Measuring efficiency of leachate treatment plant in removing microplastic and heavy metal from raw leachate of Aminbazar and Matuail Landfill

A Thesis submitted to the Department of Environmental Science, Faculty of Science and Technology, Bangladesh University of Professionals for partial fulfillment of the Requirements for the Degree of BSc. In Environmental Science

By

Samiha Masum

ID:2053201011

Under Supervision of

Dr Md. Mostafizur Rahman

Associate Professor, Department of Environmental Sciences

Jahangirnagar University

DEDICATION

This research work is dedicated to my parents who have been my source of inspiration. They continuously provided me their moral, emotional, spiritual, and financial support to help and encourage me throughout the research work. I dedicate this to my teachers for constantly guiding and teaching me. Moreover, to my friends who encouraged me to finish my research. And, to the Almighty Allah for the guidance, strength, power, state of mind, protection, and skills to conduct this research work.

ACKNOWLEDGEMENT

My sincere gratitude goes to my supervisor Dr. Md. Mostafizur Rahman, Associate Professor, Environmental Sciences, Jahangirnagar University, and Co-supervisor, Md. Selim Reza, Scientific officer, Institute of Technology Transfer and Innovation (ITTI), Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka. I would also like to thank my seniors and friends who were with me in this process and constantly encouraged me during the research work. Ashikur Rahman Shanto and Intehum Taufiq students at the Bangladesh University of Professionals (BUP) in the Department of Environmental Science, my seniors who have always been there for me and helped me out during my thesis completion journey. Last but not least, I would like to convey my gratitude to my parents for their encouragement in this journey.

DECLARATION

I hereby declare that the research work entitled "Measuring efficiency of leachate treatment plant in removing microplastic and heavy metal from raw leachate of Aminbazar and Matuail Landfill" has been carried out under the Department of Environmental Science, Faculty of Science and Technology, Bangladesh University of Professionals in fulfillment of the requirement for the Degree of BSc in Environmental Science. I have composed this research based on original research findings from experiments acquired by me along with references from published literature. This has not been submitted in part or full for any other institution for any other degree. I also certify that there is no plagiarized content in this thesis (Maximum 25%).

Name: Samiha Masum

Roll No: 2053201011

Session: 2019- 2020

Department of Environment Science

Faculty of Science and Technology

Bangladesh University of Professionals

CERTIFICATE OF THE SUPERVISOR

This is to certify that Samiha Masum carried out her project under my guidelines and supervision, and hence prepared the project entitled "Measuring efficiency of leachate treatment plant in removing microplastic and heavy metal from raw leachate of Aminbazar and Matuail Landfill". So far as I am aware, the researcher duly acknowledged the other researchers' materials and sources used in this work. Further, the project was not submitted to any other Universities or institutions for any other degree or diplomas. It is thus recommended that the project be submitted to the Department of Environmental Science, Faculty of Science and Technology, Bangladesh University of Professionals, in fulfilment of the requirements for the award of the degree of BSc in Environmental Science. **I also certify that there is no plagiarized content in this thesis (Maximum 25%).**

Dr. Md. Moastafizur Rahman

Associate Professor,

Department of

Environmental Sciences,

Jahangirnagar University

Abstract

Water that has percolated through garbage piles that have undergone both anaerobic and aerobic microbial breakdown produces landfill leachate. The effectiveness of cotreating leachate in municipal treatment facilities has come under scrutiny in light of the stricter regulations imposed on wastewater discharge in recent years. In order to lessen the environmental impact associated with municipal solid waste landfills, landfill treatment for leachate is required. The study was conducted on the efficiency of leachate treatment facility situated at Matuail and Aminbazar landfills based on two parameters which are heavy metal and microplastics. Raw and treated leachate were assessed to quantify the amount of microplastics and heavy metals and the results were varied remarkably for each of the heavy metals. Only As at Aminbazar landfill had significant removal rate but other metals showed very little difference in removal rate. At Matuail none of the metals were removed at a significant rate which shows that the treatment facility isn't sufficient to remove the heavy metals. Though all the metals were below permissible amount in raw and treated leachate except for Cr in both landfills. Microplastic quantity also wasn't satisfactory in treated leachate as the difference between ran and treated leachate was very little which indicates that the present treatment isn't sufficient to treat microplastics in efficient manner at both the landfills. The heavy metals and microplastics in landfill leachates of developed and developing countries with Bangladesh have been compared to understand what can be done to remove these pollutants. There are several methods suggested in various studies to remove microplastics and heavy metals and some have shown notable difference. To increase the efficiency of the two leachate treatment facility at Matuail and Aminbazar landfills the methods for removing microplastics and heavy metals have been discussed.

Table of Contents

Table of figures:

List of Tables:

CHAPTER I

INTRODUCTION

1. Introduction

1.1. Background of the study

Informal or unstructured landfills are prevalent and widespread in developing nations, resulting in significant detrimental impacts on the three fundamental environmental components: air, water, and soil. The disposal of non-segregated solid waste at landfill sites is a commonly observed waste management technique in poor nations, such as Bangladesh. (Akter et al., 2021)

During the process of waste disposal, solid waste undergoes a gradual and oxygen-deprived decomposition, lasting approximately 30 to 50 years. This decomposition results in the production of a significant quantity of leachate, containing decomposition byproducts, heavy metals, and various hazardous pollutants. There is a risk that these substances may permeate from the landfill site into underground aquifers, thereby contaminating crucial urban water resources. Additionally, there are potential occurrences of surface runoff and/or leachate overflow, which may result in the degradation of surface water quality in the adjacent agricultural fields, ponds, canals, and rivers. (Azim et al., 2011) Numerous studies have shown that the waste management procedures used in landfills are linked to the pollution of surface and groundwater via the release of landfill leachate, the emission of strong aromas, the dispersion of bio-aerosols, and the presence of hazardous organic compounds. (Urme et al., 2021) The primary source of landfill leachate is the water that infiltrates through the solid waste fill, enabling the transfer of pollutants from the solid phase to the liquid phase. The presence of heterogeneity in waste composition and varying compaction densities will facilitate the percolation of water, resulting in the emergence of leachate at the bottom of the site. (Mahmud et al., 2011)

Landfill leachate is composed of a diverse array of substances, including significant quantities of refractory organics, tiny organic molecules, toxic heavy metals, inorganic minerals, and organic residual contaminants, which exhibit varying concentrations. Leachate has the potential to include several components, such as suspended or colloidal fragments, dissolving parts, organic structures, inorganic structures, and unattached metal ions. (Akter et al., 2021) The Matuail landfill, which is managed by the DCC, was specifically engineered with the aim of safeguarding both the environment and the surrounding community from any detrimental effects arising from landfill gas emissions and leachate. However, in contemporary times, there has been a significant decline in the quality of leachate, and the current biological treatment method fails to provide satisfying outcomes in terms of reducing residual COD levels. There is a need for enhancement in the leachate treatment process. (Akter et al., 2021) The Aminbazar landfill is equipped with a leachate treatment facility that has a better organized collecting system compared to the one present at Matuail landfill. The organization was first founded in 2012 and started its operations in April 2018, including enhanced, automated, and scientifically advanced technologies. The primary function of this leachate treatment facility is to effectively cleanse the leachate and transform it into potable water. (Afrin et al., 2020)

The management of trash, particularly the practice of landfilling, has been identified as a potentially substantial contributor to the presence of microplastics. This is mostly due to the release of landfill leachates, which are liquid byproducts that emerge from landfilled garbage and enter surface waterways. The process of landfill stabilization involves many treatment phases for plastic waste, which in turn leads to the generation of microplastics via various physical, biological, and chemical mechanisms inside the landfill bodies and subsequently in the landfill leachate. The issue of landfill leachate as a significant contributor to microplastics warrants further attention. (Wang et al., 2023) The presence of leachate, a liquid byproduct derived from the filtration of waste materials, suggests a tendency for smaller microplastic particles to amass inside the leachate, whereas bigger particles of microplastics are more likely to stay within the landfill waste. The smaller particles tend to remain in suspension within the fluid, whereas the bigger particles are more prone to precipitation. (Wang et al., 2023)

Approximately 36% of plastics manufactured in developing nations are used for packaging purposes, including single-use plastic containers for food and beverages. These containers are then discarded in landfills or waste disposal sites after any biodegradable materials have been extracted. The co-disposal of organic waste and plastics occurs indiscriminately at many sites without undergoing any Environmental Impact Assessment (EIA) screening protocols. The majority of plastic debris that is disposed of in landfills persists in the environment for extended periods of time, undergoing fragmentation into smaller particles due to the influence of various climatic conditions. During periods of increased precipitation, a significant portion of fragmented microplastic (MP) particles are transported into watercourses, where nano-plastic particles gradually infiltrate into groundwater. In a recent study, it was discovered that microplastics (MPs) were detected in compost samples, indicating the potential transmission of harmful pollutants from plastics to compost and subsequently to soil. (Mahesh et al., 2023)

Microplastics (MPs) include a diverse assemblage of plastic particles that exhibit a diminutive size, measuring less than 5 mm in length. Microplastics (MPs) have emerged as a noteworthy representation of human-generated garbage and a catalyst for environmental contamination. Primary microplastics (MPs) are little plastic particles that are used for commercial purposes. These substances serve as primary inputs for the production of goods and are also used in the form of pellets within various industrial sectors. Secondary microplastics (MPs) refer to smaller fragments of plastic particles that are derived from larger plastic materials often used in agricultural and industrial practices. These secondary MPs are generated as a result of the degradation and disintegration of the larger plastic particles upon their introduction into the environment. The deterioration of big plastic particles in the environment may occur via two primary mechanisms: weathering and high temperature-induced decomposition, leading to the formation of secondary particles. Landfills and other surface dumps have the potential to generate airborne particles as a result of atmospheric displacement. Landfills serve as facilities for the disposal of garbage on a global scale, and are capable of accommodating a significant portion, ranging from 21% to 42%, of the total plastic waste generated worldwide. The discharge of primary and secondary microplastics (MPs) is associated with activities such as trash disposal at landfills, industrial manufacture, and the advancement of agricultural technologies. (Zhang et al., 2020)

The substantial quantity of microplastics present in the freshwater systems of affluent countries implies that the situation in Bangladesh is far more severe. The small dimensions of microplastics result in a significant surface area-to-volume ratio, facilitating the accumulation of harmful contaminants. Microplastics have a detrimental impact on animals, causing adverse effects on their physical and chemical well-being. The tiny size of microplastics poses challenges for current retrieval technology, resulting in their widespread prevalence in the environment. The need for establishing a microplastic-free environment necessitates the development of highly effective technology for the degradation of microplastics and the implementation of robust systems for plastic recycling. (Nurhasanah et al., 2021)

The elevated toxicity of heavy metals present in landfill leachate is a significant cause for worry. Landfill leachate typically contains modest amounts of heavy metals. It is widely believed that the process of landfilling, namely during the methanogenic phase, effectively reduces the concentration of heavy metals by sequestering the majority of soluble heavy metal species. In general, heavy metals tend to form chelates with humic compounds and fulvic acids. However, it is important to note that this chelation process may be disrupted by changes in pH. (Thomas et al., 2008) The practice of co-disposal of home hazardous wastes, such as paint residues, ash, electronic wastes, biomedical waste, plastic, and non-ferrous metals, alongside culinary trash is seen in Bangladesh. at addition, a considerable proportion of industrial trash is also deposited at landfill sites alongside municipal solid waste (MSW). The prevalence of heavy metals in municipal solid waste (MSW) at dumping sites is mostly attributed to these two reasons. (Karim, 2017) The presence of heavy metals in landfills may be attributed to many types of garbage. Various sources, including electronic trash, painting waste, and old batteries, contribute to the accumulation of heavy metals in landfills. The present escalation in the utilization and disposal of electronic devices, such as mobile phones and computers, prompts an inquiry regarding the quantity of metals present in these devices within waste disposal sites, as well as their subsequent behavior within the environment. This concern arises primarily due to the significant presence of lead, cadmium, mercury, arsenic, copper, zinc, and other metals within these devices. (Raisi et al., 2014)

There are several reasons that may contribute to the presence of heavy metals in leachate from landfills. Approximately 2.8 million metric tons of electrical garbage, which contains hazardous substances such as mercury (Hg) and lead (Pd), are annually created and then disposed of in landfills, agricultural areas, and bodies of water. (Rikta et al, 2018)

The impacts of heavy metals have been seen to exhibit variability in response to the prevailing circumstances inside dumpsites and the specific forms in which they are bound.

The open dumpsite, when exposed to air conditions, has several impacts as a result of oxygen diffusion. In situations characterized by strong redox capacity, the attraction of metals for Mn and Fe oxide is enhanced, whereas their affinity for carbonate, organic compounds, and sulfide is generally diminished. The rate of decomposition and acid buffering capacity of the landfills are significantly impacted by the increased potential for oxygen penetration in the higher layer and the existence of adequate water content. In this particular scenario, there is a notable decrease in alkalinity, pH, and sulfide oxidation, resulting in enhanced accessibility and release of heavy metals. The distribution and hazard of heavy metals found at disposal sites are contingent upon the specific chemical composition of these metals. (Karim, 2017)

The heavy metals found in landfill leachate are considered non-biodegradable and have the potential to degrade the quality of both surface and groundwater. Even at low concentrations, these heavy metals may be hazardous to biological systems. Heavy metals exhibit characteristics of persistence, bioaccumulation, toxicity, as well as endocrine disruption and carcinogenicity. (Parvin and Tareq, 2021) Heavy metals possess hazardous properties, exhibit persistence, have the ability to bioaccumulate, and may contaminate the water resources in the vicinity of a waste site. The presence of heavy metal contamination is known to contribute to ecological risks. The presence of leachate has the capacity to contaminate the neighboring aquatic and lithospheric systems, unless appropriate remedial actions are undertaken. (De et al., 2016)

1.2. Problem statement

At present. The waste management system in Dhaka is now facing challenges in effectively managing a substantial amount of garbage, estimated to be over 4500 tons per day. At present, the Dhaka South City Corporation (DSCC) and Dhaka North City Corporation (DNCC) are served by two landfills located at Matuail and Aminbazar, respectively. Prior to 2006, the only landfill in operation was the Matuail landfill, which was created via the collaborative efforts of the Japan International Cooperation Agency (JICA) and the Japan Debt Cancellation Fund (JDCF). In 2006, a landfill was constructed near Aminbazar with financial support from the Japan International Cooperation Agency (JICA). This landfill, which falls under the jurisdiction of the Dhaka North City

Corporation (DNCC), remains in operation despite reaching its maximum capacity in 2017. (Urme et al., 2021)

The Aminbazar landfill, managed by the Dhaka North City Corporation (DNCC), is located in the Savar upazila, about 24 kilometers northwest of Dhaka city. It was established in 2007 and spans an area of 52 acres (21 hectares). The second landfill site at Matuail, which is under the administration of the Dhaka South City Corporation (DSCC), is located about 8 km south of Gulistan and is situated inside the Matuail Union area in Dhaka. This landfill was first built in 1995 as an open-air landfill facility spanning 50 acres (20 hectares), and an additional 50 acres (20 ha) were later added in 2006.The establishment of the leachate treatment facility at Matuail took place in the year 2006. The Aminbazar landfill is equipped with a leachate treatment facility that has a more organized collecting system compared to that of Matuail. The organization was first founded in 2012 and started its operations in April 2018, including enhanced, automated, and scientifically advanced technologies. (Urme et al., 2021)

The disposal of waste, particularly through landfilling, has been identified as a potentially significant contributor to the presence of microplastics that have (Prata et al., 2020). This is primarily attributed to the release of microplastics into surface waters through the discharge of leachates, which are liquid effluents originating from landfilled waste. Microplastics are formed from the degradation of plastic materials, which are widely used across many industries due to their abundant supply and long-lasting properties. When plastic waste accumulates in landfills, it undergoes a process of breakdown into microplastics. These microplastics possess a significant surface area, which facilitates the transportation of various substances such as heavy metals, viruses, bacteria, and other pollutants of microscopic size. These substances are then carried to aquatic bodies via leachate. (Praagh et al., 2021)

Furthermore, the concentration of heavy metals and significant cations tends to increase in groundwater as well as surface water around waste disposal facilities as a result of their dispersal and geoaccumulation facilitated by landfill leachate. The inadequate handling of landfill leachate in designed landfills has negative implications for the water quality in the surrounding areas, particularly in non-engineered landfill sites. Living species, such as plants and animals, have the capacity to experience bioaccumulation of heavy metals, which may subsequently result in their transfer via the food chain and eventually impact human health. In the case of a malfunctioning leachate treatment plant, there is a potential for adverse consequences such as soil and water contamination, as well as the buildup of contaminants inside living organisms. (De et al., 2016)

Prior research has shown that the unregulated and untreated leachate originating from a landfill site has resulted in contamination of the adjacent soil, surface water, and groundwater. Research results have shown that the land in close proximity to landfill sites, which is often used by local communities for agricultural purposes, has the potential to collect harmful compounds originating from the decomposition of garbage and runoff from the landfill's location. These findings provide confirmation of previous research conducted on this subject matter. The previous investigation conducted on the Matuail landfill has shown that the overflow of leachate has the potential to affect crops in close proximity, hence corroborating the conclusions of the present research. The potential for contamination of the adjacent lowlands, which are used for agricultural and fishery purposes, is significantly elevated during the monsoon season as a result of intensified precipitation leading to increased drainage water and leachate discharge. (Urme et al., 2021)

Leachate, a byproduct generated during the process of garbage landfilling, has been identified as a significant contributor to the presence of microplastics (MPs). In the interim, the leachate exhibited a substantial presence of several pollutants, such as ammonia, heavy metals, personal care and pharmaceutical goods (PPCPs), and endocrine disrupting chemicals (EDCs). Consequently, the leachate posed a significant environmental hazard to its surrounding surroundings. Previous studies have documented the levels of classic pollutants and emergent contaminants, as well as the technologies used for their removal and the possible ecological concerns associated with their presence. (Zhang et al., 2020)

The effectiveness of a treatment facility may be assessed by conducting a comparative analysis of heavy metal and microplastic concentrations in both raw and treated leachate.The purpose of this study is to provide a comprehensive explanation and justification for the chosen research approach and methodology.

