concentration in the study was 0.412 mg/L (Figure 4.12). The highest amount, 0.61 mg/L, was discovered in yard 3, and the lowest amount, 0.234 mg/L, was discovered in yard 4. Our study's mean As value was three times greater than the value suggested by (WHO, 2011) guideline.

As may be leached from ship components such as antifouling paints, coatings, and alloys at Shipbreaking Yard 5. Ballast water used in shipbreaking has the potential to introduce As into local water supplies. Shipyard operations, including cutting, welding, and dismantling metal structures, can generate dust and fumes that may include As (Bundschuh et al., 2021). Low-quality waste management in ship-breaking zones may contribute to As pollution. Toxins, such as As, can be kept out of nearby water sources with the help of responsible waste management.

Shipbreaking reduces As levels in the water around Shipbreaking Yard 1 because of pollution-reducing practices, including disassembling and recycling decommissioned ships. As a result of settling particles and the constant motion of seawater, As is quickly diluted and removed from the water column. According to Sujauddin et al. (2017), marine species' accumulation of heavy metals lowers As concentrations. Despite the fact that environmental legislation may call for pollution and waste management procedures, effective waste management techniques are essential for reducing environmental consequences.

4.2.2 Chromium

The metal chromium (Cr (VI) is regarded as among the most potent oxidizing substances. More deadly, though, is the metals angry and caustic appearance (Proshad, et al., 2021). Cr (VI) toxicity for aquatic species is often lower than that of Cd, Pb, Hg, Ni, Cu, and Zn due to the harsh acidic nature of Cr (VI) ions. A considerable growth inhibition is observed in aquatic plants with raising of Cr (VI) concentrations {0.5 to 5 mg of Cr (VI)/I} (Tchounwou et al., 2012). Even though Cr is present in greater quantities in marine ecosystems compared to aquatic plants, it does not significantly pollute plant tissues. Intake from soil directly is shown by the fact that sorption occurs nearly exclusively through the stems of seagrass. Although there is little information on bioavailability in any species, Cr is mostly delivered to fish and invertebrates through food. According to research by (Ali et al., 2020; Geisler et al., 1991), respectively, the rates are significantly greater when aquatic animals are captured in commercial places (approximately 0.26-1.55 and 0.5 mg/L). Also, we discovered this average Cr (VI) content was 2.4 times greater than the WHO guideline threshold.

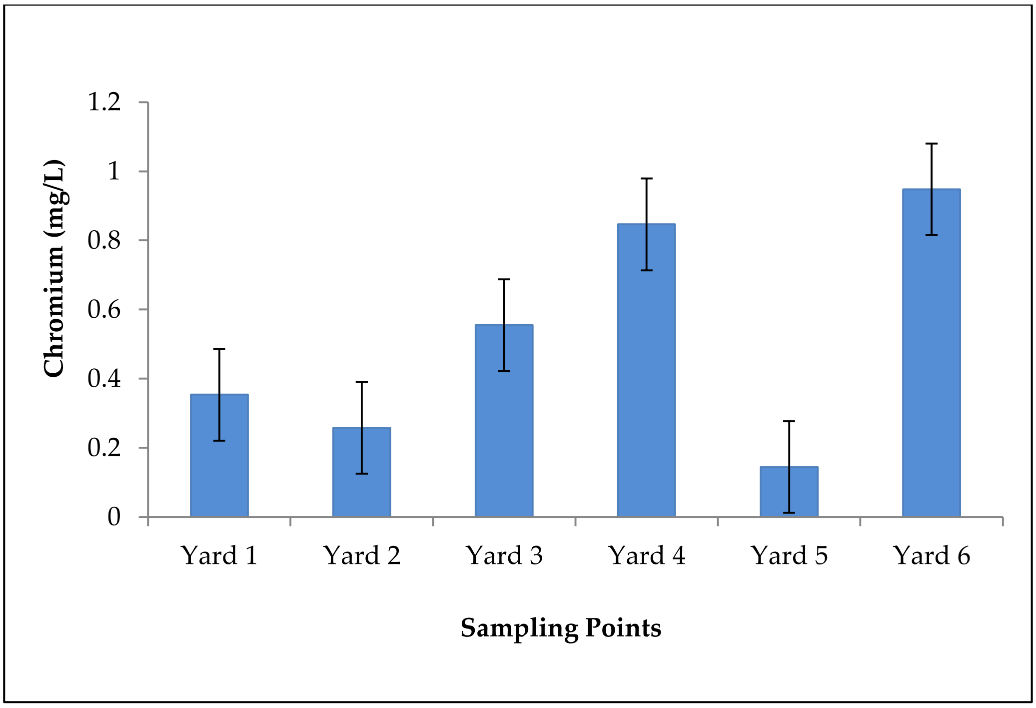

Figure 4.13 Chromium of water at different sampling points of Chattogram Shipbreaking Yard.

The average level of Cr in the study was 0.517 mg/L (Figure 4.13). Yard-6 recorded the highest value of 0.947 mg/L while yard-5 recorded the lowest value of 0.144 mg/L.

Cr is dumped into the ocean at Shipbreaking Yard 6 as obsolete or damaged ships are dismantled. Materials containing Cr (VI), such as stainless steel and coatings resistant to corrosion that deteriorate with time and moisture, as well as cutting, grinding, and welding, all contribute to this process. By ensuring compliance with laws and adopting safe disposal and recycling measures for hazardous materials, good waste management practices during shipbreaking help reduce the negative effects on the environment.

Shipbreaking operations at Shipbreaking Yard 5 can reduce the quantity of Cr in saltwater owing to corrosion and rusting, but they can also release contaminants like Cr (VI). The vast water can dilute these toxins, which lowers concentrations (Barua et al., 2017). However, because shipbreaking releases toxic compounds and heavy metals, environmental damage persists. To reduce negative consequences, proper waste management and environmental protection are crucial.

4.2.3 Cadmium

Hazardous metal cadmium (Cd) can be found in ambient water at levels not more than mg/ml (Chung et al., 2011; Ferreira et al., 2004). Cd is a hazardous metal utilized in a wide range of applications that is created as a byproduct of the production of zinc. There have been large anthropogenic Cd emissions into aquatic environments as a result of using Cd extensively in many manufacturing and agriculture processes (Zhang, 2020). When compared to other dangerous metals, Cd is highly soluble and is a substance that organisms like bivalves can accumulate. Due to the characteristics of Cd, which could cause dangerous metal poisoning, it is thought to pose a major environmental threat (Shi et al., 2016). The deleterious effects of Cd on the immunological (Kim et al., 2014) and regenerative (Shi et al., 2016) systems for many varieties have been demonstrated in a number of studies, leading to harm to the chromosome (Inglot et al., 2012).

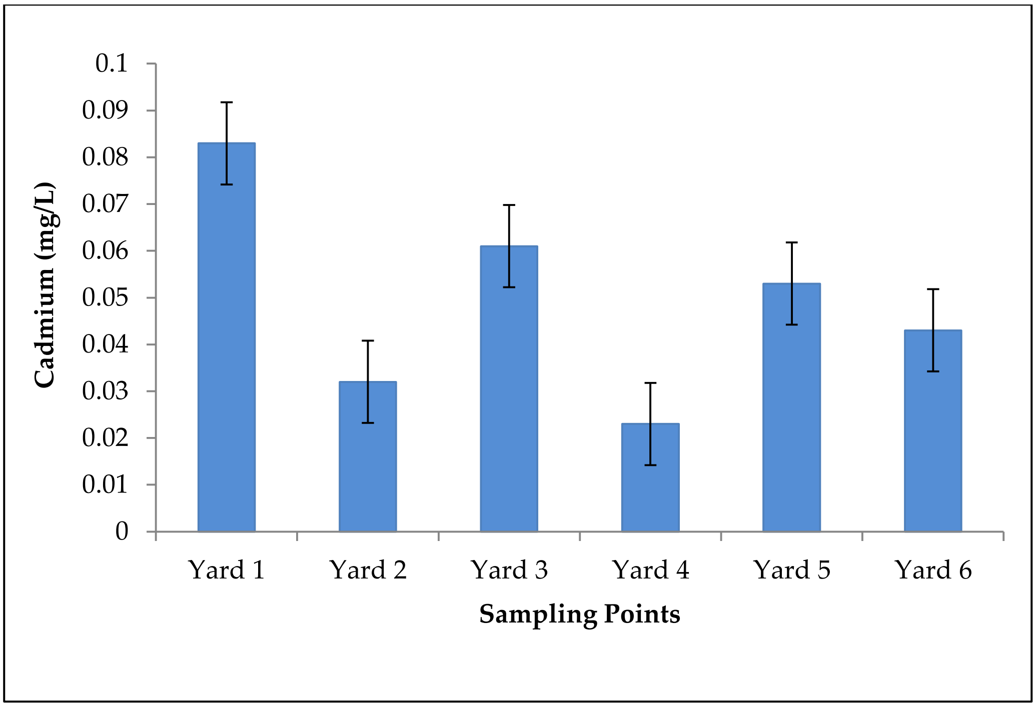

Figure 4.14 Cadmium of water at different sampling points of Chattogram Shipbreaking Yard.

Cd standard concentration in the current investigation was 0.049 mg/L (Figure 4.14). Yard-1 recorded the highest value of 0.083 mg/L while yard-4 recorded the smallest value of 0.023 mg/L. Unfortunately, our concentration of Cd was a little bit more than the WHO's recommended upper limit. As an example, (Shi et al., 2016) observed decreased Cd concentrations at the ship breaking region in Sitakunda than the findings of the present study (Abadi et al., 2018).

Due to the use of corroded or damaged materials, such as batteries and electrical components, during shipbreaking at Shipbreaking Yard 1, Cd is released into the environment. Cd may be discharged into the ocean as a result of corrosion or deterioration. The Cd-contaminated effluent that is discharged into the environment is made up of cleaning agents, coolants, and hydrocarbon leftovers from shipbreaking. Untreated sewage has the ability to reach the ocean, raising Cd levels there. Rainwater runoff from shipbreaking sites is another cause of Cd pollution.

Shipbreaking Yard 4 reduces Cd levels in marine habitats through dilution and deposition, two processes that occur naturally. These processes release heavy metals like Cd, which plankton and filter-feeding organisms can take up. Effective management is necessary to prevent pollution from hurting marine life and coastal ecosystems, despite the fact that best practices and rules reduce pollution (Chang et al., 2010).