1.3. Research gap

Previous studies have shown that leachate contains heavy metals in both raw and treated but not microplastic. No study has shown the amount of microplastics in raw and treated leachate. No study has ever shown the efficiency of leachate treatment plants in terms of microplastic and heavy metals. Landfill has been a research topic for numerous papers due to the pollution it creates in different compartments of the environment. The amount of heavy metals have been studied in every compartment as well as leachate but never the leachate treatments' efficiency in terms of heavy metal output in surface water via discharge of treated leachate. There was also no study of microplastic content to measure the treatment efficiency of leachate and this microplastic is omnipresent in every compartment of nature and is increasing fast. This research aims at assessing the treatment plant's efficiency through measuring microplastic and heavy metals in raw and treated leachate.

1.4. Rationale of the study

The rapid growth of the population in Dhaka has resulted in a substantial increase in garbage production. Unfortunately, the management of this trash has not been satisfactory, leading to the contamination of many environmental components, particularly water bodies. The research aims to examine the levels of various heavy metals in both untreated and treated leachate, with the presence of microplastics in the Matuail and Aminbazar landfills. The purpose of this research is to assess the efficacy of leachate treatment facilities in the removal of microplastics and heavy metals, which are prominent environmental contaminants.There has been a limited amount of study undertaken on the assessment of efficiency in leachate treatment plants.

The assessment of metals and micro plastics levels in both untreated as well as treated leachate is of utmost importance in enhancing the efficiency of leachate treatment facilities and ensuring effective management of leachate and waste materials. Additionally, this study aims to develop practical and effective strategies to address the issue of contamination.

The outcomes of this research will be imperative in the formulation and execution of environmental safety policies pertaining to the discharge of treated leachate. It would be advantageous for policymakers to establish revised acceptable thresholds for quantities of heavy metals and microplastics in treated leachate. This will need the alteration of waste disposal and leachate treatment facilities.

1.5. Research hypothesis

Leachate treatment facilities are not capable of dealing with heavy metal and microplastic pollution from landfills.

1.6. Research Question

1. How much microplastic is present in raw and treated leachate?
2. Is the heavy metal concentrations in treated leachate below the permissible limit set by the Government?
3. What is the concentration of heavy metals content in raw and treated leachate?
4. Is the amount of microplastic substantially low in treated leachate than raw?

1.7. Research Objectives

1.7.1. Broad Objective:

Landfill leachate is a significant source of microplastic and heavy metals. The leachate treatment plants' efficiency can be measured through these two parameters in both raw and treated leachate. So, the broad objective is to assess the microplastic and heavy metal content in both raw and treated leachate to assess the efficiency of leachate treatment plant in landfills of Aminbazar and Matuail.

1.7.2. Specific objective:

1. To assess the microplastic amount in raw and treated leachate
2. To evaluate heavy metal in raw and treated leachate

1.8. Outline of the Thesis

The outline of the thesis is discussed below:

Chapter one provides a brief introduction on the background, problem statement, research gap, rationale of the study, research hypothesis, research questions and objectives of the study.

Chapter two discusses related works of literature on the sources and impacts of heavy metal contamination in the environment, microplastic pollution and effects, leachate treatment plant and leachate sources, landfills of Bangladesh.

Chapter three discusses research methodology of the study, study area, research design, sampling technique, instruments and procedure.

Chapter four discusses the results and its explanation.

Chapter five summarizes the study as a concluding remark and recommends future prospects.

Lastly, references are attached at the end.

CHAPTER II

LITERATURE REVIEW

2. Literature review

2.1. Landfill

Landfills are now the predominant approach for waste management. (Abdel-Shafy and Mansour, 2018) A landfill refers to an expansive surface or dug site that is deliberately constructed and designated as the final location for the dumping of solid urban trash. (Urme et al., 2021)

On a global scale, it has been reported that over 37% of garbage is deposited in landfills (Kaza et al., 2018). Specifically, the United States accounts for around 52.6% of waste put in landfills, Brazil contributes 59.1%, Malaysia records 94.5%, and China accounts for 79% of waste landfilled. Numerous studies have shown a correlation between the waste management procedures used in landfills and the occurrence of surface and groundwater pollution resulting from landfill leachate. Additionally, these practices have been found to contribute to the release of noxious odors, the emission of bio-aerosols, and the presence of dangerous organic substances. The infiltration of leachate from landfills into aquifer or water at the surface, facilitated by imperfections in the barriers, presents a significant challenge to reservoirs (El-Salam & Ismail, 2013). Landfills go through a minimum of five distinct phases of trash degradation, which are followed by the creation of diverse chemicals and the release of pollutants.

(I) **Aerobic:** Aerobic conditions result in the production of water along with carbon dioxide as the primary byproducts. Carbon dioxide is emitted as a gas or may be absorbed into water, leading to the formation of carbonic acid. This acid contributes to the acidity seen in the leachate.

(II) **Acidogenic:** Microorganisms produce carbon dioxide, hydrogen, ammonia, and organic acids.

(III) **Acetogenic:** Microorganisms are capable of producing acetic acid and its derivatives, along with carbon dioxide and hydrogen.

(IV) **Methanogenic:** The composition of landfill gas typically consists of around 60% biogas and 40% carbon dioxide, making it methanogenic in nature.

(V) **Aerobic**: Aerobic respiration involves the production of carbon dioxide and water. (Schiopu and Gavrilescu, 2010)

2.2. The waste management approach used in Bangladesh

Numerous rising towns in Asia, such as Dhaka in Bangladesh, encounter significant challenges in effectively managing the escalating quantities of solid garbage produced by the expanding urban populace (Idris et al., 2004). At present. The waste management system in Dhaka is now facing challenges in effectively managing a significant amount of garbage, estimated to be over 4500 tons per day (Mahmud, 2018). At present, the Dhaka South City Corporation (DSCC) and Dhaka North City Corporation (DNCC) are served by two landfills located at Matuail and Aminbazar, respectively. Prior to 2006, the establishment of landfills in the Matuail area was limited to the one under the authority of the Dhaka South City Corporation (DSCC), which was facilitated by the Japan International Cooperation Agency (JICA) and the Japan Debt Cancellation Fund (JDCF). In 2006, a landfill was constructed near Aminbazar with financial support from the Japan International Cooperation Agency (JICA). This landfill, which falls under the authority of the Dhaka North City Corporation (DNCC), remains in operation despite reaching its maximum capacity in 2017. The extension of funds was provided in the form of assistance, and it should be noted that the Japan International Cooperation Agency (JICA) does not assume responsibility for any landfill maintenance or management operations. However, it does engage in collaborative efforts with both the Dhaka North City Corporation (DNCC) and Dhaka South City Corporation (DSCC) in relation to waste management activities carried out at the dump. (Urme et al., 2021)

The quantity of urban and industrial solid trash has seen a significant surge in several nations throughout the last decade. The observed increase may be attributed to the rising affluence of individuals, as well as the continued expansion of industries and enterprises. The per capita and total production of municipal solid waste (MSW) is seeing an upward trend, as is the rate of leachate formation. As an example, the quantity of waste generated in Rio de Janeiro, Brazil, had an increase from 6200 metric tons per day in 1994 to 8042 metric tons per day in 1997, despite no population growth seen inside the city. From 1992 to 1996, there was a yearly rise in garbage output of 3% in Norway and 4.5% in the United States. In the later portion of the 1990s, there was observed variation in the yearly per capita trash generation, with more developed nations exhibiting a range of 300 to 800 kg, while developing countries had a lower range of less than 200 kg. The French population generated a total of 24 million tons of municipal solid waste (MSW) in the course of 2002, which equated to an average of 391 kg per person. (Renou, 2007)

2.3. The potential hazards linked to landfill sites

The deposition of solid waste in landfills has the potential to have negative impacts on the environment around it and those who reside in proximity to landfill facilities. (Njoku et al., 2019) The proximity to a landfill has been associated with several health consequences, such as reduced birth weight, the occurrence of congenital malformations, and the development of respiratory disorders. (Shaddick et al., 2018) In an investigation conducted by Brender et al. (2011), a noteworthy association was seen between the closeness of residential areas to environmental dangers and the occurrence of detrimental health consequences. Specifically, heightened risks were identified for many conditions including central nervous system disorders, congenital heart conditions, premature birth, cancer, asthma, and chronic symptoms of breathing. Tomita et al. (2020) conducted a research in South Africa which revealed a substantial correlation between residing near a 5 km radius of a garbage dump and heightened susceptibility to TB, asthma, diabetes, and depression. Nevertheless, a dearth of research exists that specifically examines the health hazards faced by those engaged in waste management activities and the ecological consequences associated with the landfills in Dhaka. The study's results indicate that informal garbage pickers engage in manual segregation of recyclable material inside landfills, which they then sell as a means of sustaining their lives. The rubbish pickers, including individuals of all genders and age groups, lack official employment with either municipal authorities or commercial entities. During the course of the inquiry, it was discovered that the garbage pickers, often referred to as 'tokais', who are informal waste collectors mostly consisting of minors, do not use any sort of protective gear when engaging in the task of segregating recyclable materials such as bottles of plastic, other plastic goods, paper, and iron tools. A limited number of individuals using gumboots. Additionally, it was noted that individuals have their midday meal inside the confines of the landfill boundaries, therefore presenting significant risks to their health. (Urme et al., 2021)

2.4. Leachate and Leachate Treatment Plant:

Leachate, as defined by Britannica, is a liquid of significant contamination resulting from the decomposition of waste materials, whereby rainfall infiltrates and permeates through a substantial quantity of refuse. The introduction of leachate into groundwater and its subsequent interaction or infiltration into adjacent surface water bodies poses serious dangers to both people and the natural world.

In the past few years, there has been a significant body of scientific literature dedicated to the comprehensive examination of the gathering, storage, and proper management of highly polluted leachates, which pose a significant threat to both surface and groundwater sources. Leachates are aqueous byproducts generated from the infiltration of rainfall into waste materials, as well as the biological processes occurring inside waste cells and the inherent moisture content of the wastes. Leachates may include humic-type elements, ammonia-nitrogen, heavy metals, chlorinated inorganic and organic salts, and refractory degrading organic material. The waste management plant located in Amin Bazar produces an estimated volume of around 85 cubic meters of leachate every hour. The landfill produces an estimated volume of around 1932 cubic meters per day of leachate as a byproduct of its regular activities.

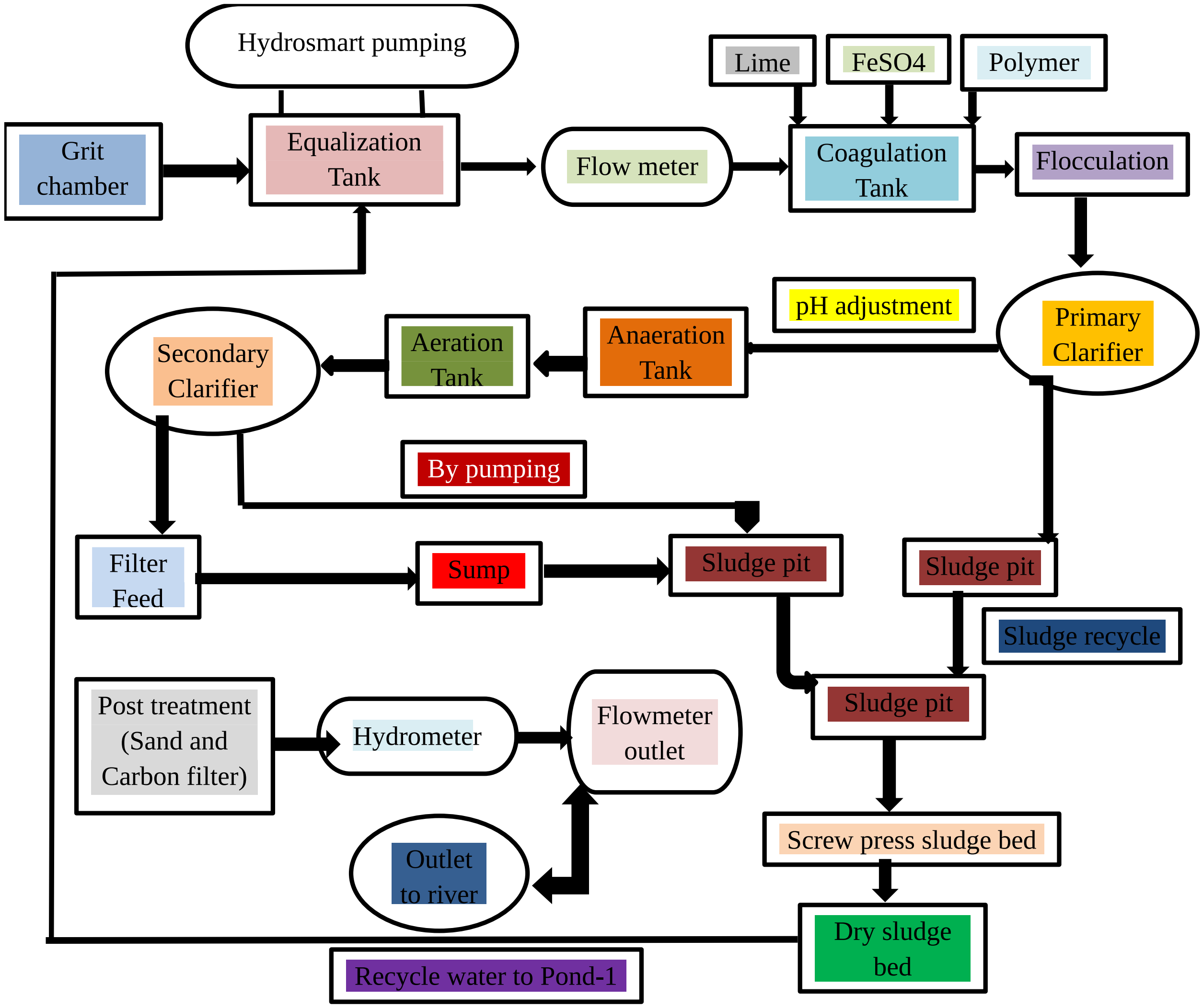


Fig 1: The flow diagram of the Leachate Treatment Plant (ETP) located at Amin Bazar is sourced from the Dhaka North City Corporation (DNCC).

Table 1: Leachate generation rate (Source: DNCC)

Month	Leachate amount (L/d)
June	2128416
July	2037457
August	1816972
September	178831

Table 2: Leachate generation rate (Source: DSCC)

Month	Leachate amount (L/d)
June	2883411
July	2346212
August	2254838
September	2042101

Table 3: 3 Test report on leachate quality parameters (Physical/ chemical/ bacteriological analysis of Raw leachate) (Source: DNCC)

SL	Water quality parameters	Unit	Concentration	ECR 1997			Minimum detection limit
				Discharge in Inland water	Discharge into public sewer	Discharge into irrigated land	
1	pH		8.18	6-9	6-9	6-9	0
2	TSS	Mg/l	13	150	500	200	5
3	Chloride	Mg/l	2000	600	600	600	1
4	Ammonia-nitrogen	Mg/l	2675	50	50	75	0.017
5	COD	Mg/l	5950	200	400	400	0.2
6	BOD	Mg/l	2300	50	250	100	0.2
7	Orthophosphate	Mg/l	80.5	----	----	----	0.04
8	Total nitrogen	Mg/l	2720	----	----	----	0.5

9	Total coliform	CFU/100 ml	TNTC	----	----	----	0

Table 4: Test report on leachate quality parameters (Physical/ chemical/ bacteriological analysis of Treated leachate) (Source: DNCC)

SL	**Water Quality Parameter**	**Unit**	**Concentration**	**ECR 1997**			**Minimum detection limit**
				Discharge in inland water	Discharge into public sewer	Discharge in irrigated land	
1	pH		6.62	6-9	6-9	6-9	0
2	TSS	Mg/l	7	150	500	200	5
3	Chloride	Mg/l	64	600	600	600	1
4	Ammonia-nitrogen	Mg/l	17.5	50	75	75	0.017
5	COD	Mg/l	57	200	400	400	0.2
6	BOD	Mg/l	27.2	50	250	100	0.2
7	Orthophosphate	Mg/l	1.21	----	----	---	0.04

Table 5: Test report of leachate quality parameters (Physical analysis of leachate) (Source: DSCC)

Sl	**Parameters**	**Leachate**		
		Raw	Aerobic	Discharge

1	Temperature (°C)	29.8	30.8	31
2	pH	7.64	7.88	8.5
3	DO (mg/l)	0.29	0.63	11.35
4	Conductivity (Ms/cm)	19.14	-----	-----

The visual manifestation of leachate upon its discharge from a conventional landfill site is characterized by a yellow or blackish hue, while its olfactory properties are marked by an acidic and malodorous scent. Over an extended duration, it is possible for leachate concentrations to surpass acceptable thresholds. Leachate represents a significant concern within the realm of landfill management. Failure to implement remedial steps to halt the ongoing influx of water into the waste materials may result in significant negative consequences for the environment. Currently, there exists a plethora of viable alternatives for the management of leachate. The handling of leachate is intricately linked to the level of technical expertise and financial resources required for the desired treatment objective. When developing a leachate treatment plan, it is crucial to consider the potential inadequacy of treatment methods that are effective for young leachate as the landfill ages (Wichitsathian, 2004).