4.2.4 Lead

Lead (Pb) accumulates in living things and has harmful effects as well as oxidative deterioration. Pb causes deformities and anemia in marine animals (Mearns et al., 2020). Pb, when stored in the bodies skeletal, renal, muscular, or central nervous systems, can have negative effects on the immunological, reproductive, and neurological systems (Molinero et al., 2018). The water from the shipbreaking zone is not suitable for human consumption since it contains levels of Pb that are significantly higher than the allowed water limit, according to the toxicity reference values (TRV) that have been released. Moreover, the mean Pb value was six times the WHO recommendation limit.

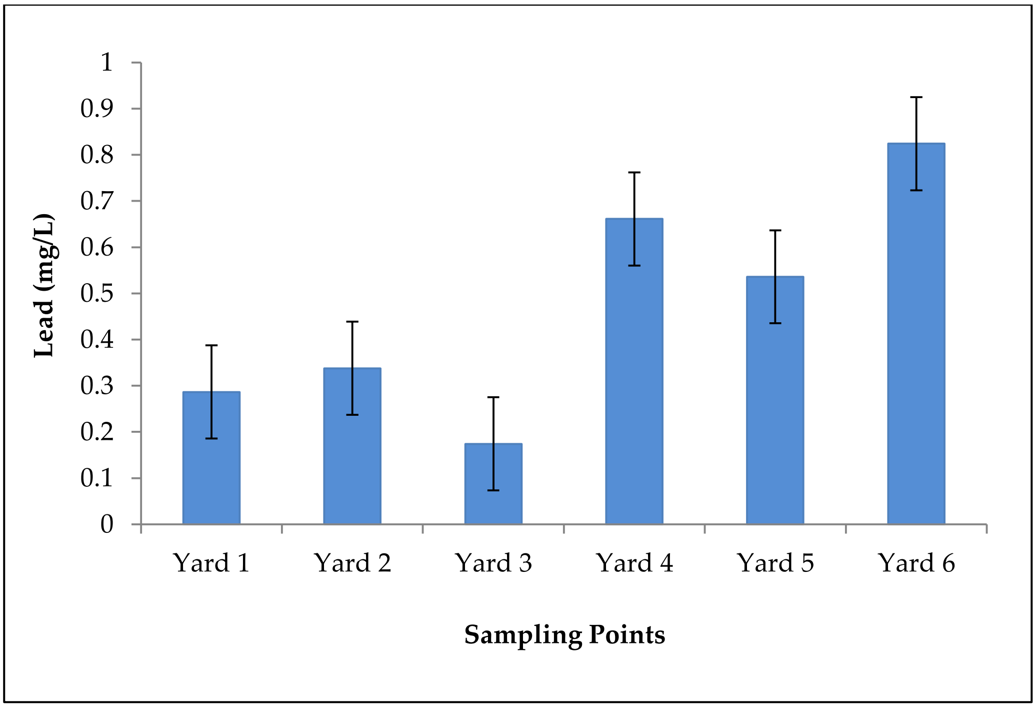

Figure 4.15 Lead of water at different sampling points of Chattogram Shipbreaking Yard.

Pb average concentration in the current study was 0.469 mg/L (Figure 4.15). Yard-6 recorded the highest value of 0.824 mg/L, while yard-3 recorded the smallest value of 0.174 mg/L.

Due to failing anti-fouling paints and coatings, shipbreaking operations at Shipbreaking Yard 6 may result in the emission of Pb particles into the water. Corrosion from metal pipes, fittings, and valves can raise the concentration of Pb in the water. Additionally, ships use traces of Pb in their lubricants and gasoline, which can contaminate saltwater when they are dismantled. In order to avoid Pb pollution in the ocean, proper waste management procedures are essential.

At Shipbreaking Yard 3, due to processes including precipitation, chemical reactions, and marine organism assimilation, shipbreaking activities lower the amount of Pb in the water. However, the destruction of ships can have a substantial negative influence on the environment, causing pollution and harm to marine ecosystems. To reduce these impacts, it is crucial to handle and dispose of hazardous chemicals properly.

4.3 HEAVY METAL POLLUTION INDEX

To ensure that the water in the study's sampled areas had an equal concentration of all metals, the heavy metal pollution index (HPI) was used. Using MPIs for the water, we were able to determine the degree of contamination at each sample location. In the present research, the heavy metal pollution index's average value was 178.16 (Figure 4.16). Yard-6 recorded the highest value of 198.47, while yard-4 recorded the smallest value of 145.38. The overall value of Heavy Metal Pollution Index is given in Table 4 of Appendix C. These findings demonstrated that the research area's water was in a dangerous condition for consumption.

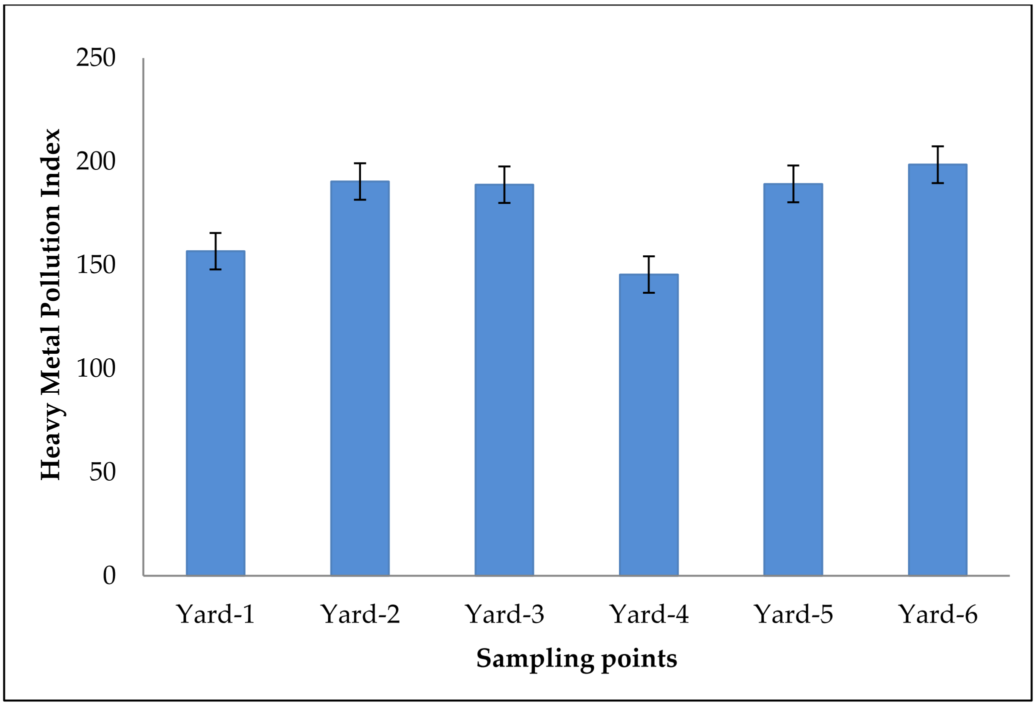

Figure 4.16 Heavy metals pollution index of water at different sampling points of Chattogram Shipbreaking Yard.

At Shipbreaking Yard 6, the High Pollution Index rises as a result of shipbreaking operations that release metals including Pb, copper, zinc, mercury, and Cd into the ocean. Pollution is a result of poor waste management techniques as well as rust and corrosion on corroded elements. When hazardous materials are handled and disposed of improperly, it results in pollution. Insufficient environmental restrictions may be the cause of this. A ship's breaking can release heavy metals into the environment, which can have an impact on both human and marine life as well as soils.

At Shipbreaking Yard 4, due to variables such as continual movement, dilution, accumulation of debris, and biological uptake, the Heavy Metal Pollution Index levels in shipbreaking zones drop. The government may enact restrictions, trash management, and erosion traps. However, the reduction might not be consistent and may differ between shipbreaking sites.

4.4 METAL CONCENTRATION IN SOIL

By serving as both sources and sinks of contaminants in aquatic ecosystems, soil contamination is one of the largest environmental concerns that ecosystems face, and soil analysis is crucial for determining how polluted the location is (Hossain et al., 2011; Hossain et al., 2021). The amount of heavy metals in several soil samples taken from the Sitakunda shipbreaking location is displayed in. The ranges for the hazardous metal concentrations were as follows: dry weight: Cr: 10.15-88.56 mg/kg; Pb: 16.99-78.56 mg/kg; As: 1.88-12.05 mg/kg; Cd: 0.01-1.16 mg/kg. Hg was not found in any of the analyzed samples, and the concentration of heavy metals in the soil samples was in the following order: Cr > Pb > As > Cd > Hg. When the levels of metal in the soil sample from the ship breaking yard are compared to the results of earlier studies conducted there, the current findings are found to be comparable to the concentrations in the soil of the ship breaking yard Sitakunda, Chattogram (Raknuzzaman et al., 2016). The current study found a higher concentration of heavy metals than previous reports for salt marsh soil along the coast of the Karnafuli River (Hossain et al., 2020; Siddique et al., 2021). The higher concentration of Cr in the water of shipbreaking places is probably due to the activities of dismantling large ships along the coast that transport enormous amounts of Cr-bearing materials, such as painting material, anti-corrosive materials, and Cr alloy.

4.4.1 Arsenic

Surrounding marine and coastal soils usually have total arsenic (As) concentrations ranging from 5 to 15 mg/kg dry weight, according to Díaz et al. (2021); however, deep-sea soil typically have an As concentration of over 40 mg/kg (Sattarova & Aksentov, 2021). According to Khajehpour et al. (2022), the As levels in riverbed soil in the UK vary between 7 and 950 mg/kg. Metal concentrations in soil from estuaries that get drainage through metal-mining sites may be much higher. Soil samples taken from the Carnon Estuary in southwest England, for example, measured total As contents ranging from 9 to 5,000 mg/kg (Khajehpour et al., 2022). Soil samples taken in southwestern Spain from the Tinto and Odiel rivers show As concentrations between 200 and 3000 mg/kg (Singare et al., 2012). Guidelines for the effects range median (ERM) and the effects vary low (ERL) 8.2 and 70 mg/kg dry weight, respectively, for total As in maritime soil (Alba et al., 2021).

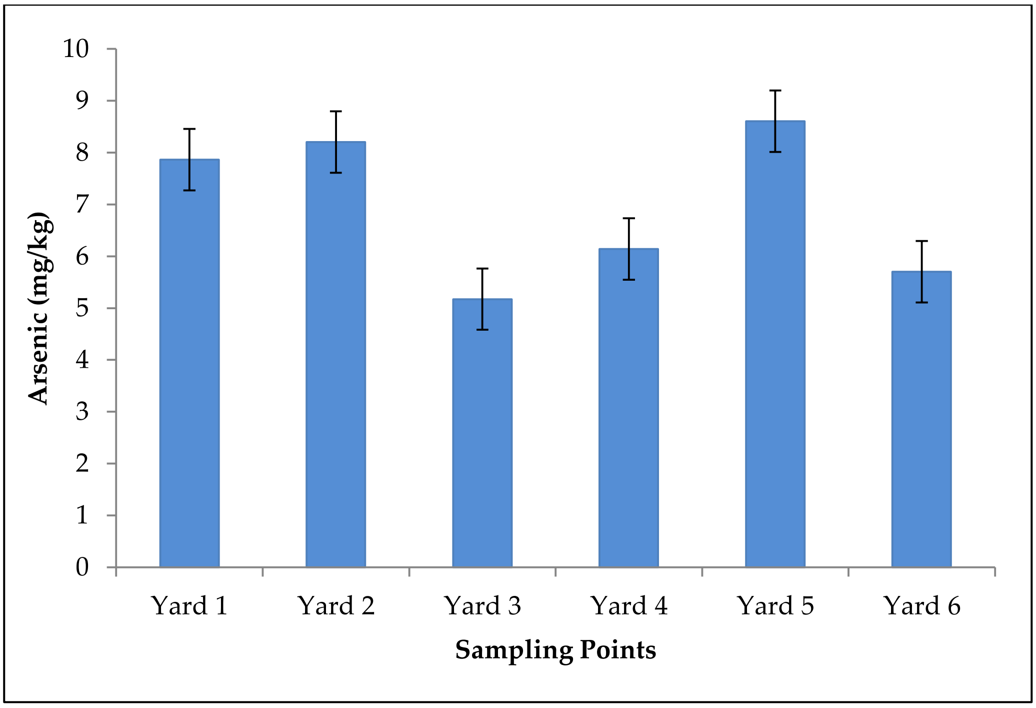

Figure 4.17 Arsenic of soil at different sampling points of Chattogram Shipbreaking Yard.

The average amount of As in this study was 6.99 mg/kg (Figure 4.17). The greatest value, 8.606 mg/kg, was discovered in yard 5, and the smallest value, 5.173 mg/kg, was discovered in yard 3. The overall value of As is given in Table 5 of Appendix C.

Due to variables including ship dismantling and recycling practices, shipbreaking activities in developing countries increase the amount of As in the soil at Shipbreaking Yard 5. Older ships and shipbuilding components like pipes and wires release As into the earth. To limit As contamination and lessen the environmental impact of shipbreaking, better waste management procedures, safer materials, and tougher environmental restrictions are required.

At Shipbreaking Yard 3, by combining soil with other elements, such as sand, pebbles, and garbage, shipbreaking can lower As levels in the soil. At shipyards that are close to water, wind and rain as well as human activity all move contaminated soil particles. Ship components drain As, and microbes degrade chemicals, lowering As levels. Although waste management, monitoring, and safety laws are essential for preventing long-term environmental damage, environmental rules and remediation initiatives can help alleviate pollution.

4.4.2 Chromium

Soil chromium (Cr) concentrations were higher than those of other metals because of the untreated wastes released into the environment by the textile, fertilizer, tannery, and petroleum sectors (Singare et al., 2012). When the Cr concentration from the current study was compared to numerous recommendations for soil quality, the levels of Cr (VI) concentration were found to be higher than the Threshold Exposure Limit (TEL), Specific Action-level Value (ASV) and Permissible Exposure Limit (PEL) standards (Kabir et al., 2020). Two factors could have contributed to the Cr enrichment of soil: (1) Natural: Concentration of minerals containing Cr (VI); and (2) Man-made: Release of oxidants with a Cr (VI) basis from industrial processes such tanneries and textile factories. Thus, the higher Cr (VI) content in the exposed deposit was most likely caused by the waste emitted from such enterprises. The study area's shipbreaking and textile industries have a history of large-scale chromate discharges, which could account for the water body's high Cr (VI) concentration (Proshad, et al., 2021).

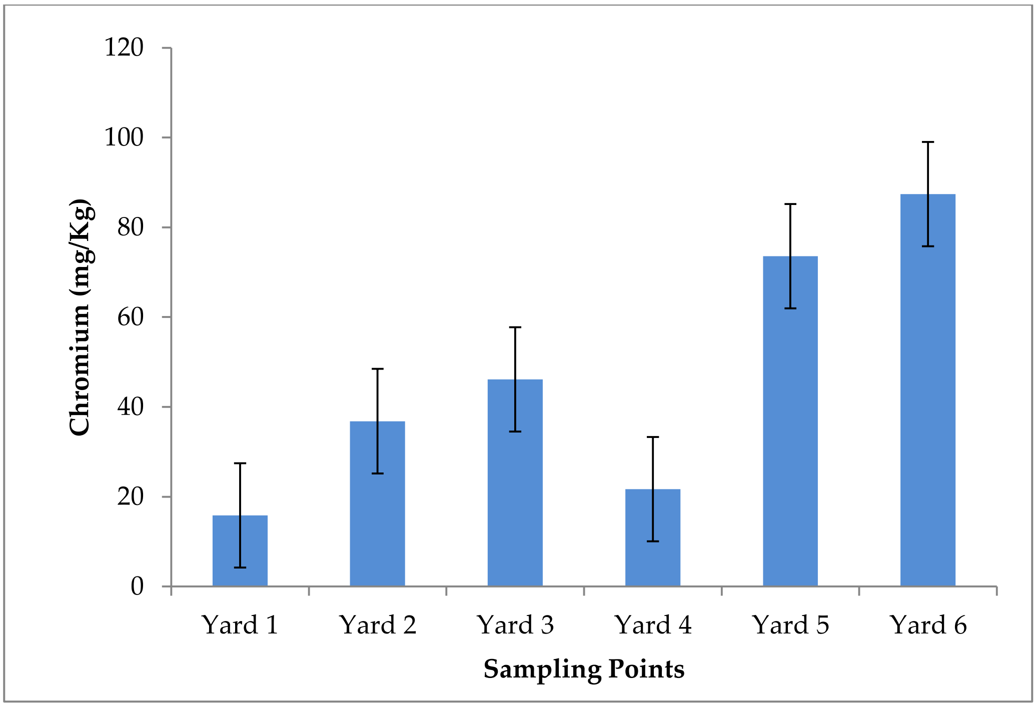

Figure 4.18 Chromium of soil at different sampling points of Chattogram Shipbreaking Yard.

The study's average value for Cr content was 46.905 mg/kg (Figure 4.18). Yard-6 recorded the highest value of 87.396 mg/kg, while yard-1 recorded the lowest value of 15.825 mg/kg.

At Shipbreaking Yard 6, due to processes like dismantling and recycling of ships, shipbreaking, also known as ship recycling, raises the amount of Cr in the soil. Shipbuilding-related paints and coatings containing Cr have the potential to flake off, leach, or release metal into the earth. Soil contamination can be made worse by poor waste management and disposal procedures in shipbreaking yards. Hexavalent Cr (VI) is hazardous and poses health concerns to both people and ecological systems. Its environmental impact must be reduced by proper management and regulation.

Shipbreaking yards can cause Cr levels to drop at Shipbreaking Yard 1 because of ship disintegration, dilution, and metal components. Cr is soluble and mobile, and it can enter the soil through bioremediation or precipitation.

Proper shipbreaking procedures can prevent pollution, damage to the environment, and long-term repercussions on ecosystems and public health.

4.4.3 Cadmium

The research area's water capacity may have changed during the winter, causing Cadmium (Cd) to precipitate in the soil and increase the concentration of amount of Cd , which, compared to summertime, were higher in wintertime (Ali et al., 2018). Saint Martin's Island had 0.3 mg/kg and Shah Porir Dwip Jetty had 0.40 mg/kg. Lower Cd concentrations were found in the coastlines of Salimpur (0.57 mg/kg), Bhatiari (0.83 mg/kg), Sonaichhari (0.94 mg/kg), Kumira (0.59 mg/kg), and Sandwip (0.19 mg/kg) (Barua, et al., 2017), revealed a lower concentration of Cd in the coastal Karnaphuli River and Chattogram shipbreaking zone, respectively (Sarker et al., 2020). These levels were 2.01 mg/kg and 0.88 mg/kg. Currently, the Cd concentration is substantially greater than what has been recorded at Shalateen, Cuddalore, and Saros Gulf beaches (Ali et al., 2016; Uluturhan, 2010). According to Maggesh et al. (2013), the silt from the coastal region of the Kallar Estuary in India contained a similar amount of Cd, 3.61 mg/kg.