The establishment of the leachate treatment facility at Matuail took place in the year 2006. The high-density polyethylene pipes, arranged in a skeleton of a fish pattern on the dumping system, facilitate the continuous movement of the raw leachate into the leachate pond. The qualitative observation checklist revealed that the leachate water purification plant in Matuail is comprised of two distinct sections, with the raw leachate being collected and stored in the raw leachate pond. Following the process of filtering, the liquid proceeds to the semi-aerobic treating pond. The maximum depth of the ponds is 15 meters. The untreated leachate undergoes treatment processes including chemical oxygen demand (COD) and biological oxygen demand (BOD). This treatment is carried out in three tanks, each containing a specific chemical agent: iron sulphate ($FeSO_4$), lime (CaO), and polymer. The semi-aerobic pond employs the cultivation of bacteria and fish for the purpose of water treatment, with a blower machine being used to provide a continual supply of air to the pond. After undergoing water toxicity testing using the fish test procedure, the uncontaminated leachate from Matuail is then transported to the adjacent area for the purpose of cultivating crops. The semi-aerobic pond is used for the cultivation of fish, which serves as a means to assess the water quality prior to the introduction of fresh leachate water into the main water system. The treatment plant operates for a duration of four hours per day under normal conditions, but during the rainy season, it extends its operation to eight hours per day in order to compensate for the increased infiltration of precipitation into the leachate. The Aminbazar landfill is equipped with a leachate treatment facility that has a better organized collecting system compared to the one present at Matuail landfill. The organization was first founded in 2012 and started its operations in April 2018, including enhanced, automated, and scientifically advanced technologies. The leachate treatment facility serves the purpose of purifying leachate and transforming it into potable water. The unprocessed leachate is collected from the garbage via pipelines and conveyed to the leachate treatment facility via a canal. The raw leachate, which has been collected in the raw leachate pond, undergoes a process using hydro-smart technology to break it down into smaller particles. Additionally, it is chemically treated using a combination of FeSO4 and CaO. Following the occurrence of a breakdown event, the subsequent coagulation and flocculation procedures are conducted inside a separate tank. Following the first purification process, the water undergoes further purification inside an aerobic pond. Within the aerobic treatment facility, bacteria are cultivated for the purpose of water purification, while a blower apparatus consistently supplies air. Following the purification process, the treated water undergoes an assessment of its dissolved oxygen levels, and upon achieving appropriate outcomes, it may be integrated into the main water supply. The effective management of the leachate pond during the rainy season poses difficulties owing to the amalgamation of rainfall and leachate water. (Urme et al., 2021)

The following test reports, conducted by the DNCC, include data on the raw leachate and processed leachate at the AminBazar landfill.

2.5. Microplastic type

Microplastics may be categorized into main or secondary types, based on their origin. Numerous sources contribute to the generation of microplastics, and these materials have an influence on the two distinct categories of microplastics that have been documented.

2.5.1. Primary Microplastic

Primary microplastics are defined as plastic fragments that are smaller than 5 mm before they are introduced into the environment. Primary microplastics mostly originate from industrial preliminary production pellets. Microplastics are commonly present in a variety of products, including facial cleansers, makeup, dental products, hand cleaners, exfoliating scrubs, drilling solutions, and clothing. Cosmetics and personal care products (PCPs) intentionally incorporate microplastics, such as those found in toothpaste and scrubs for the face (Hernandez et al., 2017). The predominant composition of microplastics consists of acrylic and polyester polymers. Resin pellets, namely polyethylene and polypropylene, are released into the ecosystem as a result of unintentional discharges from shipping containers and manufacturing incidents (Castillo et al., 2016). The ability to traverse long distances is facilitated by the lightweight, buoyant, and oceanic conditions that exist (Castillo et al., 2016). The release of primary microplastics may occur as a result of spills involving resin pellets, which may have negative effects. (Yeo et al., 2017)

2.5.2. Secondary Microplastic:

The degradation of macroplastics occurs via a combination of physical, chemical, and biological processes, resulting in the formation of secondary microplastics (Auta et al., 2017). The fragmentation of macroplastics is influenced by multiple variables, such sunlight exposure, heat, particle density, and size. Ultraviolet (UV) light induces oxidation of the plastic structure, resulting in bond breakage. The substantial surface area of UV light leads to the prediction that particles will break down into smaller entities based on their size. Secondary microplastics are readily produced by beaches and marine environments. The development in question is influenced by several factors, including exposure to UV radiation, coastal waves, turbulence, and oxygen availability (Andrady, 2017). The physical erosion caused by the waves results in the fragility of particles, causing them to break into smaller fragments. The color of objects is influenced by sunlight. Tidal and wave forces facilitate the upward movement of particles towards the water's surface, leading to their subsequent fragmentation. Several physical, chemical, and biological processes contribute to the degradation of disposable cups and plates in the environment, resulting in the formation of secondary microplastics. These processes include wave action, UV radiation, as well as the presence of plastic bottles, disposable bags, facial masks, and nets for fishing. Inland rivers are responsible for the discharge of a substantial quantity of plastic debris into the Earth's seas, hence generating secondary microplastics. The predominant constituents of microplastics are mostly polymer materials such as polyethene (PE), polystyrene (PS), polypropylene (PP), nylon, polyvinyl chloride (PVC), polyamide (PA), polylactic acid (PLA), and PET. (Conkle et al., 2018)

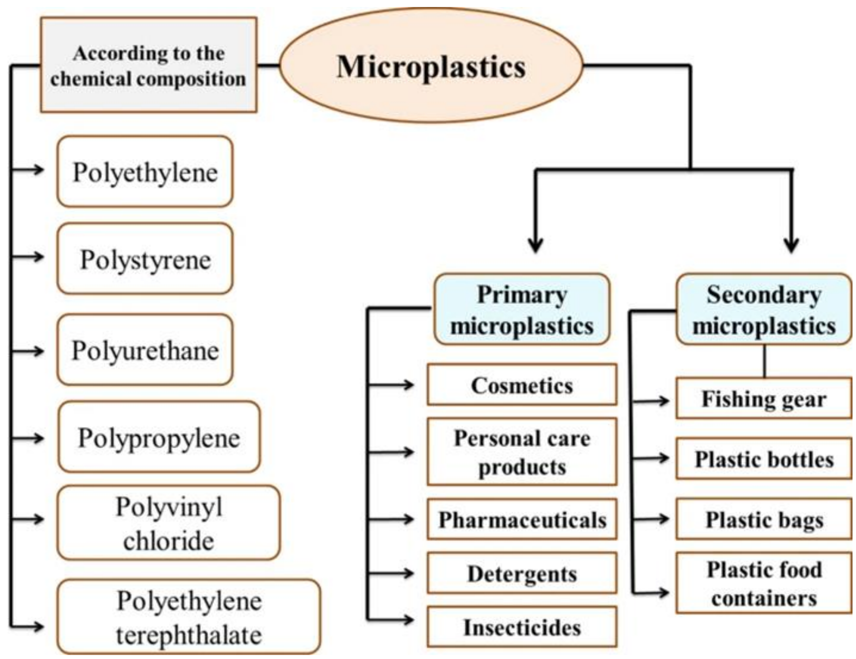


Fig 2: Types of microplastics

2.6. The sources of microplastics

Wastewater treatment plants, specifically those that only employ two different treatment methods, might potentially serve as significant sources or pathways for the introduction of microplastics into aquatic ecosystems. The release of microplastics into the environment is a consequence of plastic recycling processes, particularly in cases when effluents are not adequately cleaned (Suzuki et al., 2022). The task of identifying the sources and tracking the dispersion of microplastics in the environment presents significant difficulties. Limited knowledge exists on the mechanisms that regulate the transportation of microplastics throughout freshwater ecosystems. The movement and final destination of microplastics are significantly influenced by several factors, including but not limited to their density, size, and form. The existence of microplastics has been identified in freshwater environments. The origins of their origin included several locations, including runoff originating from terrestrial sources, effluents discharged from wastewater treatment facilities, and improperly disposed plastic debris. Further discussion will be provided below on each of these probable sources and others. According to the World Health Organization (WHO, 2019).

2.6.1. Run-off from land-based sources

Run-off from land-based sources refers to the discharge of water, together with any associated pollutants or contaminants, that flows over the land surface and into nearby water bodies such as rivers, lakes, or oceans. Numerous scholarly investigations have endeavored to elucidate the mechanisms by which terrestrial origins of microplastics infiltrate aquatic environments. However, the majority of these investigations have mostly concentrated on the pathways by which microplastics enter the marine ecosystem. Microplastics have the potential to infiltrate aquatic bodies, including freshwater environments, via a variety of human activities, infrastructural systems, and land use practices. The discharge of pollutants resulting from the degradation of road marking paints and the generation of tire wear debris has been recognized as a notable contributor to environmental contamination. (Verschoor et al., 2016). The phrase "city dust" refers to a range of causes associated with the abrasion of objects, including synthetic shoe bottoms and artificial turfs. (Boucher and Friot, 2017) argue that city dust may have significant long-term implications. In the latest research conducted by (Horton et al., 2017), it was shown that agricultural runoff has the potential to introduce microplastics into freshwater habitats. This occurrence especially prominent in regions where soil has been treated with sewage sludge or agricultural plastics, such as those used for mulching purposes.

2.6.2. Wastewater

Wastewater discharge is recognized as another major contributor to the presence of microplastic contamination in freshwater bodies. There have been documented instances of increased presence of microplastics in water bodies in both the United Kingdom and the United States subsequent to the discharge of effluent. As to the European Academies'

Science Advice for Policy, prevalent sources of contaminants in sewage systems originating from residential settings include synthetic textile fibers shed during washing, microbeads found in cosmetics, and fragmented components of larger consumer items that are inadvertently disposed of via toilets and sinks. While it is well acknowledged that treated wastewater effluent contributes to the presence of microplastics in freshwater environments, it is important to note that effective sewage treatment processes have the ability to remove a significant portion of these microplastics. In high-income nations, the predominant practice is the collection of wastewater via sewage systems, followed by subsequent treatment. Nevertheless, it is worth noting that sewer access is only available to a mere 33% of the population residing in low- and middle-income nations. According to the joint report by UNICEF and WHO in 2019, it was found that the remaining 67% of the population's wastewater is either managed via local treatment or released straight into the environment, such as the ground or water bodies. Consequently, the absence of adequate wastewater treatment infrastructure or alternative mechanisms for the collection and treatment of wastewater may provide a more significant challenge. The generation of substantial effluent is a consequence of wastewater treatment, which, despite the removal of microplastics, may nevertheless result in the discharge of a significant quantity of these particles. It has been estimated that around 65 million microplastic particles are discharged into the effluent of a wastewater treatment plant (WWTP) on a daily basis. This amounts to an average of around 100 particles per person each day. There is considerable variation in estimates such as these.

2.7. Microplastic pollution

Plastic materials constitute a significant contributor to pollution in terrestrial ecosystems, with the degradation of plastic goods being a substantial challenge for soil habitats. Plastic pollution has been identified as a significant contributor to environmental degradation in marine ecosystems. However, there is an increasing recognition of the need to address this issue in terrestrial and freshwater habitats as well. Microplastics (MPs), which are small plastic particles, have been quantified in many freshwater environments, including riverine coastlines, water bodies, and deposits found in lakes, streams, and reservoirs. (Lambert et al., 2013), there have been several toxicological studies reporting the ingestion of microplastics (MP) by different species, which has ramifications for their life cycle characteristics. Ogonowski et al.,2016), microplastics exhibit a lack of degradation. As a consequence, primary and secondary microplastics persist in the environment. The presence of microplastics has been identified in many aquatic environments, including seas and freshwater ecosystems. Additionally, microplastics have been identified as contaminants in the air, existing as pieces of particles of dust and fibers. Furthermore, investigations have shown the occurrence of microplastics inside the tissues and gastrointestinal systems of marine invertebrates such as crabs. It is quite likely that fish and birds consume microplastics that are present on the water's surface, mistaking them for food particles. The ingestion of microplastics by aquatic organisms results in reduced food consumption and diminished energy levels, hence impeding their physiological processes. The presence of microplastics has been shown to have adverse effects on both neurological functioning and reproductive processes. There is a potential for the transmission of microplastics from zooplankton and small fish to higher trophic level marine predators. An abundance of microplastics has been found in several sources, including water, beer, and food items such as seafood and table salt. Microplastics were detected in the stool samples of all eight individuals who participated in a pilot research, each hailing from a different country. The existence of microplastics has also been discovered inside the cellular and organ structures of human beings. (Rogers, 2022)

2.8. Risk to aquatic organism due to microplastic

The existence of microplastics (MP) has been documented in several environments around the globe, including freshwater and saltwater as well as urban and distant regions. (Hirai et al., 2011) Furthermore, MP has been detected in diverse habitats ranging from beaches to deep-sea sediments. (Coppock et al., 2017). The discovery of potential adverse effects of MPs on aquatic creatures has raised concerns in the scientific community. The ingestion of microplastics (MPs) may lead to hunger in aquatic organisms. (Cole et al., 2011) Several studies have shown the phenomenon of trophic transmission of microplastics (MPs). (Farrell et al., 2013) This process has been identified as a possible mechanism for the ingestion of MPs by several species (Santana et al., 2018). Various harmful substances may also be released from microplastics (MPs), including Polycyclic Aromatic Hydrocarbons (PAHs), Polybrominated Diphenyl Ethers (PBDEs), and heavy metals. (Afrin et al., 2020)

Due to their diminutive size, contemporary technologies encounter challenges in effectively recovering microplastics, hence contributing to their widespread distribution throughout the environment. The establishment of effective microplastic degrading technologies and plastic recycling systems is crucial in order to establish an environment that is free from microplastics. (Mahmud et al., 2022) Phytoplankton has significant ecological significance within aquatic ecosystems due to their provision of energy to food webs and its integral involvement in ecosystem activities, particularly carbon cycling. The presence of a significant quantity of microplastics within the marine environment has been seen to have a negative impact on the development of phytoplankton, resulting in alterations to the composition of the phytoplankton community and posing a threat to the general equilibrium of the marine ecosystem. Based on the findings of the research, it has been shown that the presence of sizable microplastic fragments in the marine environment hampers the passage of sunlight, hence impacting the efficiency of photosynthetic processes carried out by phytoplankton. Microplastics have been seen to alter the chlorophyll levels in phytoplankton. The presence of elevated levels of microplastics had a substantial impact on the abundance of phytoplankton communities. Marine organisms have a tendency to misidentify vividly colored microplastics as edible substances. Microplastics are introduced into the food chain as a result of the ingestion of fish. In recent research conducted in 2021, a total of 48 fish specimens belonging to 18 distinct species were collected and subjected to comprehensive analysis. The findings revealed that a significant proportion, namely 73.3% of the examined fish, had observable impacts attributable to the presence of microplastics. A total of 107 plastic particles were discovered throughout the gastrointestinal tracts of 35 fish specimens. (Mahmud et al., 2022)

Microplastics (MPs) have the potential to undergo transformations within the food chain or other routes, leading to a range of detrimental effects on biota. These effects include asphyxia, stomach blockage, intestinal damage, and malnutrition. Furthermore, it has been shown that MPs have the ability to traverse the cell membrane and infiltrate many tissues and systems inside an organism, hence inducing detrimental effects at both the level of cells and molecules. (Zhang et al., 2021)