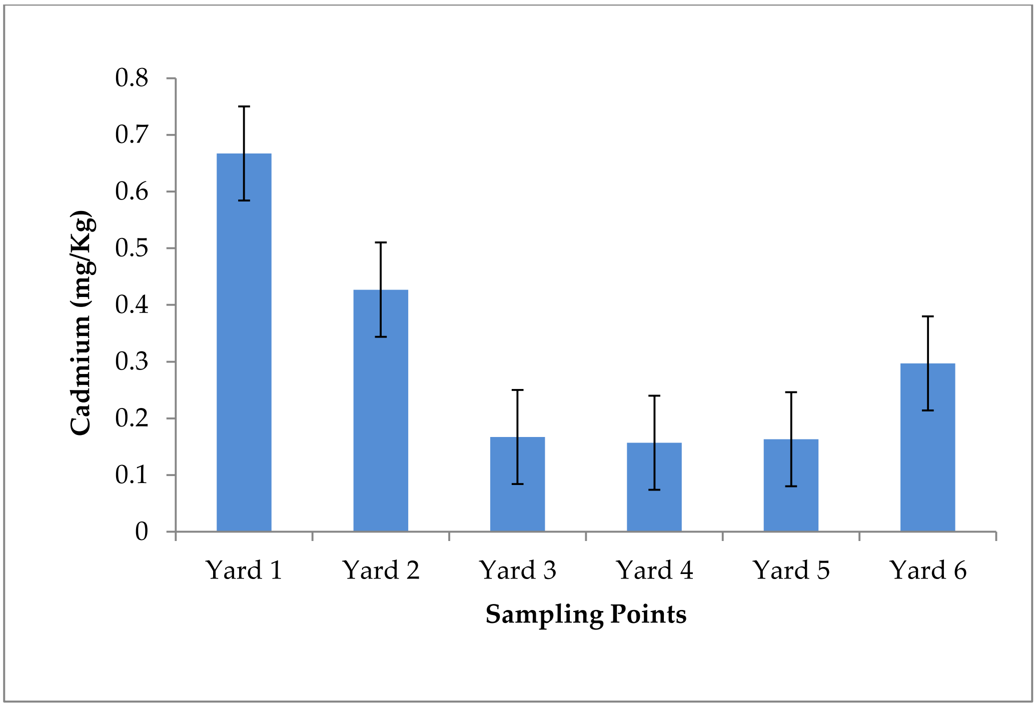

Figure 4.19 Cadmium of soil at different sampling points of Chattogram Shipbreaking Yard.

The study's average value for Cd content was 0.313 mg/kg (Figure 4.19). Yard-1 recorded the greatest amount of 0.667 mg/kg, while Yard-5 recorded the lowest amount of 0.157 mg/kg.

Cd levels in soil can rise at shipbreaking facilities as a result of a number of factors, including shipbuilding materials, metal components, and inadequate waste management practices at Shipbreaking Yard 1. Paints, coatings, and metals found on ships have the potential to degrade and release Cd into the earth. Additionally, garbage from shipbreaking can release Cd into the soil nearby. In some locations, poor waste management procedures result in the incorrect disposal of hazardous chemicals, contaminating neighboring soil and water sources. The heavy metal Cd is poisonous and dangerous for both the environment and people's health. To reduce Cd and other harmful contamination, proper waste management and environmental protection measures are crucial.

Ship component dispersal, heavy metal leaching, and contaminated water discharge all contribute to lower Cd concentrations at Shipbreaking Yard 5. While shipbreaking activities induce soil transport and erosion, plant species absorb Cd. Soil removal, containment, or treatments are all possible remediation methods. Restoring shipbreaking sites and efficiently reducing dangers depend on proper management and cleanup.

4.4.4 Lead

According to previous researchers(Ali et al., 2022; Shikazono et al., 2012), this may be the result of point- and non-point-source pollution from things like the production of cables, lubricants, tires, cement, and leaded gasoline as well as urban runoffs and atmospheric deposition. According to earlier research in Bangladesh and other nations, the majority of metal concentrations were discovered to be beyond some well-established benchmark criteria. Municipal runoffs, atmospheric deposition, steelworks, Pb gasoline, and other non-point sources may contribute the most lead (Pb) to the soil in the Bhairab River urban region (Ali et al., 2022). The organic composition must have been altered by resuspension and precipitation, as Pb concentrations in soil were discovered to be substantially greater in the winter compared to the summer (Ali et al., 2018; Bastami et al., 2014).

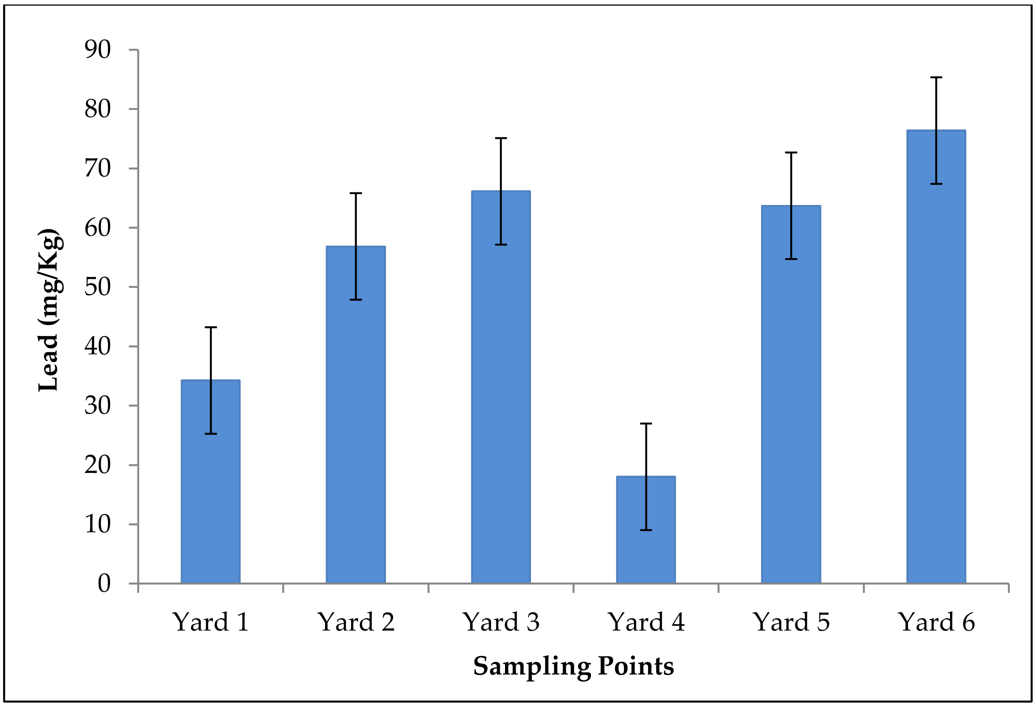

Figure 4.20 Lead of soil at different sampling points of Chattogram Shipbreaking Yard.

The study's average value for Pb content was 52.55 mg/kg (Figure 4.20). Yard-6 recorded the greatest amount of 76.396 mg/kg, while Yard-4 recorded the lowest amount of 18.016 mg/kg.

Due to Pb based paints, coatings, electrical components, ballast water, and other Pb containing compounds at Shipbreaking Yard 6, shipbreaking—the dismantling of old ships to recover valuable materials—can increase the amount of Pb in the soil. Lack of adequate controls in shipyards may cause Pb contamination and tiny dust particles. The environment and communities must be protected from Pb contamination by proper management and respect for environmental standards.

At Shipbreaking Yard 4 Pb concentrations gradually decrease as a result of shipbreaking activities due to the discharge of Pb particles and dust. Pb concentrations are reduced as these particles settle into the soil and combine with those from uncontaminated areas. Rainwater and other natural processes naturally absorb Pb into the ground and then leach it out. Authorities are motivated to decrease pollution because of environmental legislation and public awareness. Preventing additional contamination and protecting communities and ecosystems requires effective environmental management and cleanup solutions.

4.5 ASSESSMENT OF SOIL CONTAMINATION

The assessment of soil contamination is a very important process that looks at the presence and amount of harmful substances. This helps guide remediation and control strategies.

4.5.1 Geo-accumulation Index

The Geo-accumulation Index (I_{geo}) assesses the contamination levels of soil or soils based on the concentration of trace elements or pollutants. Ships often contain hazardous materials like heavy metals, PCBs, asbestos, and hydrocarbons, which can accumulate in soil during shipbreaking. Shipbuilding activities generate waste, such as leftover fuels, lubricants, paints, and chemicals, which can contribute to higher pollutant levels (Li et al., 2022). Shipbreaking can also result from inadequate containment measures, a lack of strict environmental regulations, and improper handling and disposal of hazardous materials. The I_{geo} index increases depending on shipbreaking practices, site conditions, and environmental factors in each location.

Igeo is a crucial environmental index that can assess the degree of pollution in soil samples and distinguish between metal sources that are the result of human activity and those that are natural in nature. Following average Igeo values, Pb > Cr > As > Cd was the sequence in which the research area's toxic metal contamination was delimited. Pb was determined to have the highest Igeo value (3.65), and Cd had the lowest Igeo value (-1.05). Pb was discovered to be "heavily contaminated," Cr (VI) to be "moderately contaminated," and As to be "uncontaminated to moderately contaminated" at the sample site (Table 4.1).

Table 4.1. The results of Geo-accumulation index of heavy metals in soil samples of Shipbreaking Yard.

Sample ID	Geo accumulation Index (I_{geo})			
	As	Cd	Pb	Cr (VI)
Yard 1	0.03	-0.53	2.1	1.61
Yard 2	0.27	0.31	0.44	0.53
Yard 3	-0.08	-1.05	3.26	1.36
Yard 4	0.37	-0.6	1.56	2.11
Yard 5	-0.09	-1.05	0.99	0.44
Yard 6	0.02	0.15	2.3	1.01

Same results were found by (Ramanathan et al., 2012; Yuksel et al., 2022) at the Chinese gold mine in the mining city of Zhaoyuan operations were the main cause of heightened hazardous metal levels in the aquatic condition. Soil from the Vatukoula Goldmine include higher than permitted concentrations of Cd, Pb, As, and Cr (VI). Igeo readings for the majority of the hazardous metals show that they are "moderately to highly pollute. "High quantities of hazardous metals were found in tailing dams and soils in areas with gold mining and processing in other studies (Wang et al., 2019), this was in line with what we discovered. The soil of the Nakauvadra-Rakiraki River system were completely free of any metals found to be unpolluted to moderately polluted ($0 < Igeo < 1$), with the exception of Cd, which had a moderately polluted ($0 \le Igeo < 2$) quality, and Pb, which had a moderately to badly polluted ($2 < Igeo < 3$) quality.

As and other elemental contaminants in the environment, especially in soils and sediments, can be quantified using the geo-accumulation index (*Igeo*). An uptick in *Igeo* at Shipbreaking Yard 4 is indicative of increased As concentrations caused by demolition, poor waste management, accidental spills, and lax environmental restrictions. Careful environmental management, waste disposal, and regulatory control can lessen the negative effects of industrial activity on soil and ecosystems (Li et al., 2022).

According to the Geo-accumulation Index, there has been a decrease in As contamination at Shipbreaking Yard 5. These point to a slow but steady decline in As contamination, which may be the result of remediation methods, stronger waste management regulations, and adjustments to the shipbreaking process. This has the potential to Pb to enhanced procedures and safer handling of pollutants (Alharbi et al., 2022).