2.9. Heavy metal presence and source at landfills

The disposal of municipal solid waste (MSW) has been shown to have a significant environmental impact, particularly in relation to the presence and effects of heavy metals inside the dumping site. The impacts of heavy metals have been seen to exhibit variability depending on the prevailing circumstances inside dumpsites and the specific forms in which they are bound. The open dumpsite, when exposed to air conditions, has several impacts as a result of oxygen diffusion. The association between metals and Mn and Fe oxide is enhanced under situations characterized by high redox potential. Conversely, the affinity of metals for carbonate, organic compounds, and sulfide tends to diminish. The degradation rate and acid buffer capacity of the dumpsite are significantly impacted by the increased potential for oxygen penetration in the higher layer and the presence of adequate moisture content. In this particular scenario, there is a decrease in alkalinity, pH, and sulfide oxidation, resulting in the increased availability and release of heavy metals. (Prechthai et al., 2008) The movement and danger of heavy metals found at disposal sites are contingent upon the specific chemical composition of these metals. In the Matuail area, there is a strong association of heavy metals with the fine fraction. The levels of Cd and Co in the sites are rather negligible, while Matuail exhibits much higher concentrations of Cr, Cu, Mn, Ni, and Zn. The practice of co-disposal of home hazardous wastes, such as paint residues, ash, electronic wastes, biomedical waste, plastic, and non-ferrous metals, together with culinary trash, is seen in Bangladesh. at addition, a substantial proportion of industrial trash is also deposited at landfill sites alongside municipal solid waste (MSW). The prevalence of heavy metals in municipal solid waste (MSW) at dumping sites is primarily influenced by these two variables. The heavy metal components in the municipal solid waste (MSW) at the Matuail dumping site in Dhaka were observed to have the following order of average concentration: zinc (Zn) > copper (Cu) > manganese (Mn) > chromium (Cr) > lead (Pb) > nickel (Ni) > cobalt (Co) > cadmium (Cd). The findings indicate that the Matuail dumpsite has elevated levels of pollution with Zn, Cu, Mn, Cr, and Pb. The study sites were analyzed for the concentration of heavy metals in municipal solid waste (MSW) and compared to the documented levels of heavy metals found in the dumping site in Japan, India and Thailand. (Prechthai et al., 2008) The findings indicate that the concentration of heavy metals in municipal solid waste (MSW) at the specified dumping site is comparatively lower than that seen at other dumping locations. In the context of Bangladesh, the predominant method of home waste disposal involves depositing it at designated dumping sites. The recycling of resources from municipal solid waste (MSW), both at secondary and ultimate disposal sites, plays a significant role in reducing the concentration of heavy metals in the trash found at these dumping sites. The mobility and toxicity of heavy metals in waste materials are mostly influenced by their binding configurations. The solubility of metals in rainfall is generally low, rendering them essentially insoluble. Consequently, it is not anticipated that metals will be discharged into rainwater under the typical circumstances found at dumping sites. Nonetheless, the accessible components of metals such as lead (Pb), manganese (Mn), and copper (Cu) have considerable importance since they may readily enter the food chain. (Karim et al., 2017)

Approximately 2.8 million metric tons of electronic trash, which contains hazardous substances such as mercury (Hg) and lead (Pb), are annually produced and then disposed of in landfills, agricultural areas, and bodies of water (EDSO, 2010). The occurrence of high levels of heavy metals in fertilizers due to human activities such as agricultural and industrial practices leads to elevated concentrations of lead (Pb) and nickel (Ni) in soil and water systems, thereby impacting the metal content found in vegetables. (Alegria et al., 1991) The presence of metals derived from discarded vegetables in solid waste can potentially contribute to elevated levels of metals in landfill leachate. Leachate, which is the liquid that drains from landfills, is predominantly composed of dissolved organic matter (DOM). This DOM constitutes a significant portion, accounting for more than 85% of the total organic matter in terms of organic carbon found in leachates. (Zhang et al., 2009) The DOM has the potential capacity to form complexes with heavy metals, hence influencing their speciation. (Wu et al., 2011) A prior research conducted by Baun and Christensen (2004) revealed that a significant proportion of heavy metal was linked to dissolved organic matter (DOM) present in landfill leachate. The presence of a significant number of functional compounds in the structures of humic substances (found in dissolved organic matter) has been seen to result in a strong affinity towards heavy metals. This phenomenon has been documented in studies. (Terbouche et al., 2010) These functional groups facilitate the formation of complexes between dissolved organic matter and heavy metals. (Rikta et al., 2018)

Table 6: Major sources of heavy metal (Singh et al., 2022)

SL	Heavy metal	Common source
1	Cu	Copper can come from various fertilizers, photovoltaic cell, tanning process
2	Zn	Soldering, cosmetics and other pigments are primary anthropogenic source
3	Cr	Comes from tanning and leatherworking industries as well as chrome plating
4	As	Wooden electrical poles preserved with arsenic based preservatives, pesticides, fertilizers, emission of untreated effluents, oxidation of pyrite
5	Hg	Coal, combustion, municipal solid waste incineration, volcanic eruption
6	Cd	Typical cadmium sources include plastics, electroplated components, photoconductors, pigments, rubber, batteries
7	Pb	Most lead originates from items like old paints, batteries, plumbing, jewelry, food containers and other household items

2.10. Heavy metal pollution in environment from landfill leachate

The predominant route by which leachate is transported to aquatic ecosystems is via the subsurface layers of unsaturated soil, originating at the base of the landfill and ultimately reaching the groundwater below. Due to the absence of engineered liners and adequate leachate collection systems in the majority of landfills in developing nations, particularly in Bangladesh, there is a potential for hydraulic connections to facilitate the movement of leachate from groundwater to surface water. In the context of monsoon floods in a sub-tropical nation such as Bangladesh, it is possible for surface water to get contaminated as a result of the vulnerable design of landfill sites and inadequate management practices. This study examines the mechanisms via which the no lining or faulty lining of a leachate pond might result in the migration of hazardous leachate into both groundwater and water on the surface. The migration of leachate may be influenced by many physical, chemical, and biological processes, which can lead to changes in composition and a decrease in strength compared to the initial state. The migratory variables under consideration may rely on the stratification of the soil under the landfill, the hydraulic characteristics of the groundwater system, and the chemical makeup of the leachate. The evaluation of heavy metals and organic pollution in surface and groundwater next to landfill sites in developing nations is of utmost importance due to the presence of aquatic flora and fauna in these regions. Furthermore, the local population often relies on the use of this groundwater for normal drinking purposes, so placing itself in a precarious situation with regards to potential heavy metal exposure. (Parvin and Tareq, 2021)

2.11. Health risk associated with heavy metal

The global prevalence of heavy metals in water has emerged as a critical concern owing to the substantial threats it poses to human well-being. Exposure to lead (Pb) in humans has been associated with several detrimental effects, including the development of anemia, weakness, as well as damage to the kidneys and the brain. The use of water that is polluted may lead to the development of several serious health conditions, including but not limited to skin sores, gangrene affecting the leg, skin, lung, bladder, and liver, as well as the potential for cancer (. Prolonged use of water contaminated with nickel has been associated with adverse effects on the respiratory system and neurological system, including the development of dry cough and cancer. (Genchi et al., 2020) Cadmium (Cd) and hexavalent chromium (Cr (VI)) are water pollutants that possess significant toxicity and carcinogenic properties. Both manganese (Mn) and iron (Fe) are important nutrients for human beings. Nevertheless, the excessive absorption of these metallic elements by ingestion of food and water may give rise to detrimental health consequences such as Parkinson's disease, hyperkeratosis, diabetes mellitus, cardiovascular disease, alterations in pigmentation, as well as illnesses affecting the kidneys, liver, and neurological system the presence of various metals in a significant concentration in drinking water sources might potentially lead to the manifestation of synergistic or opposing effects within the population that is exposed to these metals. (Parvin et al., 2022)

The high concentration of zinc (Zn) and copper (Cu) in food and plants is a matter of significant concern due to their toxicity to both people and animals. (Zhuanget al., 2009) Moreover, it is important to note that cadmium and lead are classified as non-essential metals due to their toxic nature, even in minuscule concentrations (Fernandes et al., 2008). These metals, specifically lead and cadmium, have been identified as potential carcinogens and have been linked to the development of several diseases, particularly those affecting the cardiovascular system, kidneys, blood, nerves, and bones. (Jarup, 2003) The release of these heavy metals into aquatic environments can result in their entry into the food web through biomagnification, posing various health risks to humans. (Faisal et al., 2014) The migration of leachate, which contains a significant amount of heavy metals, from landfill boundaries and its subsequent release into the surrounding environment, is a matter of great environmental concern. The primary factor influencing the accumulation process is the generation of leachate from the landfill, and the overall process is influenced by the intensity of rainfall. (Alam et al., 2020)

2.12. Definition of terms

Heavy metals- Heavy metals refer to metals and metalloids that possess densities above 5g/cc and atomic numbers surpassing 20. (Raychaudhu et al. 2021),

Microplastic- Microplastics, often known as MPs, include a diverse array of plastic particles that are less than 5 mm in length. (Afrin et al., 2020)

Leachate- Leachate refers to the liquid that infiltrates the layers of a landfill. The generation of leachate occurs as a result of liquids found inside waste materials and external water sources, such as rainfall, permeating through the refuse. This process involves the absorption of both organic and inorganic substances via physical extraction, as well as hydrolytic and fermentation processes. (Akter et al., 2021)

Landfill- A landfill may be described as a substantial expanse of land or a deliberately dug location that is purposefully constructed to serve as the ultimate destination for the disposal of solid waste generated by municipalities. (Urme et al., 2021)

AAS- Atomic absorption spectroscopy (AAS) is a widely used analytical technique utilized for the determination of metallic element concentrations in various materials.

CHAPTER III

METHODOLOGY

3. Materials and methods:

3.1. Study area

The Aminbazar landfill is situated in the Savar Upazila of Dhaka, Bangladesh, in close proximity to the Turag and Karnatali floodplains, specifically located at coordinates 23° 47' 34" North and 90° 17' 52" East. Dhaka city is geographically partitioned into two administrative entities known as Dhaka North and Dhaka South corporations, each of which accommodates designated landfills for the purpose of garbage management inside the city. The AminBazar dump is operated by the Dhaka North City Corporation, whereas the Matuail Landfill is managed by the Dhaka South City Corporation. Amin Bazar constitutes one of the fifty-four administrative divisions of the Dhaka North region. The present site may be classified as a semi-aerobic landfill spanning around 20,234 hectares, primarily designed to expedite the disposal process of waste materials. (Urme et al., 2021)

The Matuail landfill is situated at a distance of around 300 meters from the primary roadway of Matuail, specifically located at coordinates 23° 42' 97" North and 90° 27' 2" East. It is positioned in the southeastern region of Dhaka and is roughly 3.75 kilometers away from the central point of Gulistan in Dhaka. The current landfill has an area of around 100 acres (40.5 hectares), and officials are actively pursuing the acquisition of an additional 81 acres (32.8 hectares). More than 65 percent of the daily trash generated in Dhaka is gotten rid of at the Matuail dumpsite. The spot that was formerly used as an open-air dump has been transformed into a clean landfill. (Urme et al., 2021)

Fig 3: Aminbazar sanitary Landfill

Fig 4: Matuail sanitary landfill

3.2 Research Design

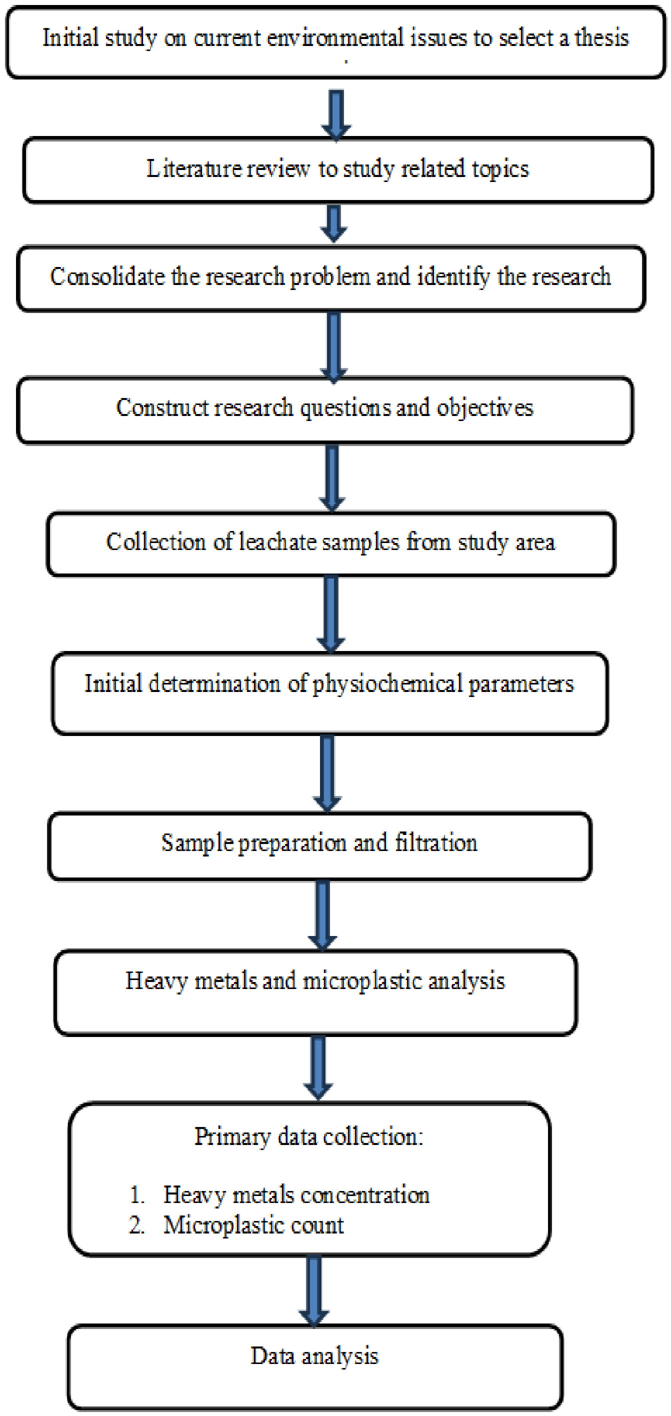


Fig 5: Flowchart of research design

3.3. Data Collection Sources:

The current research work has been designed based on primary work where primary data are used for most of the work. Secondary data are used for diverse indexing purposes and to conduct various evaluations between present research work and existing studies.

Primary data: The primary data for this research were the physical parameters, heavy metals and microplastic content collected through various instruments.

Secondary data:

The secondary information was obtained from different scientific papers, technical reports, books, and review articles.

Fig 6: Raw and treated leachate collection from raw and treated leachate ponds at Aminbazar and Matuail Landfills

3.4 Materials and instruments:

The materials and instruments used in the research is presented with their purpose of use in the table below:

Table 7: Required materials for the study

SL NO.	Materials used	Purpose of use
1	Sample leachate	Used for several laboratory analysis
2	500ml Pyrex bottles	Used for preserving and transporting samples
3	500ml plastic bottles	Used of preserving and transporting samples
4	Measuring cyclinder	Used for measuring the volume of liquid, chemicals
5	Volumetric flask	Used for preparing solution for heavy metal assessment
6	Graduated pipette	Used to accurately measure and transfer liquids
7	beaker	Used to make solutions
8	Multiparameter	Used to measure physiochemical parameters
9	Filter paper	Used to filter samples for microplastic identification
10	Funnel	Used to channel sample during filtration into volumetric flask
11	GPS	Used to collect GPS location
12	Vacuum filter	Used to filter sample solution

13	Atomic Adsorption Spectroscopy	Used for determining heavy metals
14	ArcGIS	Used for preparing the study area map
15	SPSS-Software	Used for statistical analysis and correlation analysis

3.5. Sampling technique

For this study two types of samples were collected from the study areas: raw leachate and treated leachate from Aminbazar and Matuail landfills' leachate ponds. Five leachate samples for microplastic and three for heavy metals were collected from each of the raw and treated leachate ponds.

Five 500ml pyrex bottles were used to collect five samples of raw and five samples of treated leachate from leachate ponds for microplastic analysis. Pyrex bottles were used instead of plastic for microplastic analysis to eliminate the possibility of microplastic addition from bottles because plastic bottles can also exert microplastics from Aminbazar landfill and the same process was followed to acquire samples from Matuail landfill.

Six 500ml plastic bottles were used to collect three samples of raw and three of treated leachate from raw and treated leachate ponds respectively for heavy metal analysis from Aminbazar landfill and the same procedure was followed to acquire sample from Matuail landfill.

The sample bottles were rinsed before sampling with DI water to eliminate any contaminant and air dried before sampling.The samples were collected and taken to laboratory were it was stored safely. In order to mitigate the potential loss of specific cations, including Cd, Cu, Cr, Ni, and Zn, during the heavy metal evaluation, a little amount of HNO3 was introduced into each bottle. This addition serves to inhibit adsorption or ion exchange between the cations and the glass container walls. The first sample for raw leachate from Aminbazar and Matuail landfills was collected at three different points of raw leachate pond and then mixed to make one composite sample. This process was done for other raw leachate samples taken for microplastic and heavy metal analysis to homogenize the samples that will be representative of the sampling pond. For the treated leachate the same procedure was followed to make composite samples that will be representative of the whole raw and treated leachate ponds.

3.6. Elemental analysis:

3.6.1. Microplastic digestion

First, two 500ml beakers and poured 100ml of treated and raw leachate collected in a 500ml Pyrex bottle. Made two solutions using 100ml of raw leachate and treated leachate with 30ml of H_2O_2. Then 2 magnets were placed in the beakers and both of the beakers were placed onto a hotplate with a magnetic stirrer where it was observed for 30 mins at approximately 120 degree Celsius and 250t/min. Then after 30 mins the hot plate was switched off and the magnets were taken out using pincher and washed with distilled water to remove any microplastic on the magnets into the beakers. The same process was done to make nine more sample solutions using raw and treated leachate samples to make three replicates of each of the raw and treated samples. Then the beakers were stored after wrapping the mouth with foil paper.

Fig 7: Sample processing

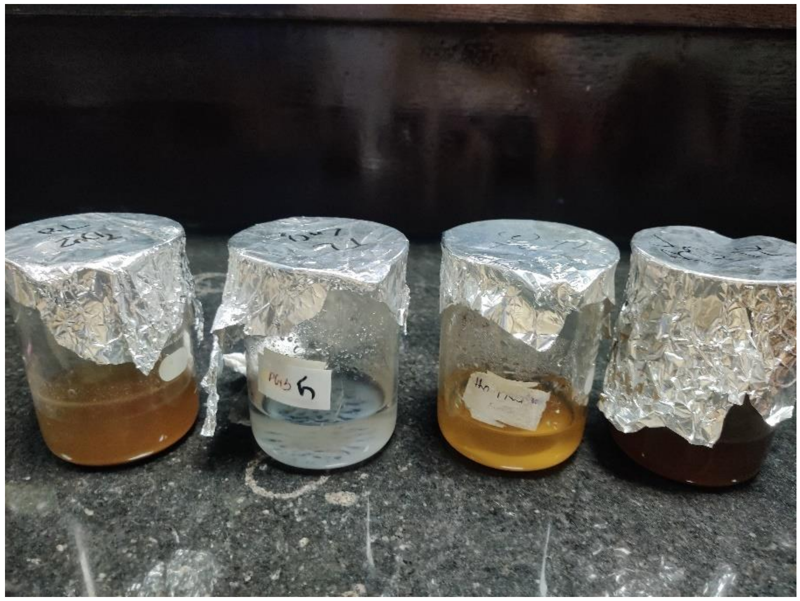


Fig 8: Sample digestion (1)

The same process was done for both landfills to make twenty sample solutions for both raw and treated leachate. Then after a few days five gm of $ZnCl_2$ was made into the solution using 10ml distilled water and twenty of this solution was made that were mixed with all the leachate sample solutions for density separation.

After some days, the digested solutions were centrifuged to separate the sediment from leachate liquid.Then vacuum filtered all the samples onto nylon filter paper for microplastic accumulation on the filter paper. Then the filtered papers were stored in petri dishes and labeled for recognition later easily.

3.6.2. Heavy metal digestion:

First, In 4 beakers all of the raw and treated leachate of Matuail and Aminbazar were taken only to 100ml. Then 20ml of HNO_3 was added to each of the 4 beakers and placed on a hotplate in a fume hood for acid digestion.Then after 1 hr hydrochloric acid was added 50ml in each beaker. Then after some time H2002 was added a little bit in every beaker and with that some HNO3 because the leachate wasn't getting clear.

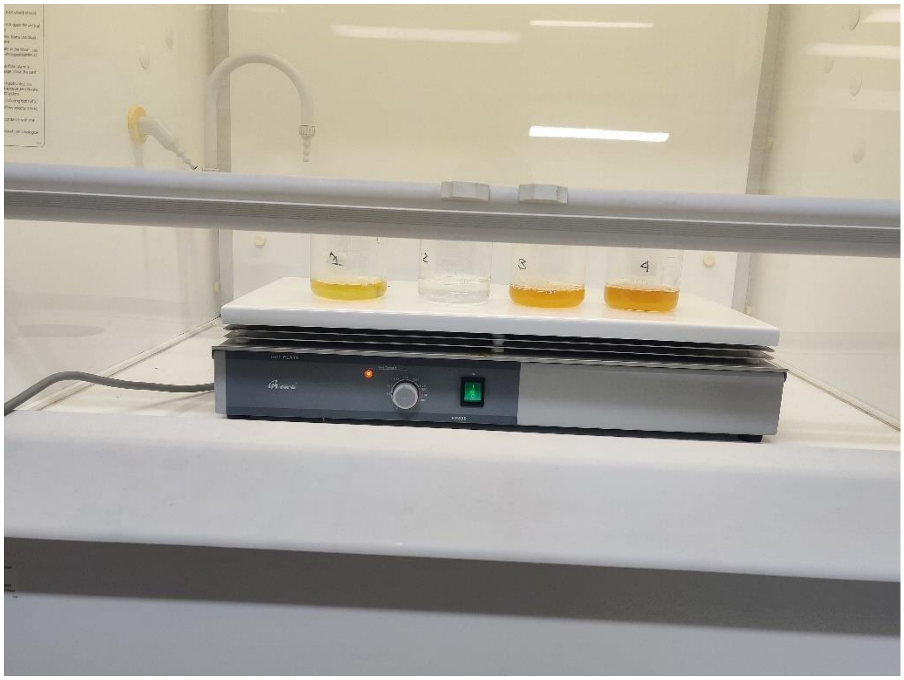


Fig 9: Sample digestion (2)

Then after 2hrs the beakers were taken off from the hotplate and placed to cool off.

The leachates were then poured into volumetric flasks and DI water was added to make the solution 100ml. This was done for the rest of the samples to make exactly 20 sample solutions total for both raw and treated leachate from Matuail and Aminbazar landfills.

Then each of the samples were vacuum filtered to clear out the solution. After that the flasks were refrigerated.

Fig 10: Vacuum filtration

The Solutions were taken out from the fridge and were left to defrost. After 40 mins, 1000 microliters solutions from each of the volumetric flasks were taken out using pipette and transferred into small cups. One extra cup was taken which contained distilled water. The 5 cups were then placed in the holes of Atomic absorption spectrophotometer for detection of heavy metal intensity. Metals were measured for both the landfill leachates which are As, Pb, Cd,Mn, Cr, Ni.

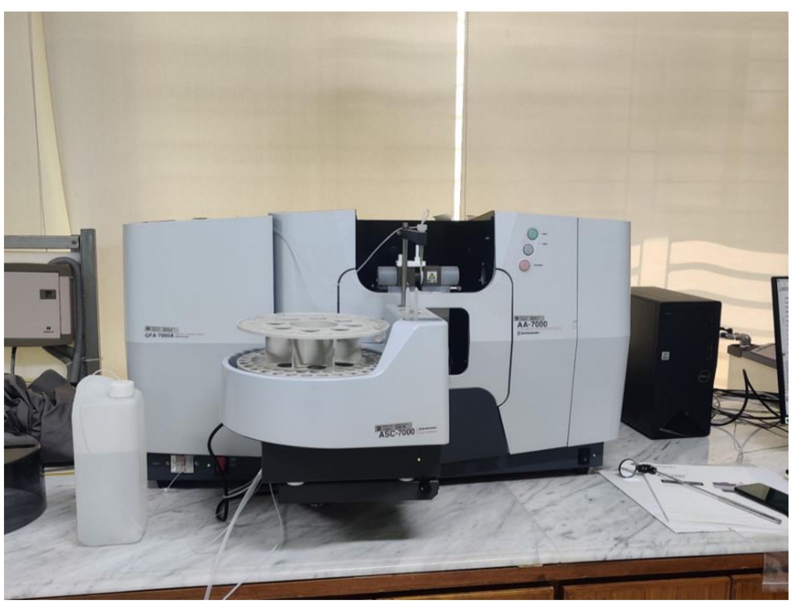


Fig 11: Heavy metal analyzing machine AAS

3.7. Quality control

In order to maintain quality assurance and quality control, blank samples, replicate samples were analyzed. Some precautions were strictly enforced to control contamination during the experiment. All glassware was washed three times with MilliQ water and wrapped in aluminium foil paper until it was ready to use. The experiment was carried out by an investigator wearing laboratory coats and polymer-free white gloves, and the laboratory window was kept closed during the experiment. The beaker was covered with aluminium foil paper during the digestion of the water and sediment samples. A glass petri dish was used to store the glass fibre filter paper. The filter paper was left out in the open while counting microplastics with a stereomicroscope to avoid getting dirty from microplastics in the air. Several blank tests were performed to assess the possibility of contamination. In the lab, a piece of intake filter paper was put in a Petri dish and left there for ten days without covering it. Count the microplastics on the filter paper under a microscope after ten days. The blank test filter paper contained no microplastics (Parvin. et al 2022). Quality and quantity control ensure data accuracy during sampling. Researchers should wear 100% cotton and latex gloves. Polythene envelopes and aluminum foil protect samples from atmospheric MPs (Noik & Tuah, 2015). To reduce pollution, PMs must be tested. Compare on-site MPs to standards library MPs. (Ng & Obbard, 2006)

3.8. Analysis of physiochemical parameters of leachate

Seven crucial parameters were chosen for physiochemical examination of raw and treated leachate quality. Temperature, Ph, DO, TDS, EC, salinity and turbidity are among them. The parameters were measured using multiparameter instrument (Hanna Hi-9829).

3.9. Indices for heavy metal assessment and significance analysis

Heavy Metal Pollution Index (HPI)

The HPI technique was created by allocating a rating or weightage (W) to each selected parameter and determining the pollutant parameter upon which the index would be based. The rating is an arbitrary number between zero and one, and its selection indicates the relative relevance of specific quality factors (Biswas et al., 2017). The calculation of heavy metal pollution index (HPI) was done by using the following equation (Eq.1):

$$HPI= \frac{\sum_{i=1}^{n} WiQi}{\sum_{i=1}^{n} Wi} \ldots\ldots\ldots\ldots\ldots\ldots\ldots [1]$$

Where, Wi, The unit weight age of the ith parameter, Qi = The sub-index of the ith parameter.

The unit weight age of the ith parameter (Wi) is inversely proportional to the recommended standard for ith parameter. The equation for the calculation of unit weight age is as follows (Eq.2):

$$Wi=\frac{K}{Si} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [2]$$

Where, S, Standard concentration value for the ith parameter, K = Constant of = proportionality.

In this study, the maximum tolerance guideline for drinking water quality by ECR (1997) is taken as the standard values (Si).

The sub-index of the ith parameter (Qi) is calculated by the following equation (Eq.3):

$$Qi=\frac{Vi}{Si} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [3]$$

Where Vi, is Measured concentration value for the ith parameter in ug/l, Si, is Standard concentration value for the ith parameter in µg/l. In general, an HPI score of 100 is deemed "Critical."

3.10. Statistical Analysis

Using Microsoft Excel, statistical analysis was performed by computing the range of values, the mean, the standard deviation, the coefficient of variance, etc. Moreover, Pearson's correlation and one way ANOVA analysis among the heavy metals was conducted within each sample to discover the potential sources of heavy metals in soil, water, and plants. The analysis was performed using the SPSS v.26 software package (SPSS Inc., Chicago, USA).

CHAPTER IV

RESULTS AND DISCUSSION

4. Results and Discussion

4.1. Analysis of physiochemical parameters:

Physicochemical parameters of a landfill give knowledge about the age and treatment processes' efficiency. It is crucial in determining what type of waste is being landfilled the most and what type of pollution it can create. Th following table gives information about the physicochemical parameters taken during sampling through potable meters at Matuail and Aminbazar landfill.

Table 8: Physiochemical parameters of raw and treated leachate from Matuail landfill

Location	Sample ID	pH	Temperature(°C)	EC (mS)	TDS (ppt)	Salinity (psu)	Turbidity (NTU)	DO (mg/L)
Matuail	RL-1	7.932	30.2	9.09	4.73	5.42	327	5.78
	RL-2	7.86	30.2	8.93	4.72	5.45	348	5.86
	RL-3	7.75	30.2	9.43	4.8	5.62	359	5.56
	RL-4	7.86	30.2	9.52	4.72	5.44	324	5.74
	RL-5	7.88	30.2	8.74	4.723	5.04	366	5.38
	RL-6	7.42	30.2	8.04	5.06	4.83	345	6.23
	RL-7	7.72	30.2	9.23	5.52	5.71	388	6.67
	RL-8	7.92	30.2	9.01	4.81	4.88	362	5.03
	Mean	7.8042	30.2	8.978	4.8753	5.315	353.7	5.81
	SD	0.153965		0.4121704	0.2524387	0.3004163	19.78242767	0.4833908
	TR-1	7.87	30.2	9.59	4.54	5.85	94.9	6.93
	TR-2	7.82	30.2	9.8	4.95	5.28	96.3	6.9
	TL-3	7.63	30.2	922	4.82	5.4	94.4	6.04

	TL-4	7.78	30.2	9.72	5.5	5.08	100.3	6.46
	TL-5	7.38	30.2	9.06	5.75	5.9	110.6	6.53
	TL-6	3.84	30.2	9.04	5.06	5.28	98.8	6.92
	TL-7	7.82	30.2	9.82	4.8	5.27	102.7	6.48
	TL-8	7.88	30.2	9.81	4.55	4.42	104.6	6.32
	Mean	7.341	30.2	9.561	4.979	5.215	99.73	6.563
	SD	1.239206287		0.323640747	0.424406776	0.467576494	5.034999724	0.285542369
ECR, (1997)		6.5–8.5	20–30	0.35	1	----	10	6
WHO, (2017)		6.5–8.0	----	0.25	0.5	----	5	4–6

The raw and treated leachate from Matuail landfill have mean pH of 7.8042 and 7.341respectively which indicates that there weren't many changes occurred during the treatment of leachate to the pH but according to the ECR (1997), or WHO (2017) the pH of both the raw and treated leachate are within the acceptable range for discharge into surface water. It ensures that the pH of the treated leachate discharged into the adjacent surface water is safe and isn't of concern. The values refer to a mature landfill leachate. The study showed that the pH value for new landfills normally varies from 4.5 to 7.5, and for mature landfills, it varies from 6.6 to 7.5. (Hredoy et al., 2022) Stabilized leachate shows fairly constant pH with little variations and it may range between 7.5 and 9. (Umar et al., 2010) Samples of leachate were alkaline in nature. Leachate's pH shifts to an alkaline state when the bacteria that produce methane consume the free unstable fatty acids. Whilst trash deposition is still occurring at the landfill site, there is a significant ratio of old and stable garbage to recently deposited waste, which prevented the observation of acidogenic leachates. (De et al., 2016) The temperature of both raw and treated leachate showed same value which is mostly 30 degree Celsius or a little beyond that value. Though according to ECR (1997) for surface water the temperature is in an acceptable range and not harmful. The mean EC is 8.978 mS and 9.561 mS for both raw and treated leachate respectively which is way higher than the standards set by ECR (1997) and WHO (2017) for surface water. Extremely high conductivity values are caused by an abundance of cations and anions. The treated leachate has more conductivity than raw leachate which indicates that there were more cations and anions in treated leachate than raw ones. Major ions including calcium, magnesium, sodium, and potassium are primarily responsible for the leachate samples' conductivity. (Johansen and Carlson, 1976) Three tanks containing three different types of chemicals—ferrous sulphate ($FeSO4$), lime (CaO), and polymer—are used to treat the raw leachate using chemical and biological oxygen demand methods. (Urme et al., 2021) Due to the treatment with these chemicals the cations and anions may bind with the leachate and increase the conductivity of treated leachate. The mean salinity of the raw and treated leachate is 5.315 psu and 5.215 psu respectively which indicates that there wasn’t much change in the salinity due to treatment because it is same for both raw and treated leachate. TDS of raw leachate is 4.8753 ppt and for treated leachate it is 4.979 ppt which shows that the treatment plant wasn’t efficient in removing total dissolved solids successfully. Though according to ECR (1997) and WHO (2017) for surface water the value of mean TDS of treated leachate was much lower. The mean turbidity for raw and treated leachate is 353.7 NTU and 99.73 NTU respectively. The values show that there is a significant drop of turbidity from raw to treated leachate. The turbidity significantly reduced but it is still beyond the range set by ECR (1997) and WHO (2017) for surface water which means that discharging it into surface water might be risky for the aquatic ecosystem. The mean DO of raw and treated leachate were 5.81 mg/l and 6.563 mg/l respectively. The DO for both the leachate is quite good according to the ECR (1997) or WHO (2017) for surface water because it is within the limit and suggest that the BOD was lower in raw leachate which retained the DO to permissible limit. Though treating didn’t affect much because the DO of treated leachate wasn’t much higher than the raw ones. An adequate supply of DO is necessary for good water quality, survival of aquatic organisms and decomposition of waste by microorganism. Since the treated leachate will be dumped in surface water it was safe to discharge. The lowest value of DO in untreated leachate indicates organic pollution. (Jahan et al., 2016)

Table 9: Physicochemical parameter of raw and treated leachate from Aminbazar landfill