In Shipbreaking Yard 3, the amount of Pb and other soil contaminants is being tracked using the *Igeo*. Soil contamination by Pb indicates long-term shipbreaking activities involving the destruction of historic ships, the use of hazardous products, the incorrect disposal of waste, and other sources of soil pollution (Panqing et al., 2023).

According to the *Igeo*, which assesses the amount of Pb in soils, shipbreaking yard 2 Pb content has decreased. Remedial actions, natural processes, industrial activity, waste disposal procedures, and human interventions are among the factors causing this decline. To properly comprehend the observed decline in Pb levels, though, a thorough grasp of environmental and health concerns are required (Kibria et al., 2016).

The *Igeo*, which shows higher levels in Shipbreaking Yard 4, measures Cr (VI) pollution in soil. This growth is a result of a number of factors, including industrial operations, inappropriate disposal, mishaps, and insufficient environmental controls. To solve the problem, efficient waste management must be implemented, the sources must be looked into, and any polluted soil needs to be remedied. To stop additional pollution, it might also be required to implement monitoring and regulatory procedures (Alharbi et al., 2022).

Soil Cr (VI) pollution is being addressed at Shipbreaking Yard 5 through remediation efforts, enhanced waste management, stronger environmental restrictions, and natural processes including weathering and leaching. There may be a connection between the increased vigilance and the decline in the Igeo index measured at yard 5, but this has to be looked into further (Kibria et al., 2016).

Due to its history of intensive industrial use, poor waste management, and inadequate environmental restrictions, Shipbreaking Yard 2 is a textbook case of soil contamination. For an analysis of Cd buildup in soil, use the Geo-Accumulation Index. In order to solve this problem, we need accurate environmental evaluations, effective waste management, and the cleanup of polluted areas. Soil pollution can be avoided in the future if sustainable shipbreaking procedures are encouraged (Kibria et al., 2016).

The decline in Cd levels in Shipbreaking Yard 5 can be linked to a number of things, including cleanup efforts, natural processes, changes in activity, and sample variability; however, to pinpoint the exact cause, a full examination of the site's past is necessary.

4.5.2 Contamination Factor

The contamination factor (CF) is a method for quantifying the degree of pollution in a region or substance, taking into account the presence of contaminants such as heavy metals. The presentation of contamination elements from soil samples from a shipbreaking yard (Table 4.2). In the current investigation, the sampling site's degree of contamination factor, which was 11.7964, indicated a moderate degree of contamination ($6 \leq C_d < 12$) and was where the largest CF was discovered. In the sampling location, the lowest degree of CF was discovered to be 5.23, which indicated low degree of contamination ($C_d < 6$).The average levels of contamination for each metal were determined to be as follows: Pb: 2.67 (moderate contamination); Cd: 0.444 (low contamination); Cr (VI): 2.96 (moderate contamination); and As: 1.10. (Moderate contamination).

Table 4.2. The contamination level of the soil samples from the shipbreaking yard.

Sample ID	Contamination Factor (C_f)				Degree of Contamination (C_d)
	As	Cd	Pb	Cr (VI)	
Yard 1	1.55	0.04	2.84	2.83	7.26
Yard 2	0.92	0.05	1.82	2.44	5.23
Yard 3	0.095	0.047	2.67	3.12	5.93
Yard 4	1.02	0.05	2.45	3.02	6.54
Yard 5	0.61	0.05	2.00	0.44	3.31
Yard 6	1.45	0.034	3.26	1.01	5.63
Mean	1.10	0.04	2.67	2.96	5.65

Shipbreaking Yard 1 is a potential source of soil contamination due to the presence of hazardous materials, oil spills, chemicals, and the deconstruction of aging ships. Incorrect waste management, the use of large machinery, and natural disasters can all Pb to soil pollution (Kibria et al., 2016). Strict environmental rules, adequate training, safe handling, and regular monitoring, in addition to the development of better shipbreaking procedures, are vital to reducing this risk (Panqing et al., 2023).

Due to remediation efforts, increased adherence to environmental rules, and enhanced waste management, the CF at Shipbreaking Yard 3 has dropped. The yard may have instituted better waste management, cleaner practices, and routine monitoring to pinpoint the origins of contamination. Weathering and microbial degradation are two natural processes that can help clean up contaminated soil over time. Increased understanding of environmental and health dangers linked with shipbreaking activities may have led to improved procedures and pollution prevention. The actual causes of the drop in CF at Shipbreaking Yard 3 must be determined through a thorough site-specific assessment (Kibria et al., 2016).

4.5.3 Enrichment Factor

Enrichment factor (EF) is frequently used in a variety of applications, including analytical chemistry and environmental research (e.g., evaluating the concentration of trace elements and determining the concentration of contaminants in soil). Informed decisions can then be made based on the EF value, which aids researchers and analysts in determining the relevance of the observed concentrations. The analyzed sampling site's EF is shown in (Table 4.3). In the most recent analysis, all metals (Pb, Cr (VI), and As) except Cd had EF values that were greater than 1, indicating that the sources of those metals (Pb, Cr, and As) are more likely to be artificial A score of ($0.5 \leq EF \leq 1.5$) indicates that metal traces may be caused by crystal materials or by the weathering naturally processes of the environment (Yang et al., 2020).

Shipbreaking can raise the amount of EF in the soil because ship parts are made of dangerous materials like heavy metals. These things can seep into the ground and run off into nearby bodies of water, making the land dirty. Ineffective waste management, a lack of regulations, or unintentional spills can also result in soil contamination (Khan et al., 1992). Ships that carry large amounts of fuel and oil also pollute the soil. Soil pollution and environmental damage can be kept to a minimum by following environmental laws and best practices. Effective waste management, garbage containment, and cleanup can help lessen the harm that shipbreaking does to soil and ecosystems (Hasan et al., 2013).

Table 4.3. Heavy metal Enrichment Factor in soil samples from a Shipbreaking yard.

Sample ID	Enrichment Factor			
	As	**Cd**	**Pb**	**Cr (VI)**
Yard 1	1.55	0.03	3.57	2.61
Yard 2	0.92	0.04	1.94	2.11
Yard 3	0.95	0.04	3.26	2.36
Yard 4	1.02	0.03	2.56	2.11
Yard 5	0.61	0.025	3.99	1.44
Yard 6	0.02	0.03	3.3	4.01
Mean	0.845	0.0325	3.103333	2.44
Std	0.461907	0.00559	0.672772	0.787189

Due to factors including disassembling aging ships, poor waste management, soil features, and historical pollution sources, As levels in Shipbreaking Yard 1 are rising. To pinpoint the origins and direct cleanup activities, a thorough environmental evaluation is required (Kibria et al., 2016).

As levels in the soil at Shipbreaking Yard 6 are measured using the enrichment factor. As levels go down when the EF goes down. EF can change because of things like cleaning up the soil, changing how ships are broken up, natural processes, environmental laws, and government incentives (Panqing et al., 2023).

Because of past ship maintenance, insufficient waste management, weathering processes, industrial vicinity, and lax environmental restrictions, the EFin the soil at Shipbreaking Yard 2 may rise. The physical characteristics of the soil, pH level, amount of organic matter, and mineral makeup all affect Cd mobility and retention, which may have an impact on groundwater (Alharbi et al., 2022).

The EF indicates that the Cd concentration at Shipbreaking Yard 2 is lower than the background level. Changes in the shipbreaking industry, cleanup initiatives, waste disposal procedures, natural processes, and the entry of uncontaminated soil, sample variability, and data-gathering techniques are some of the factors that have contributed to this decline. To comprehend the precise causes, more research and analysis of historical data are required (Alharbi et al., 2022).

At Shipbreaking Yard 5, the EF a measure of soil pollution due to things like dismantling old ships, improper management of Pb containing components, precipitation, deteriorating infrastructure, and natural soil features, is rising. A thorough environmental evaluation is required to establish the sources and methods of Pb contamination since changes in environmental rules and enforcement may have an impact on how these yards handle Pb - containing products (Kibria et al., 2016).

Due to ship maintenance and dismantling activities, Shipbreaking Yard 2 frequently experiences Pb pollution. Cleaning up the yard, enacting stronger laws, and supporting plant species with hyperaccumulation properties are all possible ways to lower the concentration of Pb in the soil. Environmental evaluation and monitoring chart the evolution of the EF through time.

Pollution from Cr (VI) can be found in the soil of many shipbreaking yards as a result of careless trash disposal, deteriorating ship parts, and rainwater leaching. The environmental damage and human health concerns posed by this contamination are real. Keeping an eye on and controlling Cr (VI) pollution at Shipbreaking Yard 6 is essential for keeping the environment and people safe (Kibria et al., 2016).

Cr Enrichment Factor for soil can be reduced by Shipbreaking Yard 5, which is in charge of dismantling and recycling obsolete ships. This decline is attributable to the development of waste and debris as well as the separation and recycling of resources like steel and other metals. This does not, however, ensure soil contamination (Alharbi et al., 2022).

4.5.4 Pollution Load index

The Pollution Load Index (PLI), a numerical indicator used to assess pollution levels in a particular location while taking into account various contaminants and their concentrations, offers a thorough picture of environmental effects. The calculated PLI amount of harmful metals in soil is outlined in (Figure 4.21). If the estimated PLI score is more than one, only harmful metals are present in the area under study, according to (Tomlinson et al., 1980b)'s research. The shipbreaking zone's whole sampling network has all values between 1.91 and 3.10, indicating that the silt in the Study Rivers around the coast was highly contaminated (PLI > 1). We computed and published PLI values for all study sites so that you can comprehend the actual concentrations of the cumulative PHM load and evaluate the status of sequential contamination. Every sampling site exhibited PLI values greater than unity, which may have been a result of the effects of shipbreaking and other industrial activity in the research sites. At sample sites compared to other sampling stations, pollutant concentrations are higher. The general public can obtain some information from the PLI about the quality of the soil. Also, it provides crucial data on the level of pollutants in the area for study to decision-makers (Suresh et al., 2012).

In the present research, the pollution load index's average value was 2.48 (Figure 4.21). The yard with the highest value of 3.1 was yard 2, while the yard with the lowest value of 1.91 was yard 4. The overall value of pollution load index is given in Table 9 of Appendix C.