Location	Sample ID	pH	Temperature(°C)	EC (mS)	TDS (ppt)	Salinity (psu)	Turbidity (NTU)	DO (mg/L)
Aminbazar	RL-1	8.036	30.4	9.91	5.02	5.66	394	5.9
	RL-2	7.893	30.3	9.92	4.86	5.61	314	5.84
	RL-3	8.04	30.3	9.8	5.4	5.67	388	5.63
	RL-4	8.038	30.3	9.92	5.42	5.42	390	5.7
	RL-5	7.9	30.3	8.73	5.4	5.66	344	5.78
	RL-6	8.24	30.3	8..88	4.87	5.8	393	6
	RL-7	8.002	30.2	8.9	4.9	4.5	389	5.44
	RL-8	7.93	30.3	9.78	5.03	4.68	390.2	5.9
	Mean	8.0365	30.3	9.56	5.117	5.523	377.88	5.783
	SD	0.123049		0.444348	0.2275	0.538785	26.92346	0.159307
	TR-1	7.04	30	0.314	0.1634	0.16	3.2	5.73
	TR-2	7.08	30	0.263	0.1319	0.13	3.2	6.04
	TL-3	7.04	30	O.245	0.1235	0.2	3.22	5.9
	TL-4	7.2	30	0.37	0.137	0.23	3.31	5.86
	TL-5	7.23	30.2	0.363	0.1456	0.144	3.5	6.3
	TL-6	7.045	30	0.214	0.1524	0.156	3.32	6.02
	TL-7	7.23	30	0.334	0.1785	0.166	3.37	6.4
	TL-8	7.066	30	0.323	0.1232	0.163	3.18	5.87
	Mean	7.1037	30.04	0.2625	0.12972	0.1719	3.34	6.032
	SD	0.081622		0.052245	0.051665048	0.035902	0.298179	0.2348427
ECR, 1997		6.5–8.5	20–30	0.35	1	----	10	6
WHO, 2017		6.5–8.0	----	0.25	0.5	----	5	4–6

The raw and treated leachate from Aminbazar landfill have mean pH 8.0365 and 7.1037 respectively. according to the ECR (1997) the pH of both the raw and treated leachate are within the acceptable range but raw leachate's a little higher the range set by WHO for surface water pH which indicates that it might be harmful for the surface water if the raw leachate gets mixed with surface water. The leachates are slightly alkaline in nature. Leachate's pH shifts to an alkaline state when the bacteria that produce methane consume the free unstable fatty acids. Whilst trash deposition is still occurring at the landfill site, there is a significant ratio of old and stable garbage to recently deposited waste, which prevented the observation of acidogenic leachates. (De et al., 2016) The alkaline nature of treated leachate is maybe due to treatment with CaO. The temperature of both raw and treated leachate showed same value which is mostly 30 degree Celsius or a little beyond that value. Though according to ECR (1997) for surface water the temperature is at the higher end of acceptable range but not harmful if discharged. The mean EC is 9.56 mS and 0.2625 mS for both raw and treated leachate respectively. The treated leachate is safe to be discharged into surface water because it complies with the standards set by ECR (1997) and WHO (2017) for surface water but the raw leachate is not. If the treated leachate is mixed then it wouldn't affect the water much because of dilution. The mean salinity of the raw and treated leachate is 5.523 psu and 0.1719 psu respectively which indicates that the treatment worked in terms of reducing salinity. TDS of raw leachate is5.117 ppt and for treated leachate it is 0.12972 ppt which shows that the treated leachate has less dissolved solids than raw ones. The treated leachate is below the permissible limits set by ECR (1997) and WHO (2017). The mean turbidity for raw and treated leachate is 377.88 NTU and 3.34 NTU respectively. The values show that there is a significant drop of turbidity from raw to treated leachate. The turbidity significantly reduced and it is below the range set by ECR (1997) and WHO (2017) for surface water. The mean DO of raw and treated leachate were 5.783 mg/l and 6.032 mg/l respectively. The DO for both the leachate is quite good according to the ECR (1997) or WHO (2017) for surface water because it is within the limit and suggest that the BOD was lower in raw leachate which retained the DO to permissible limit. Though treating didn't affect much because the DO of treated leachate wasn't much higher than the raw ones. An adequate supply of DO is necessary for good water quality, survival of aquatic organisms and decomposition of waste by microorganism. Since the treated leachate will be dumped in surface water it was safe to discharge. (Jahan et al., 2016)

4.2. Quantification of microplastic particles

The calculator analysis of the landfill leachate from 2 different landfills were estimated. For both the landfills raw and treated leachate were quantified to estimate how much microplastic is removed from the leachate treatment process which would indicate how efficient the treatment plant is. 5samples from raw leachate pond and 5 from treated leachate pond were collected for each of the landfills and the amount of microplastics were calculated and the mean values are shown in the figure below:

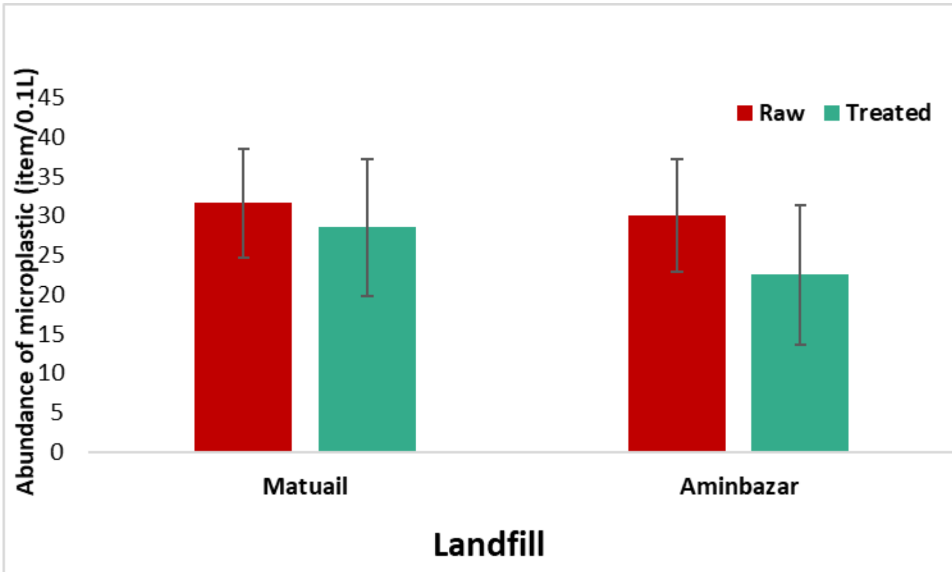


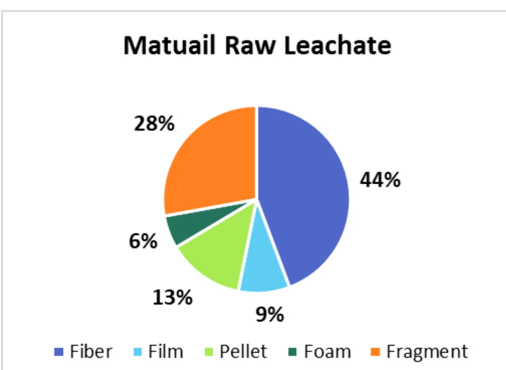
Fig 12: Comparison of mean value of microplastics between raw and treated leachate from Matuail and Aminbazar landfill

The figure depicts that the mean raw leachate value for both Matuail and Aminbazar landfills are quite the same. For Matuail it is 31.6 MPs/0.1L and for Aminbazar it is 30 MPs/0.1L which suggests that leachate is a significant source of microplastics, and both the landfills receive huge amounts of plastic waste which gives rise to the generation of microplastics. The mean amount of microplastics in treated leachate in Matuail landfill is 28.5 MPs/0.1L which is not very low compared to raw leachate's microplastic concentration which indicates that the leachate treatment system doesn't remove microplastics significantly and it is a huge drawback of the treatment plant because this treated leachate goes into surface water and may also contaminate groundwater due to improper lining which can cause significant microplastic pollution in both surface and groundwater. This microplastic contaminated leachate may cause microplastic accumulation in aquatic organisms and the people who drink groundwater around the landfill area. The treated leachate has a little less microplastic abundance than raw ones which may be because the treated leachate is discharged continuously while the raw leachate stays a little bit longer in the leachate pond before going to treatment facility.

For the Aminbazar landfill the mean abundance of raw leachate is 30MPs/0.1L and the abundance of treated leachate is 22.5MPs/0.1L which depicts that the treatment plant didn't significantly reduce the microplastic volume and it is a drawback of the treatment plant. Though the difference between the amount of microplastics in raw and treated leachate is less than Matuail but still the difference isn't significant to state that the leachate treatment plant is Aminbazar is working well than Matuail. Aminbazar landfill is surrounded by Turag, Dhaleshwar, Karnatoli rivers and the leachate is received by those rivers which are contaminated by microplastics every day. Due to lack of proper segregation approach of different kinds of waste and cheapest method of waste management, plastic wastes accumulate in landfills and aren't recycled which causes microplastic formation after a while and this microplastics due to tiny shape gets into leachate. The leachate then carries it to the nearby waterbodies. Like Matuail Aminbazar landfill poses serious risk of microplastic pollution in the surrounding waterbody and aquifers which requires modification of the leachate treatment plant to reduce the abundance of microplastic for safe discharge of leachate.

4.3. Morphological observation of microplastic particles

The visible potential of micro-plastic particles is estimated after visual observation of the particles on the microscope and collecting pictorial data from the Motic microscope. The potential microplastics come in various shapes, like fragments, fiber, films, and granules.



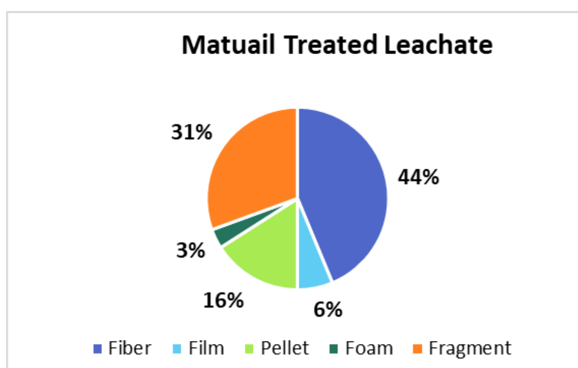
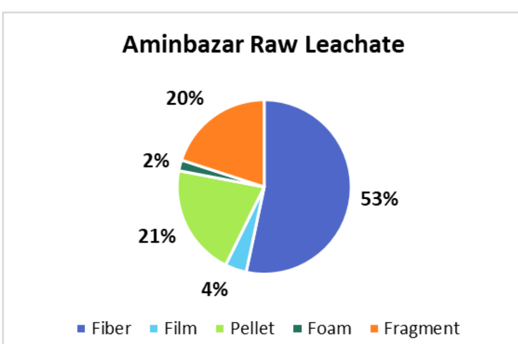


Fig 13: Depiction of different shapes prevalent in microplastic particles in raw and treated leachate of Matuail

Another important feature of MPs in effluent is their shape. (Kabir et al., 2022) The most prevalent shape in both raw and treated leachate was fiber. The second most found shape was fragment.

Fiber and fragments from landfills with precipitation may be more likely to permeate the leachate because of their shape. (Kabir et al., 2022) The fiber shape accounts for 44% of all microplastics studied in raw leachate samples. Fragment accounts for 28% of the all the microplastics estimated. Pellet, foam, film accounted for approximately 13%, 9%, 6% respectively which is very small amount compared to the amount of fiber and fragment found in the samples. In treated leachate same trend can be observed like the shapes in raw leachate which is most prevalent ones are fiber and fragments. Fiber accounted for 44% of all the microplastics quantified and fragment accounts for 31%. Pellet, film, foam possessed minor percentage of the total microplastics found which are approximately 16%, 6% and 3% respectively.

Because the fibers were tiny, they were simpler to pass through the trash and into the leachate, which was the main reason for the predominance of fibrous MPs in the leachate. (Kabir et al., 2022)



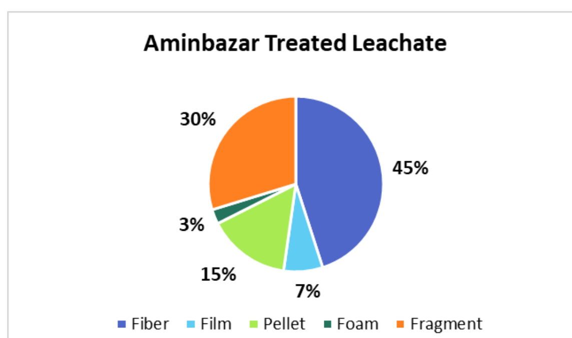


Fig 14: Depiction of different shapes prevalent in microplastic particles in raw and treated leachate of Aminbazar landfill

Like the pie chart for Matuail landfill here in Aminbazar landfill the most prevalent shape seen are fiber and fragment. In raw leachate fiber accounts for 53% of the microplastics calculated and fragments hold 20% of all shapes. In raw leachate pellet also holds major percentage which is more than fragments and is 21%. Foam and film are rarely found in leachate which is proved by the mean percentage in raw leachate that are 4% and 2% respectively. In treated leachate's pie chart the most prevalent shapes are fiber and fragment that holds mean value of 45% and 30% of all microplastic shapes respectively. Pellet also accounts for a major percentage among all the shapes which is 15%. Foam and film hold very low percentage which are 7% and 3% respectively. The percentages show that foam and film shapes are not that prevalent in leachate microplastic abundance and fiber and fragments shapes are mostly observed among leachate microplastics.

From MP's shape, the parent plastic items can be identified. Films, for instance, are typically made from plastic containers and bags. Plastic bags are translucent and thin, thus exposure to the sun can easily break them. The most common sources of granules and spherical are microbeads, containers made of plastic, water bottles, and food storage containers. (Kabir et al., 2022)

4.4. Color variation of microplastic particles

The samples had eight different particle colors: red, blue, green, purple, transparent, white, pink and black.

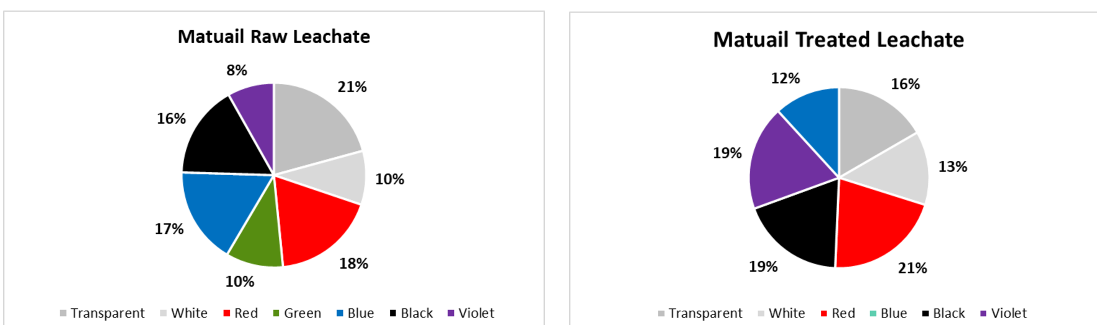


Fig 15: Color distribution of microplastics in Matuail landfill's raw and treated leachates

From the above figure in Matuail raw leachate seven types of colored microplastics were found in which the most dominant one is transparent color which accounts for 21% of all colored microplastics and it is followed by red colored microplastics which were found to be 18% of the total microplastics estimated. Blue is also found to be prevalent in microplastics and holds 17% of total amount of MPs followed by black which holds 16% of total concentration of MPs. Green, white and violet are less prevalent, green and white account for only 10% each and violet accounts for 8% of all the MPs present. In treated leachate the most abundant color is red contrary to the raw leachate which accounts for 21% of total volume of MPs. Then black and purple were seen the most after red and both hold 19% of the total percentage of MPs. Transparent, white, and blue colored MPs hold the least percentages which are 16%, 13%, 12% respectively.

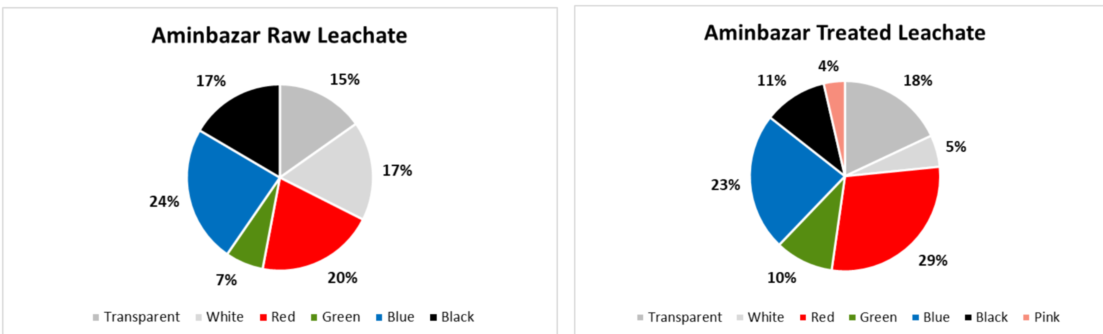


Fig 16: Color distribution of microplastics in Aminbazar landfill's raw and treated leachates

In the figure above it is seen that the most prevalent color among MPs of raw leachate is blue which accounts for 24% of all the MPs. It is followed by red which accounts for 20% of colored MPs. Then black and white are the third most abundant colored MPs found that hold approximately 17% of the total MPs found. Transparent colored MPs are 15% and green ones found were the least in amount among all, which is 7%. In treated leachate the most dominant color is red which accounts for 29% of all colored MPs followed by black color that holds approximately 23% among all MPs. Transparent colored MPs were found to be 18% and black were found to be 11%. Green was also scarce among the MPs and were found to be only about 10%. White and pink were very rare and leachate from Aminbazar may have very little amount of these two-colored MPs because according to the estimation these were found to be only 5% and 4% respectively.