At Shipbreaking Yard 2, due to variables like poisonous compounds, hazardous substances, and poor waste management techniques, the PLI level in the soil at the shipbreaking yard rises. Ships contain asbestos, PCBs, heavy metals, and other potentially dangerous materials that are released into the environment during deconstruction. PLI levels are raised as a result of unintentional spills and leaks, poor waste management, and disturbances of large machinery and equipment. Pollution is sometimes a result of insufficient infrastructure and a lack of environmental rules. To lessen pollution and its effects in these places, proper waste management, adherence to laws, and safer shipbreaking techniques are essential (Kibria et al., 2016).

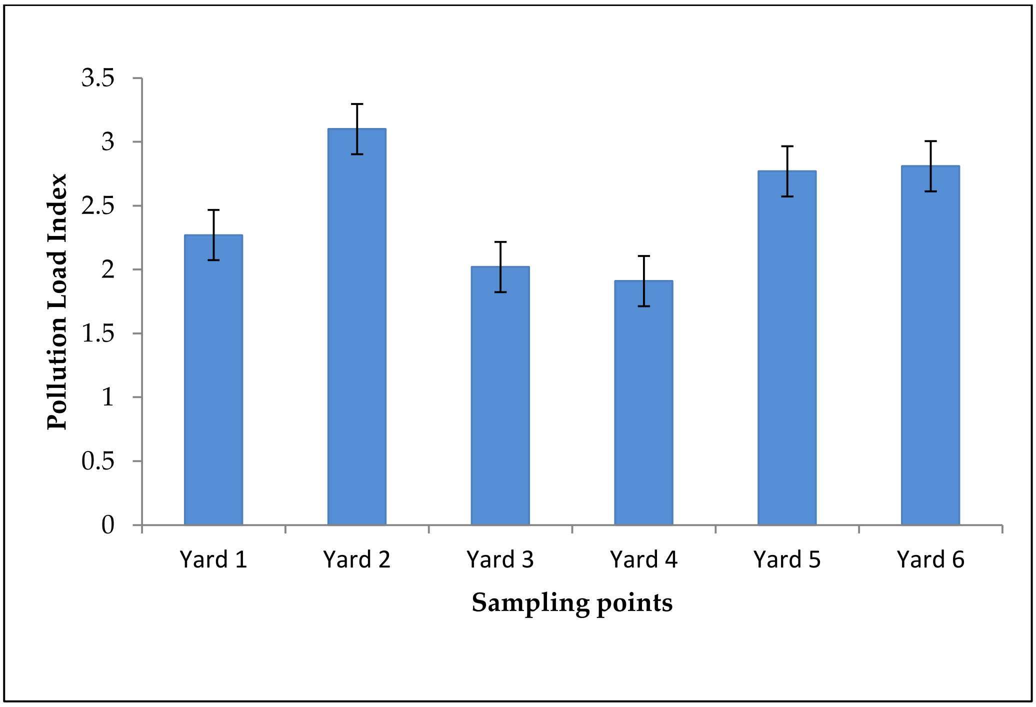

Figure 4.21 Pollution Load Index of soil at different sampling points of Chattogram Shipbreaking Yard.

At Shipbreaking Yard 4, PLI levels at shipbreaking sites might go down due to shipbreaking activities, natural processes, or remediation initiatives. Soil depletion due to leaching pollution. Even when soil stabilization, containment, and cleanup are completed, pollution levels may still be high, and they may remain so for years (Kibria et al., 2016).

4.5.5 Potential Ecological Risks Indices

The ecological risk indices that could be linked to the risk index (E_r^i and RI) were assessed in order to calculate the danger of the soil constituents under examination. Shipbreaking activities can increase PERI Indices levels in soil due to hazardous materials, waste generation, and inadequate waste management practices. Ships are complex structures with heavy metals, asbestos, PCBs, and other toxic chemicals, which can contaminate the environment. Shipbreaking activities also generate waste, which can end up in soil if waste management practices are inadequate. Inadequate waste management and containment practices can Pb to increased PERI levels. To protect marine environments, stringent environmental regulations and responsible shipbreaking practices are crucial. For all metals, the ecological risk (RI) is below (RI < 100), suggesting a low danger. A high risk of hazardous metals is indicated by the value of (160 ≤ E_r^i< 320), in contrast to. The symbol hazardous metals present a very significant risk (E_r^i ≥ 320). Only the risk index is used method for assessing contamination generally because hazardous metal poisoning in an environment that is natural, particularly the habitat in the water, is typically difficult. The geochemical makeup of the basin and the elevated quantities of hazardous metals caused by the dumping sites of household and industrial trash has an impact on the aquatic ecosystems.

The potential ecological risk index is used in the current investigation. As demonstrated in (E_r^i) for all metals, Pb was followed by As, Cd, and Cr (VI) in decreasing order (Table 4.4). The highest results came from the Yard 2 site. The Yard 2 site displayed the greatest (E_r^i) for Pb of all the sites (771.00). According to (Obhodaš et al., 2006), one argument for why hazardous metals exists is that it mixes a number of metallic elements used in production. The locations were, however, the components are categorized as having a minimal ecological risk as (E_r^i's) data were less than 30, which was a sign of this. A very high-risk limit was also indicated by the fact that the RI for every metal in the research zone was significantly higher than 100. The investigation comes to the conclusion that hazardous metals offer environmental risks even in the Shipbreaking area.

The report also recommended that steps be taken to preserve the ecosystem of the coastal region and put in place an emergency action plan.

Table 4.4. Risk Index and Potential Ecological Risks for Hazardous Metals in soil at different sampling points of Chattogram Shipbreaking Yard.

Sample ID	**Potential Ecological Risks (PERI)**				**RI (Risk Index)**
	As	**Cd**	**Pb**	**Cr (VI)**	
Yard 1	21.39	17.71	429	2.5	470.6
Yard 2	35.15	23.91	771	4.12	834.18
Yard 3	23.47	10.38	392	2.16	428.01
Yard 4	19.52	9.27	507	1.57	537.36
Yard 5	33.55	18.15	575	3.87	630.57
Yard 6	30.36	21.85	601	3.68	656.89
Average	27.24	16.87833	545.8333	2.983333	592.935

Due to the presence of heavy metals, chemicals, and physical disturbances, shipbreaking yard 2 might result in higher PERI scores in the soil. These heavy metals have a harmful effect on plants, soil organisms, and the environment when they leak into the soil. Strict environmental legislation, appropriate waste management, and sustainable shipbreaking methods, like ship recycling facilities, are necessary to reduce these dangers (Panqing et al., 2023).

The ecological risks PERI in the soil at shipbreaking yard 3 can be mitigated by a variety of strategies, including soil remediation, natural processes, and a steady reduction of contaminants. Planting plants, strengthening environmental rules, and restoring yards are all practices that can be implemented to improve soil stability and cut PERI. Reducing PERI should be prioritized to protect the health of employees and the environment; this will require investments in remediation and long-term planning (Kibria et al., 2016).

Chapter 5: CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The investigation's findings show that metal concentrations were higher than the permissible level for the environment. The assessed indicators of the quality of the water (CI and MPI) showed that the study area's water had become unsafe for human consumption, which ultimately had an impact on the analyzed metal contents. The yard had the highest concentration of Pd, then Cr (VI), As, and Cd. Only As and Cd showed a noticeable variance in distribution across all the elements. Contaminated metals had a devastating effect on the coastal ecosystem's ecological productivity, putting the study area at high risk according to the risk index and the projected environmental risk assessment. The soil quality was moderately to substantially damage by hazardous metals, particularly As, Cb, and Pd, according to geochemical index analysis (*Igeo*, PLI, and CF).

Furthermore, the multivariate analysis showed that human activities instead of geogenic sources were affected by introducing both metals to the area for study. As a result, there were substantial environmental dangers related to hazardous metals from the ship-breaking process. The expansion of the shipbreaking yard in the country should only be authorized if there is minimal pollution. The continuation of this venture cannot in any way be justified by a longer stretch of the seashore; rather, the appropriate authorities should select another location, such as a dockyard. As soon as possible, before it's too late, preventative measures should be taken to reduce the environmental and health concerns connected with shipbreaking.

The ship-breaking industry in Bangladesh has a positive impact on the economy but also negatively impacts the environment and biodiversity. Extreme contamination was found in yards (1, 4, and 6) during this investigation. In order to ensure that the pollution generated is kept to a minimum, it is crucial to take adequate safeguards against the health and environmental dangers that are connected with shipbreaking. Finding out the consequences of shipbreaking yards on the environment, human health, and marine life might be the subject of future studies. Given the beneficial impact on the economy of shipbreaking in Bangladesh, it is impossible to stop the sector. In contrast, it is important to remember that the shipbreaking business has a negative impact on the environment and biodiversity. Sustainable methods need to be used in our Chattogram coastal area to lessen the harmful effects of the shipbreaking and recycling industries.

5.2 RECOMMENDATIONS

The importance of shipbreaking to national economies means it must be allowed to continue. The following measures could be adopted to ensure the long-term viability of ship-breaking operations along the Chattogram coast: After hearing from industry groups, employers, and workers, the government should develop and execute a set of national guidelines for shipbreaking that prioritize safety and sustainability.

Government policy should ensure worker rights and welfare, occupational safety and health (OHP), and environmental friendliness. The Factory Act of 1965 calls for bringing the industry under the Ministry of Industry's jurisdiction.

Chattogram's Master Plan calls for the construction of recreational facilities at Sitakunda; however, this plan must be altered until definitive research is conducted by specialists on the effects of shipbreaking being developed at its current site.

a. To break a ship, one needs a certificate stating that it is gas-free. Before a ship can be reached for breaking, the Mercantile Marine Department requires that all oil be removed and the oil tanks be cleaned chemically or physically.
b. Before the Department of Environment (DoE) and the Department of Shipping can issue a certificate of compliance for the prevention of pollution during ship-breaking, they must conduct thorough and regular inspections of the entire yard.

When possible, we should leave the ocean alone so that marine life can thrive and people can stay healthy. Because many shipbreaking materials are poisonous and hazardous to aquatic life and human health, they are banned in many countries. Therefore,

a. An immediate scientific study, both short-term and long-term, is required to evaluate the effects of shipbreaking on coastal water, soil, and human health.
b. No one should be granted a ship-breaking license unless he can provide proof that he has leased the necessary land for the activity.
c. In place of beachfront locations, the authority should choose a "certain isolated and protected scrapper's yard" for ship demolition.
d. Public awareness will be raised by the dissemination of assessment results in national and international publications.

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Appendices

Appendix A:

1. The laboratories of CUFL and BCSIR in Chattogram have the equipment and chemicals needed to measure water and soil quality parameters.
2. This part of the thesis includes essential data.
3. At the time of sampling, some pictures of pollution were taken around the Shipbreaking Yard.

Appendix B: INSTRUMENTS AND CHEMICALS

Multi parameters Meters

A Japanese Multiparameters Meter (HACH sension™378) has been used to measure pH, Salinity, Electrical Conductance, Total Dissolved Solids, Dissolved Oxygen, and Biochemical Oxygen Demand.

Ultra Violet-Visible Spectroscopy

(UV-VIS) (Model: VP-100) is used for the determination of metals.

Apparatus

Refractometer, Colour Comparator, BOD incubator, BOD bottles, Plastic bottles, Soft tissue paper, Whitman Filter paper (70 mm), Liebig Condenser (30cm), Beaker, Conical flask, Flat bottom flask, Funnel, Burette, Erlenmeyer flask, Volumetric Flask, Desiccators provided with a desiccant, Analytical balance capable of weighing up to 0.1mg, Blackman Conductivity Meter.

Reagent and chemicals

Standard Sulfuric Acid H_2SO_4, Standard NaOH, HNO_3, $HClO_3$, $K_2Cr_2O_7$, $AgSO_4$, Ag_2SO_4, Mercuric Sulfate, $HgSO_4$ crystals, EDTA, NH_4OH, $MgSO_4.7H_2O$, Erichrome Black T, Methyl Red, Methyl Orange, Phenolphthalein, Standard Silver Nitrate ($AgNO_3$), Standard Sodium Chloride Solution (NaCl), Standard Carbonate (Na_2CO_3), $KHC_8H_4O_4$, Buffer solution (pH-10), $KMnO_4$, $Na_2C_2O_4$, HCl, Activated Carbon, Vanadate-Molybdate reagent, Ammonium metavandate (NH_4VO_3), Standard Phosphate Solution, Murexoide in tablet form, Ferroin Indicator, Ferrous Ammonium Sulphate (FAS), Potassium Hydrogen Phthalate ($HOOCC_2H_4COOK$) standard.

Appendix C:

Table 1: Collection and preservation of Samples Collection of Samples

Determination	Container	Min. size mL	Preservation	Maximum Storage Recomended	Regulatory
Acidity	P.G.(B) FP	100	Cool,=<6°C	24h	14d
Alkalinity	P.G.FP	200	Cool,=< 6°C	24h	14d
BOD	P.G.FP	1000	Cool,=< 6°C	6h	48h
CO_2	P. G	100	Analyze immediately	025h	N.S.
COD	P.G. FP	100	Analyz as soon as possible or add H_2SO_4 to pH<2, Cool, =<6°C	7d	28d
Specific Conductance	P.G. FP	500	Cool,=< 6°C	28d	28d
Hardness	P.G. FP	100mL	pH<2	6months	6months
Chromium Vl	P(A). G(A). FP(A)	250	Cool=<6^{0}C, pH 9.3-9.7	28d	28d
Copper	-	-	-	-	-
Mercury	P(A). G(A). FP(A)	500	pH<2, cool=<6^{0}C	28d	28d
Nitrate	P.G.FP	100	Analyze as soon a possible;=< 6^{0}C	48h	48h
Ammonia	P.G. FP	500	Analyze as soon as possible; pH<2, cool=< 6^{0}C	7d	28d
Nitrite	P.G. FP	100	Analyze as soon as possible; cool=< 6^{0}C	None	48h
pH	P.G	50	Analyzed imediatly	0.25h	0.25
Phosphate	G(A)	100	For dissolved phosphate filter immediately cool=< 6^{0}C	24h	24h
Metals	P(A), G(A), FP(A)	1000	For dissolved metals filer immediately, add HNO_3 to pH<2	6months	6months
Salinity	G. wax seal	240	Analyze immediately	6months	N.S.
Temperature	P.G. FP	-	Analyze immediately	0.25h	0.25h
Turbidity	P.G. FP	100	Analyze same day; store in dark up to 24h, Cool , =<6^{0}C	24h	48h
P^H	p, g	50	Analyze Immediately	2 Hours	--
D.O	G/BOD Bottle	300	Analyze Immediately	30 Min	--
BOD_5	p, g	1000	Refrigerate	6h/48h	--
TDS	p, g	2000	Refrigerate	7 days	--
COD	p, g	100	2mL H_2S0_4	7 days	--
Turbidity	p, g	1100	Analyze same day/ Refrigerate	--	
T. Alkalinity	p, g	200	Analyze same day/ Refrigerate	--	
T. Hardness	p, g	100	Add H_2N0_3 to P^H <2	6 Month	
Iron	p(A), g(A)	500	Add H_2N0_3 to P^H <2	6 Month	
Manganese	p(A), g(A)	500	Add H_2N0_3 to P^H <2	6 Month	
Nitrate Ion	p, g	100	as soon as possible or Refrigerate	7 days	
Chloride	p, g	50	Not required	28 days	
Cromium	p, g	500	Add H_2N0_3 to P^H <2	24 Hours	
$P0_4^{3-}$-P	p, g	500	Analyze as soon as possible or Add H_2N0_3 to P^H <2	7 days	

Table 2: Water quality Parameters of Bangladesh Standards and WHO Guide Line

Sl. No.	Water Quality Parameters	Bangladesh Standards (ECR, 1997) (mg/L)	Standards (Marine water quality) (WHO Coastal water standard)	Methods/ Equipment
01	Water Temperature	40 ^{0}C	-	Mercury Celsius thermometer, Digital thermometer, DO meter, IR thermometer.
02	Air Temperature	-	-	Mercury Celsius thermometer, Digital thermometer, DO meter, IR thermometer.
03	pH	6-9	6.0-8.5	pH Meter, Multi parameter.
04	DO	4.5-8.0	4.5-6	Multi parameter, Azide Modification Method of Winkler, Permanganate Modification
05	BOD 5 Day, 200C	50	5.0	5 days Incubation, Multi parameter, Azide Modification Method of Winkler.
06	COD	200	-	Closed Reflux Method.
07	Salinity	-	-	Multi parameter, Conductivity meter, Refractometer.
08	Total Suspended Solids	10	20 mg/L (Partly clear)	Filtration and Drying, Multi parameter.
09	Total Dissolved Solid	2100	500	Multi parameter
10	Oil and grease	10	10	Glassware
11	Turbidity	10 NTU	3NTU	Turbidity meter.
12	Electric Conductivity	1200-μs/cm	3000-μs/cm	Multi/Conductivity meter.
13	Total Alkalinity	-	-	Titrimetric method.
14	Hardness as $CaCO_3$	200-500	-	Titrimetric method.
15	Ammonia	0.5		UV-VIS, AAS.
16	Chlorine (Residual)	470-789	600	Titrimetric Method.
17	NH_3	5	-	UV-VIS, AAS.
18	Phosphate-P	6	-	UV-VIS, AAS.
19	Colour	15 Hazen	-	Colour Comparator.
20	Zinc	5	-	AAS.
21	Iron	0.3-1.0	-	AAS.
22	Metal (As, Cr, Cd, Pb)	0.05	0.01	AAS.
23	Cupper	1	2	AAS.

Table 3: Physico-chemical parameters of water sample (Physicochemical) in the Shipbreaking Yard from Sp-1 to Sp-18

Yard No.	Sample ID	Water Temp. °C	pH	EC µS/cm	TDS mg/L	DO mg/L	BOD mg/L	COD mg/L	TSS mg/L	Salinity ppt	Oil & grease mg/L	Turbidity NTU
Yard - 1	Sp-1	29.57	8.54	3512.12	1756.01	6.18	4.03	74.13	3033.01	5.49	10120.00	278.48
	Sp-2	29.67	8.64	3512.22	1756.11	6.28	4.13	74.59	3033.09	5.59	10120.09	278.58
	Sp-3	29.77	8.74	3512.32	1756.22	6.38	4.23	75.47	3033.11	5.69	10120.20	278.68
Yard -2	Sp-4	29.34	7.62	1215.57	607.68	6.58	6.94	72.45	4292.73	11.37	9180.73	196.53
	Sp-5	29.44	7.72	1215.67	607.78	6.48	7.04	72.48	4292.83	11.27	9180.83	196.63
	Sp-6	29.54	7.82	1215.77	607,87	6.38	7.14	72.66	4292.93	11.17	9180.93	196.73
Yard - 3	Sp-7	30.90	7.63	1352.47	676.23	7.17	4.17	79.36	2993.79	16.47	7352.79	103.59
	Sp-8	31.00	7.73	1352.57	676.33	7.27	4.27	79.18	2993.99	16.57	7352.89	103.69
	Sp-9	31.10	7.73	1352.67	676.43	7.37	4.37	79.27	2993.89	16.67	7352.99	103.79
Yard - 4	Sp-10	28.34	7.81	1546.77	773.11	7.58	3.51	83.44	4515.59	15.24	1284.36	368.81
	Sp-11	28.44	7.91	1546.87	773.22	7.68	3.61	83.76	4515.69	15.34	1284.46	368.91
	Sp-12	28.54	7.71	1546.97	773.32	7.78	3.71	83.65	4515.79	15.44	1284.56	368.71
Yard - 5	Sp-13	30.01	8.17	1953.23	976.51	5.56	2.56	91.75	3803.48	11.37	8243.15	676.87
	Sp-14	30.11	8.27	1953.33	976.61	5.66	2.66	91.74	3803.58	11.47	8243.25	676.97
	Sp-15	30.21	8.37	1953.43	976.71	5.67	2.76	91.50	3803.68	11.57	8243.35	676.77
Yard - 6	Sp-16	29.11	7.97	2592.57	1296.16	6.30	2.34	93.27	4115.49	17.62	6818.18	417.16
	Sp-17	29.22	8.07	2592.67	1296.26	6.40	2.44	93.44	4115.39	17.72	6818.28	417.06
	Sp-18	29.32	8.17	2592.77	1296.36	6.50	2.54	93.65	4115.59	17.82	6818.38	417.26

Table 4: Analysis of Water Quality in the Shipbreaking Yard from Sp-1 to Sp-18.