MPs' hues are determined by the color of their parent plastics and the length of time they live. For instance, colorful particles are most likely from the disintegration of regularly used plastic goods, such textile and packaging products, whereas clear fibers may come from the breaking apart of fishing lines or nets (Wang et al., 2020). But the weathering process has the power to alter them. However, the color of the MPs can provide critical hints about the solid waste composition and the duration of the fragmentation process. For example, the dominant, white-colored plastics indirectly indicate the degradation process that takes place on-site for a long time, transforming other color contents into white color. The high abundance of transparent color suggested that most particles were aged and presented in the landfill system for a long time. (Kabir et al., 2022)

4.5. Size variation of microplastic particles

The greatest length of a plastic particle is referred to as its size in microplastic. When determining whether microplastic can harm both individuals and the environment, one of its most important properties is its size. The removal effectiveness of MP by various treatment units can be influenced by size, which is highly significant. The poor elimination effectiveness for that treatment phase may be recorded because breaking during the treatment phase creates several tiny MPs from one bigger MP particle. (Kabir et al., 2022)

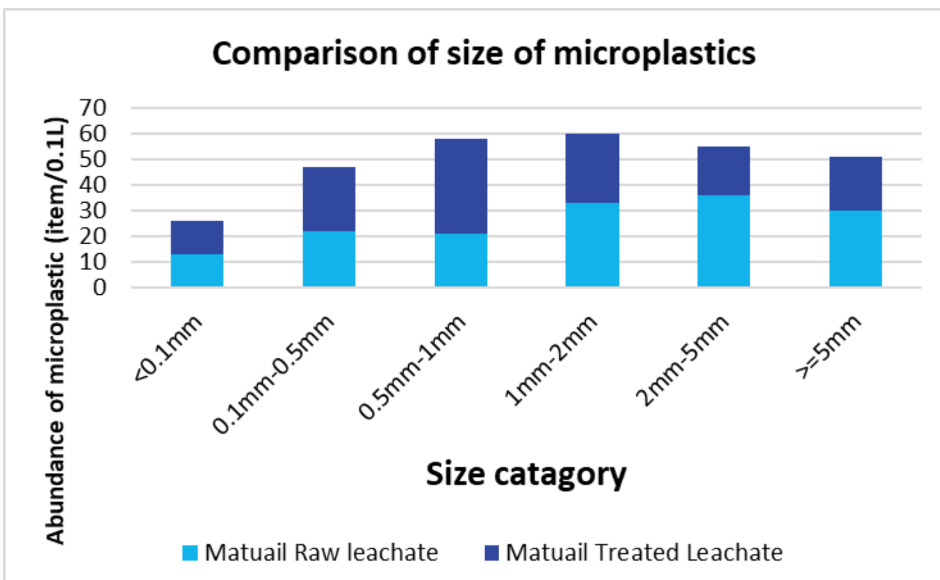


Fig 17: Comparison of microplastic abundance according to size in Matuail landfill's leachate

According to the figure above microplastics ranged between 2mm-5mm were found the most in raw leachate of Matuail which was 36MPs/0.1L. Though in treated leachate the most of the microplastics were in the category of 0.5mm-1mm. The reason can be that raw leachate undergoes treatment and ultimately discharged into treated leachate pond and while going through the process the MPs in the leachate abrade and deposit as smaller forms. This causes most of the MPs in treated leachate to be smaller in size than raw leachate's MPs. In raw leachate MPs were least found in the size category of <0.1mm and 0.5mm-1mm. 13 MPs/0.1L were found to be in the size of <0.1mm and 21 MPs/0.1L were found in the size range of 0.5mm-1mm. However, majority of MPs in treated leachate were found in the category of 0.5mm-1mm and 1mm-2mm. The small sized particles abundance in treated than raw is due to the abrasion caused during the transport of MPs from raw leachate pond to treated leachate via leachate treatment plant. The lowest number of MPs in the size range of <0.1mm was found in treated leachate. MPs in that size is very hard to detect so there maybe some error in observation during counting. In the size range of 0.1mm-0.5mm 22 MPs/0.1L were found in size range >=5mm 30MPs/0.1L and in 1mm-2mm category 33 MPs/0.1L were found in raw leachate. In treated leachate, 21 MPs/0.1L were found in the size category of >=5mm, 13MPs/0.1L in <0.1mm, 25MPs/0.1L in 0.1mm-0.5mm, 37MPs/0.1L in 0.5mm-1mm, 27MPs/0.1L in 1mm-2mm, 19MPs/0.1L in 2mm-5mm range.

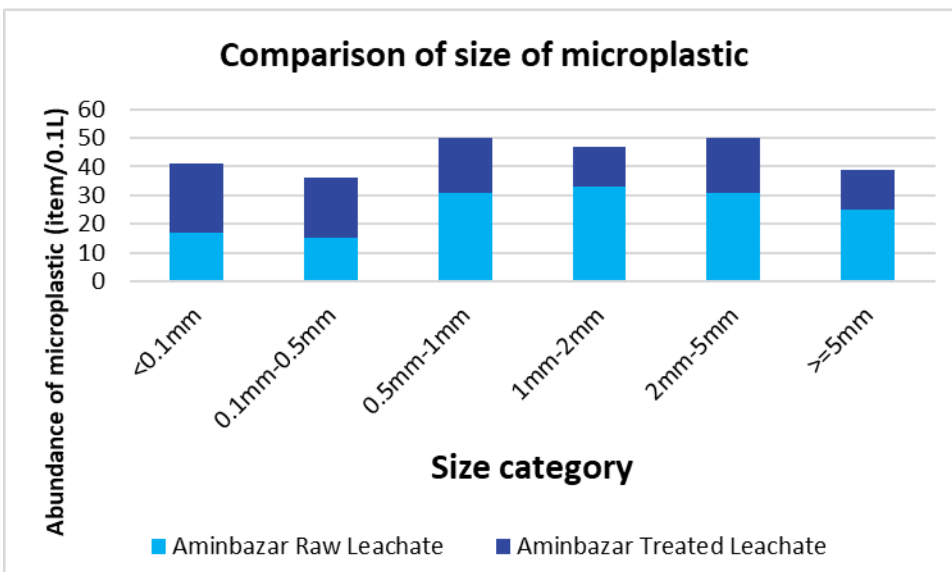


Fig 18: Comparison of microplastic abundance according to size in Aminbazar landfill's leachate

According to the figure the majority of MPs in raw leachate of Aminbazar belongs to the size category of 1mm-2mm. 33MPs/0.1L were found to be in the size of 1mm-2mm range. The least number of MPs were found in the range of 0.1mm-0.5mm which is15MPs/0.1L. In treated leachate majority of the MPs belonged to the size range of <0.1mm that is 25MPs/0.1L. The least number of MPs which was 14 MPs/0.1L were in each of the size ranges of 1mm-2mm and >=5mm. The small sized particles abundance in treated than raw is due to the abrasion caused during the transport of MPs from raw leachate pond to treated leachate via leachate treatment plant. In the size range of <0.1mm 17MPs/0.1L were found in size range >=5mm 25MPs/0.1L were found in raw leachate. In both 0.5mm-1mm and 2-3mm the same number of MPs were found which is 31MPs/0.1L for each category in raw leachate. For treated leachate, 21MPs/0.1L in 0.1mm-0.5mm, 19MPs/0.1L were found in both 0.5mm-1mm and 2mm-5mm range each.

Table 10: Microplastic detection and quantification in different countries' landfill leachates compared with Bangladeshs'. (Silva et al., 2020)

SL No.	Country	Location of landfill	Leachate treatment type	Microplastic	
				Untreated leachate (0.1L)	Treated leachate (0.1L)
1	Finland	South west	Filtration and Active Carbon	0.03	0.032
2	Finland	Lahti	Artificial soil filtration	0.197	0.003
3	Norway	Skedsmokorset	Sequencing Batch Reactor	0.13	0
4	Iceland	Fifholt	Sand bed filtration	0.02	0.006
5	Bangladesh	Aminbazar	Sand and active	30	22.5

			carbon filtration		
6	China	Shanghai	-----	0.79–24.58	
7	Bangladesh	Matuail	------	31.6	28.5

In the table above microplastic content in landfill leachate are mentioned for developed and developing countries. In developed countries due to advanced waste management process such as- segregation and recycling of wastes, very little amount of microplastic is generated in the landfill leachate shown in the table and due to proper leachate treatment process this little amount of microplastic gets treated and ultimately very low amount of microplastic is released into the waterbodies from leachate. For instance, in Norway 0.13 MPs per litre is generated which is treated by sequencing batch reactor and reduced to zero or no microplastic in treated leachate. However, in developing countries like China and Bangladesh the scenario is totally different for both landfilling and leachate treatment practice which causes huge amount of microplastic to release into the environment.

4.6 Heavy metal concentration in landfill leachates of Bangladesh

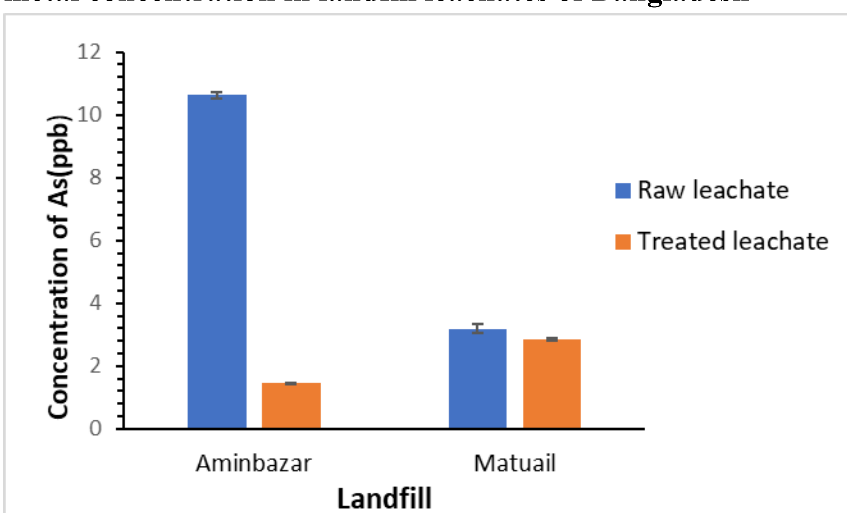


Fig 19: Mean concentration of Arsenic in raw and treated leachate of Matuail and Aminbazar landfills

According to the graph the concentration of As in raw leachate at Aminbazar landfill is a lot higher than the raw leachate of Matuail landfill. However, the treated leachate of

Aminbazar shows a dramatic reduction of As concentration which isn't visible at the treated leachate of Matuail landfill. It indicates that the treatment plant of Aminbazar landfill is able to remove As from raw leachate successfully which can't be true for Matuail because according to the bar diagram there is very less difference of As concentration between raw and treated leachate. It indicates that the treatment plant isn't sufficiently removing As from raw leachate in Matuail landfill's. As concentration in Matual landfill's leachate is 7ppb lower than AMinbazar's raw leachate.

The leaching of As from wood wastes such as building and demolition projects, utility poles, furniture, landscape structures, and wood products industries, which is often treated with chromated copper arsenate (CCA) preservatives, may result in higher metal levels in wood. (Rikta et al., 2018) Though the concentration of As in both landfill's leachates are very low, lower than the permissible limit set by ECR(1997) for inland surface water which stipulates that the discharge of the treated leachate from the landfills to their surrounding waterbody isn't harmful to the ecosystem.

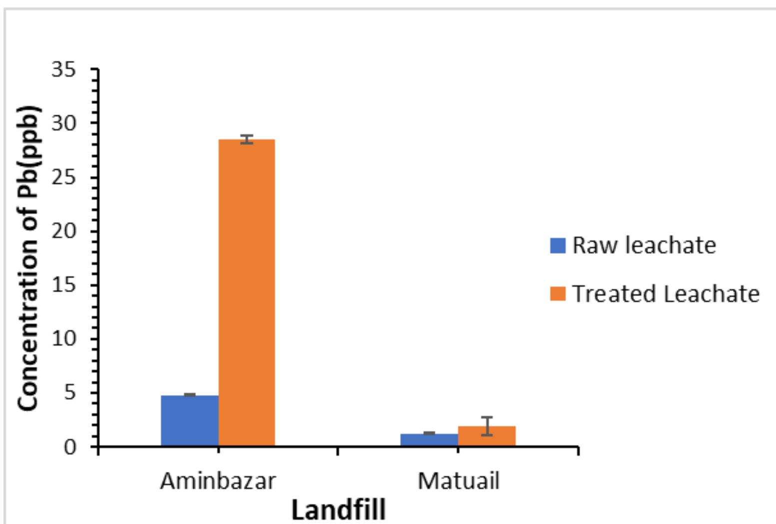


Fig 20: Mean concentration of Lead in raw and treated leachate of Matuail and Aminbazar landfills

In the bar diagram above it can be seen that the amount of Pb in both Aminbazar and Matuail's raw leachate is lower than the amount found in treated leachate and for Aminbazar the diffenrece is drastic. For Aminbazar landfill's raw leachate Pb was found to be 4.8027±0.05 and for treated leachate it is 28.5102±0.28 which is a lot higher than the raw leachate's Pb concentration. One reason for this anomaly can be oxidative dissolution which occurs when aerobic treatment is done for leachate treatment. In aerobic treatment increased microbial activity leads to dissolution of certain metals making them soluble and mobile in leachate which is the reason Pb increased in treated leachate in the landfills. (Hredoy, 2022) Some treatment processes involve the precipitation of certain contaminants as solids, which are then separated from the water. If these precipitates are not effectively separated and remain in contact with the water, they may dissolve back into the solution, contributing to higher lead concentrations. Lime is often used to increase the pH of the water, which can lead to the precipitation of metals like lead as hydroxide solids. The chemical reaction can be represented as follows: Pb2++2OH−→Pb(OH)2↓Pb2++2OH−→Pb(OH)2↓ In cases where the separation process is not optimized, or if conditions change (such as pH or temperature variations), there is a risk of redissolution of the precipitated lead back into the water. This can lead to higher measured lead concentrations in the treated water. The level of Pb in the leachate indicates the disposal of lead batteries, lead based paints, plastics, and pipes in the site. (Raisi et al., 2014) The concentration of metal ions is in general low due to the decreasing solubility of many metal ions with increasing pH. However, lead is an exception, since it forms very stable complexes with humic acids. (Bhalla et al., 2013)

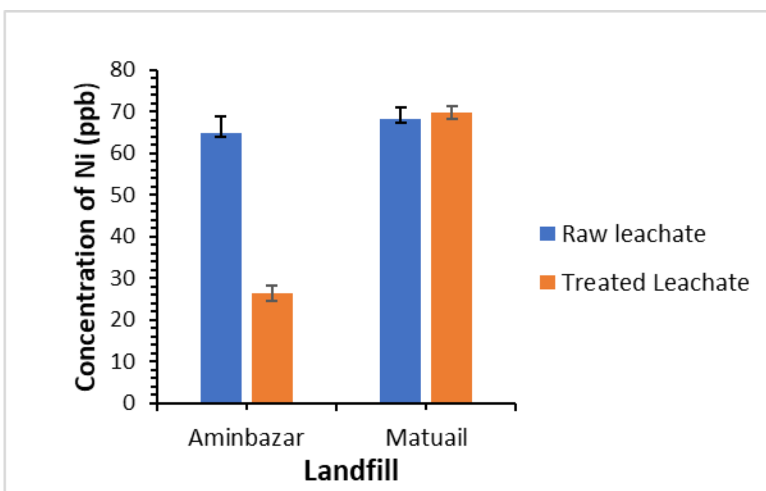


Fig 21: Mean concentration of Nickel in raw and treated leachate of Matuail and Aminbazar landfills

The bar diagram shows that the concentration of Ni in Aminbazar landfill's raw leachate is 64.8106±2.86 ppb and in treated it is 26.2322±1.28 ppb which points out that the treatment plant efficiently removes Ni from leachate and the amount of Ni is lower than the range set by DOE (2003) and ECR (1997) inland surface water meaning that discharge of the treated leachate is safe for the surrounding water bodies. On contrary, at Matuail landfill the concentration of Ni in treated is slightly higher than the raw leachate and the concentration of both raw and treated leachate is higher than raw leachate of Aminbazar landfill. The concentration of Ni in raw and treated leachate of Matual landfill are 1.2186±0.016 and 0.8291±0.011respectively. The increase in quantity of Ni in treated leachate can be due to the reason of oxidative dissolution caused by aerobic treatment. (Hredoy, 2022)

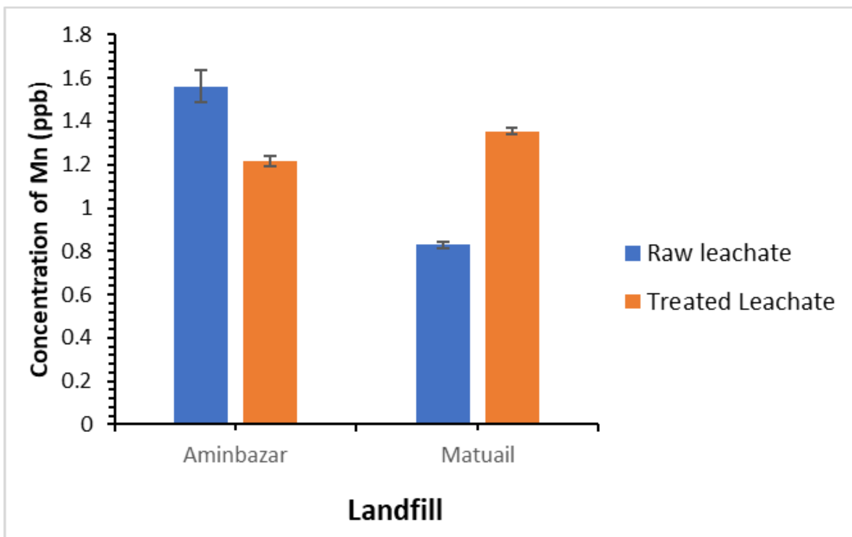


Fig 22: Mean concentration of Manganese in raw and treated leachate of Matuail and Aminbazar landfills

The concentration of Manganese in raw leachate of Aminbazar and Matuail are very low, 1.5598±0.05 ppb and 0.8291±0.011 ppb respectively. The leachate's low manganese content suggests that the dumpsites have a very high redox potential. In these circumstances, metals bond more strongly to Mn and Fe oxide, causing Mn to precipitate with carbonate and sulfide and remain at the disposal site. (Karim et al., 2017) The treated leachate of Aminbazar landfill is moderately low in the concentration of Mn which is1.2186±0.016 ppb but at Matuail opposite situation is seen. The treated leachate has more Mn than raw leachate, 1.3547±0.012 ppb which maybe because of oxidative dissolution by aerobic treatment.