Yard No.	Sample ID	Heavy Metal Pollution Index (HPI)
	Sp-1	156.66
Yard - 1	Sp-2	156.76
	Sp-3	156.86
	Sp-4	190.22
Yard - 2	Sp-5	190.32
	Sp-6	190.42
	Sp-7	188.64
Yard - 3	Sp-8	188.84
	Sp-9	188.74
	Sp-10	145.28
Yard - 4	Sp-11	145.38
	Sp-12	145.48
	Sp-13	189.09
Yard - 5	Sp-14	189.19
	Sp-15	189.29
	Sp-16	178.55
Yard - 6	Sp-17	178.45
	Sp-18	178.35

Table 5: Heavy metals concentrations of water samples in the Shipbreaking Yard from Sp-1 to Sp-18.

Yard No.	Sample ID	Arsenic (As) mg/L	Cadmium (Cd) mg/L	Lead (Pb) mg/L	Chromium (Cr) mg/L
	Sp-1	0.24	0.073	0.266	0.343
Yard - 1	Sp-2	0.34	0.083	0.286	0.353
	Sp-3	0.44	0.093	0.276	0.363
	Sp-4	0.22	0.022	0.347	0.247
Yard - 2	Sp-5	0.32	0.032	0.337	0.257
	Sp-6	0.42	0.042	0.327	0.267
	Sp-7	0.51	0.051	0.164	0.544
Yard - 3	Sp-8	0.61	0.061	0.174	0.554
	Sp-9	0.71	0.071	0.184	0.564
	Sp-10	0.222	0.013	0.651	0.836
Yard - 4	Sp-11	0.232	0.023	0.661	0.846
	Sp-12	0.242	0.033	0.671	0.856
	Sp-13	0.533	0.043	0.545	0.134
Yard - 5	Sp-14	0.543	0.053	0.535	0.144
	Sp-15	0.553	0.063	0.555	0.154
	Sp-16	0.33	0.035	0.834	0.957
Yard - 6	Sp-17	0.43	0.045	0.824	0.947
	Sp-18	0.53	0.055	0.844	0.937

Table 6: Heavy metals concentrations of Soil samples in the Shipbreaking Yard from Sp-1 to Sp-18.

Yard No.	Sample ID	Arsenic (As) mg/Kg	Cadmium (Cd) mg/Kg	Lead (Pb) mg/Kg	Chromium (Cr) mg/Kg
	Sp-1	7.877	0.657	34.15	15.815
Yard - 1	Sp-2	7.867	0.667	34.25	15.825
	Sp-3	7.857	0.647	34.35	15.835
	Sp-4	8.196	0.417	56.72	36.62
Yard - 2	Sp-5	8.206	0.427	56.82	36.82
	Sp-6	8.216	0.437	56.92	36.72
	Sp-7	5.163	0.158	66.04	46.02
Yard - 3	Sp-8	5.173	0.167	66.14	46.12
	Sp-9	5.183	0.179	66.24	46.22
	Sp-10	6.155	0.146	18.01	21.58
Yard - 4	Sp-11	6.145	0.157	18.11	21.68
	Sp-12	6.135	0.169	18.21	21.78
	Sp-13	8.616	0.153	63.78	73.48
Yard - 5	Sp-14	8.606	0.163	63.68	73.58
	Sp-15	8.626	0.143	63.88	73.68
	Sp-16	5.700	0.287	76.29	87.29
Yard - 6	Sp-17	5.711	0.297	76.39	87.39
	Sp-18	5.721	0.277	76.49	87.49

Soil Quality Assessment in the Shipbreaking Yard

Table 7: The results of Geo-accumulation index (Igeo) of heavy metals in the soil of the Shipbreaking Yard from Sp-1 to Sp-18.

Yard No.	Sample ID	Geo accumulation Index (Igeo)			
		As	Cd	Pb	Cr(VI)
Yard - 1	Sp-1	0.01	-0.43	2.01	1.52
	Sp-2	0.03	-0.53	2.1	1.61
	Sp-3	0.02	-0.63	1.90	1.72
Yard - 2	Sp-4	0.17	0.21	0.34	0.63
	Sp-5	0.27	0.31	0.44	0.53
	Sp-6	0.37	0.41	0.54	0.43
Yard - 3	Sp-7	-0.18	-1.01	3.15	1.24
	Sp-8	-0.08	-1.05	3.26	1.36
	Sp-9	-0.01	-1.10	3.37	1.48
Yard -4	Sp-10	0.25	-0.01	1.45	2.01
	Sp-11	0.37	-0.6	1.56	2.11
	Sp-12	0.49	-0.16	1.67	2.23
Yard - 5	Sp-13	-0.01	-0.95	0.89	0.32
	Sp-14	-0.09	-1.05	0.99	0.44
	Sp-15	-0.18	-1.15	0.79	0.56
Yard - 6	Sp-16	0.01	0.04	2.1	1.03
	Sp-17	0.02	0.15	2.3	1.01
	Sp-18	0.03	0.26	2.4	1.06

Table 7: The contamination level of the soil sample from the Shipbreaking Yard from Sp-1 to Sp-18.

Yard No.	Sample ID	Contamination Factor (C_f)				Degree of Contamination
		As	Cd	Pb	Cr(VI)	
Yard - 1	Sp-1	1.54	0.04	2.83	2.81	7.22
	Sp-2	1.45	0.01	2.94	2.73	7.13
	Sp-3	1.66	0.08	2.75	2.94	7.43
Yard - 2	Sp-4	0.81	0.01	1.91	2.32	5.05
	Sp-5	0.92	0.05	1.82	2.44	5.23
	Sp-6	0.73	0.09	1.73	2.56	5.11
Yard - 3	Sp-7	0.084	0.036	2.58	3.02	5.72
	Sp-8	0.095	0.047	2.67	3.12	5.93
	Sp-9	0.076	0.058	2.76	3.22	6.11
Yard - 4	Sp-10	0.91	0.05	2.34	2.91	6.21
	Sp-11	1.02	0.01	2.45	3.02	6.54
	Sp-12	1.23	0.09	2.56	3.13	7.01
Yard - 5	Sp-13	0.50	0.08	1.90	0.32	2.8
	Sp-14	0.61	0.05	2.00	0.44	3.31
	Sp-15	0.72	0.01	2.10	0.56	3.39
Yard - 6	Sp-16	1.44	0.033	3.15	1.01	5.63
	Sp-17	1.35	0.024	3.27	0.90	5.54
	Sp-18	1.56	0.045	3.36	1.11	6.07

Table 8: Heavy metal Enrichment Factor (EF) in soil from the Shipbreaking Yard from Sp-1 to Sp-18.

Yard No.	**Sample ID**	**Enrichment Factor**			
		As	**Cd**	**Pb**	**Cr(VI)**
	Sp-1	1.55	0.01	3.45	2.50
Yard - 1	Sp-2	1.44	0.03	3.57	2.61
	Sp-3	1.66	0.02	3.68	2.72
	Sp-4	0.81	0.03	1.83	2.01
Yard - 2	Sp-5	0.92	0.04	1.94	2.10
	Sp-6	0.73	0.05	1.75	2.23
	Sp-7	0.84	0.03	3.16	2.24
Yard - 3	Sp-8	0.95	0.04	3.25	2.36
	Sp-9	0.76	0.05	3.37	2.48
	Sp-10	1.01	0.01	2.45	2.01
Yard - 4	Sp-11	1.02	0.03	2.56	2.11
	Sp-12	1.03	0.05	2.67	2.21
	Sp-13	0.50	0.015	3.78	1.32
Yard - 5	Sp-14	0.61	0.025	3.89	1.44
	Sp-15	0.72	0.035	3.97	1.56
	Sp-16	0.01	0.02	3.1	4.00
Yard - 6	Sp-17	0.02	0.03	3.3	4.01
	Sp-18	0.03	0.04	3.5	4.02

Table 9: Pollution Load Index (PLI) of the Shipbreaking Yard from Sp-1 to Sp-18.

Yard No.	Sample ID	Pollution Load Index (PLI)
	Sp-1	2.16
Yard - 1	Sp-2	2.27
	Sp-3	2.38
	Sp-4	3.10
Yard - 2	Sp-5	3.1
	Sp-6	2.90
	Sp-7	1.91
Yard - 3	Sp-8	2.02
	Sp-9	2.23
	Sp-10	1.81
Yard - 4	Sp-11	1.91
	Sp-12	1.71
	Sp-13	2.65
Yard - 5	Sp-14	2.77
	Sp-15	2.89
	Sp-16	2.7o
Yard - 6	Sp-17	2.81
	Sp-18	2.92

Table 9: Risk Index (RI) and Potential Ecological Risks (PERI) for Hazardous Metals in Soil from the Shipbreaking Yard from Sp-1 to Sp-18.

Yard No.	Sample ID	Potential Ecological Risks (PERI)				RI (Risk Index)
		As	Cd	Pb	Cr(VI)	
Yard - 1	Sp-1	21.39	17.70	429	2.5	470.6
	Sp-2	21.29	17.61	419	2.05	459.95
	Sp-3	21.49	17.82	439	2.01	480.32
Yard - 2	Sp-4	35.04	23.82	750	4.01	812.87
	Sp-5	35.15	23.91	771	4.12	834.18
	Sp-6	35.26	23.70	762	4.23	825.19
Yard - 3	Sp-7	23.37	10.28	372	2.06	407.71
	Sp-8	23.47	10.38	392	2.16	428.01
	Sp-9	23.57	10.48	382	2.26	418.18
Yard - 4	Sp-10	19.41	9.16	517	1.45	547.02
	Sp-11	19.52	9.27	507	1.57	537.36
	Sp-12	19.63	9.38	527	1.69	557.7
Yard - 5	Sp-13	33.44	18.04	565	3.96	620.44
	Sp-14	33.55	18.15	575	3.87	630.57
	Sp-15	33.66	18.26	555	3.78	610.7
Yard - 6	Sp-16	30.25	21.74	610	3.57	665.56
	Sp-17	30.36	21.85	601	3.68	656.89
	Sp-18	30.47	21.96	615	3.77	671.2

Photographs

Images of the Shipbreaking yard at Chattogram

Field measurement of pH, TDS, EC, DO and Temperature.






Images of the Laboratory work.