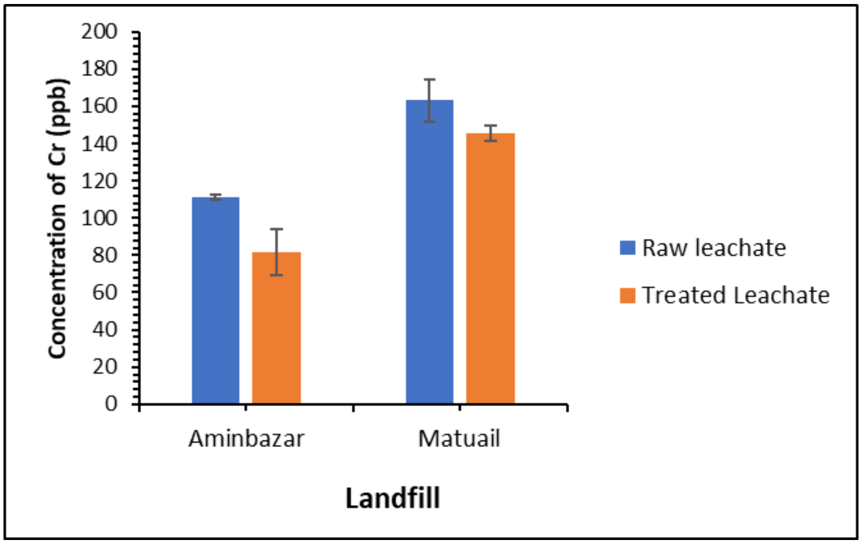


Fig 23: Mean concentration of Chromuim in raw and treated leachate of Matuail and Aminbazar landfills

The bar diagram depicts the mean concentration of Cr in raw and treated leachate of both Matuail and Aminbazar landfill. The figure shows that Cr concentration in both the raw leachate in Aminbazar and Matuail is higher than the treated leachate. The concentration Cr in raw leachate of Aminbazar landfill is 110.9109±0.92 ppb and in treated it is 81.7696±8.83 ppb. The concentration reduced approximately 20ppb but the amount in treated leachate is still higher than the permissible limit set by ECR (1997) for inland water body which is 50ppb. Smiliarly in raw leachate of Matuail the amount of Cr is 162.9952±8.43 ppb and in treated it is 145.4494±2.89 ppb which shows that the treatment wasn’t good enough and very little amount of Cr was removed from the leachate. It indicates that the discharge of leachate will be harmful for the aquatic organisms in the surrounding waterbodies of Matuail and Aminbazar because the concentration of Cr in treated leachate from both the landfill exceeds the limit set by ECR (1997) for inland surface water. The existence of Pb-Cr batteries, colored bags made of polythene, abandoned plastic items, and empty paint jars in the disposal site may be the cause of the

Cr in the leachate samples. Another important source of Cr is the effluent from electroplating and leather tanning. (De et al., 2016)

Table 11: The level of heavy metals (µg/g) in leachate from various countries (Parvin and Tareq, 2021)

Countries	Mn	Pb	Cd	Cr	Ni
Brahmapuram, Kochi, India	-		200	120	530
Ramna MSW, North India	-	BDL	BDL	1770	BDL
Pathumthani, Thailand	-	100	10	-	-
Ram Indratransfer station, Bankok, Thailand	-	440	26500	-	-
AmpangJajar, Malaysia	-	300	0	0	0
Kuala Sepetang, Malaysia	-	400		50	30
BerisLalang, Malaysia	-	1000	BDL	-	40

BDL= Below Detection Limit. All data given in ug/l unit

Landfill	Leachate	As	Pb	Cd	Ni	Mn	Cr
Aminbazar	Raw	10.62±0.08	4.80±0.05	BDL	64.81±2.86	1.55±0.05	110.91±0.92
	Treated	1.44±0.34	28.51±0.28	BDL	26.23±1.28	1.21±0.016	81.76±8.83
Matuail	Raw	3.18±0.14	1.22±0.02	BDL	68.23±2.01	0.82±0.011	162.99±8.43

	Treated	2.83±0.034	1.91±0.06	BDL	69.60±1.11	1.35±0.012	145.44±2.89
WHO (2000)			50	10			
ECR (1997)		50	50		100	100	50

Table 12: Heavy metal detected from raw and treated leachate of Matuail and Aminbazar landfill

BDL=Below Detection Limit, Detection unit ug/l

From the tables above it can be seen that Pb has been detected significantly less in the landfills' leachates of Bangladesh than any other countries. Pb has been found in Thailand Malaysia 100ppb-1000pbb where as in Matuail landfill leachate it was detected to be 1.2ppb and in Aminbazar 4.8ppb. Ni detected in the landfills' leachate of Bangladesh was 64.8 ppb in Aminbazar and 68.2 ppb in Matuail whereas in Indian landfill it was found to be a lot high which is 530ppb but in Malaysia it was less than the amount found in Bangladesh, 0nly 30ppb. Cr detected in one Indian landfill was similar and one was quite a lot than the landfill leachates of Bangladesh. In one landfill leachate it was detected 120ppb and in another 1770ppb. On the other hand, in Matuail landfill it was detected162 and in Aminbazar 110.91 which are quite similar to the first landfills leachate Cr amount in India. Cd was detected in India, Thailand and Malaysia but not in the leachates of Bangladeshi landfills.

From the table above it can be seen that all the metals in raw and treated leachate are below the permissible limit of DOE(2003), WHO(2000), ECR(1997) for inland surface water except Cr in Matuail landfill where the treated leachate exceeds the limit set by ECR(1997) and discharging this leachate can cause Cr poisoning in the aquatic system of inland surface water around Matuail landfill.

4.7. Heavy metal pollution Index:

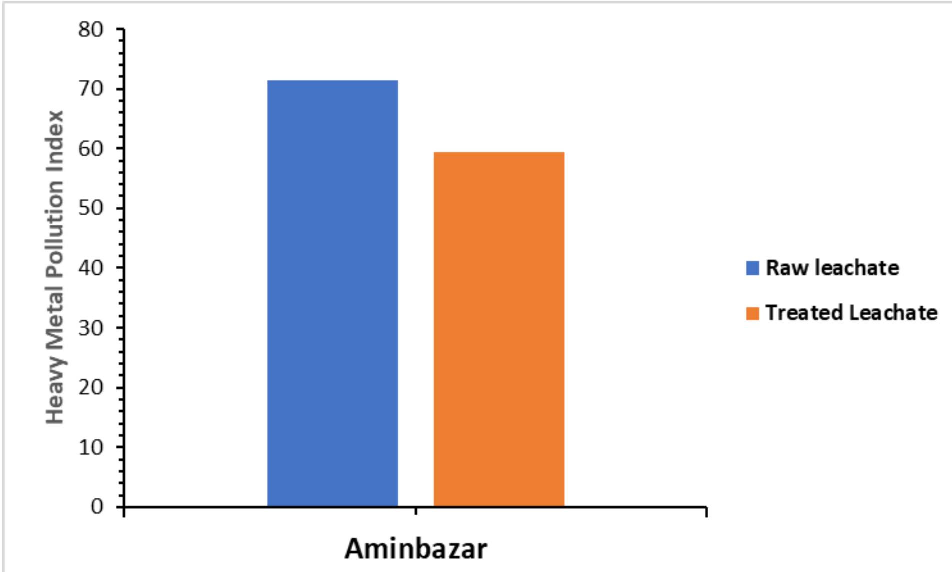


Fig 24: HPI of leachate at Aminbazar landfill

The calculated heavy metal pollution index in the raw and treated leachate from Aminbazar landfill is shown in in Figure. Cd was excluded from this assessment as Cd was found to be below detection limit in all the sampling points. The HPI score for raw leachate is 71.46 and for treated leachate it is 59.29. The high value of HPI indicates that if the leachate gets mixed with water there may be pollution in water due to leachate. Though the HPI of raw leachate is more than treated leachate which shows that due to leachate treatment the HPI reduced in treated leachate.

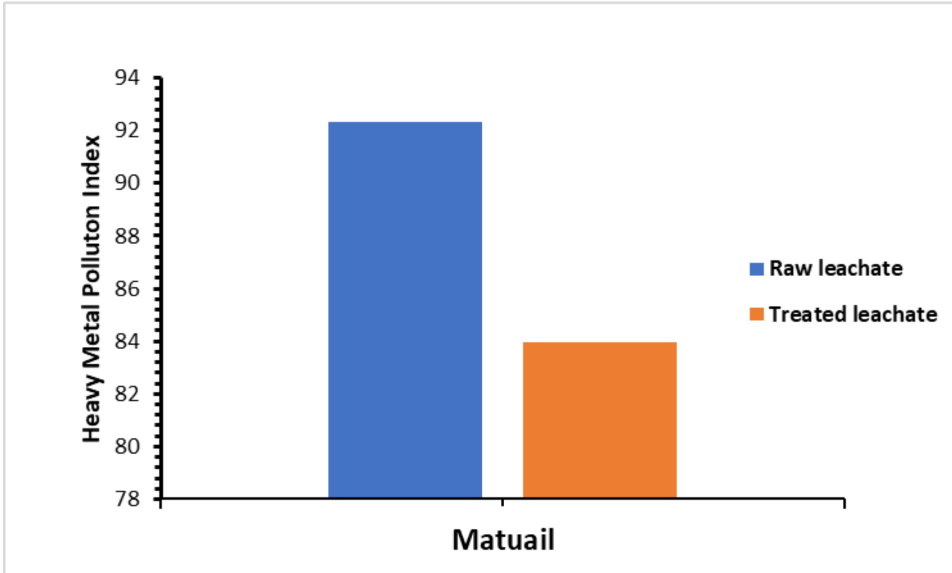


Fig 25: HPI of leachate at Matuail landfill

The calculated heavy metal pollution index in the raw and treated leachate from Aminbazar landfill is shown in in Figure. Cd was excluded from this assessment as Cd was found to be below detection limit in all the sampling points. The HPI score for raw leachate is 92.33 and for treated leachate it is 83.97. The high value of HPI indicates that if the leachate gets mixed with water there may be pollution in water due to leachate. Though the HPI of raw leachate is significantly lower than treated leachate which shows that the treatment facility isn't working properly.

Table 13: Classification of leachate based on HPI range for water (Elumala et al., 2017):

Landfill			HPI range	Quality
Aminbazar	Raw	71.46	<25	Excellent
	Treated	59.29	26-50	Good
Matuail	Raw	92.33	51-75	Poor
	Treated	83.97	76-100	Very poor
			>100	Unsuitable

According to the table above, the HPI of raw and treated leachate of Aminbazar landfill are 71.46 and 59.29. Both of these falls in the HPI range of 51-75 for water which indicates poor quality for water. It means that the leachate is not suitable to be mixed in water or lese it might affect or raise the HPI of water deeming it unhealthy for ecosystem. Both raw and treated leachate if gets mixed with water the water condition may turn poor according to the HPI range for heavy metals.

The HPI for raw and treated leachate at Matuail landfill are 92.33 and 83.97 respectively. The HPI of Matuail landfill for both raw and treated leachate are greater than the HPI of Aminbazar landfill which indicates higher heavy metal pollution at Matuail than Aminbazar. The HPI for raw and treated leachate at Matuail falls in the range of 76-100 for water. The is range indicates very poor quality of water but as this discussion is about leachate the result interprets that if the raw or the treated leachate gets mixed with the water around the area the water may get unsuitable for any purpose.

4.8. Correlation

Table 14: Correlation among the analyzed heavy metals in raw leachates of Matuail and Aminbazar landfill

As	Pb	Ni	Mn	Cr	
As	1				
Pb	1.000**	1			
Ni	-.638	-.647	1		
Mn	.998**	.998**	-.682	1	
Cr	-.988**	-.985**	.545	-.983**	1

**. Correlation is significant at the 0.01 level (2-tailed).

Pearson's correlation analysis supports the above findings. A statistically significant correlation among the variables (Pb, Cd, Cr, and Ni in this study) indicates mutual dependence, influence interaction, and dispersion from similar sources. (Zhang et al., 2008). The correlation matrix in Table 12 shows correlations among analyzed heavy metals in the raw leachate samples of Matuail and Aminazar landfills. However, Cd has been excluded from the correlation analysis as the concentrations of Cd were found to be below detection limit at all the sampling points. The correlation matrix reveals that there is significant perfect positive correlation between Pb and As at 99% confidence level ($r=1.000$, $p<0.01$). It indicates that the if the value of As increases the value of Pb will increase and vice versa. The association may suggest that As and Pb have similar environmental circumstances or sources that cause their concentrations to rise at the same time for both the landfills. There is also significant positive correlation between As and Mn at 99% confidence level ($r=0.998$, $p< 0.01$) and between Pb and Mn ($r=.998$, $p<0.01$). For both As-Mn and Pb-Mn, the correlation values of 0.998 show extremely strong positive linear connections. The concentration of the two elements rises in a very predictable and linear fashion when the concentration of one element rises. The robust positive correlations imply that increases in manganese concentration are correlated with increases in arsenic content in the raw leachate from both of these landfills; the same pattern is true for lead and manganese. The relationships could point to shared origins or external factors affecting these components' amounts in the leachate. Significant negative correlation is found in Mn-Cr ($r = -0.983$, $p<0.01$). Cr has strong negative correlation with both As and Pb ($r=-.988$, $p<0.01$), ($r=-.985$, $p<0.01$) respectively. The significant negative correlations that have been detected are exceedingly unlikely to have happened by accident, as indicated by the p-values being below 0.01. The statistical significance of the data indicates a strong rejection of the null hypothesis, which posits that there is no link in the population among Mn and Cr, Cr and As, or Cr and Pb. The negative correlations imply that increases in one element's concentration are linked to decreases in the other element's concentration in the raw leachate from both of these landfills. The negative correlations may point to variations in the environmental processes or sources that are affecting these elements' concentrations.

Table 15: Correlation among the analyzed heavy metals in treated leachates of Matuail and Aminbazar landfill

	As	Pb	Ni	Mn	Cr
As	1				
Pb	-.999**	1			
Ni	.996**	-.999**	1		
Mn	.983**	-.983**	.986**	1	
Cr	.982**	-.984**	.989**	.999**	1

**. Correlation is significant at the 0.01 level (2-tailed).

Pearson's correlation analysis supports the above findings. A statistically significant correlation among the variables (Pb, Cd, Cr, and Ni in this study) indicates mutual dependence, influence interaction, and dispersion from similar sources. (Zhang et al., 2008). The correlation matrix in Table shows correlations among analyzed heavy metals in the leachate samples of Matuail and Aminazar landfills. However, Cd has been excluded from the correlation analysis as the concentrations of Cd were found to be below detection limit at all the sampling points. The correlation matrix reveals that there is significant negative correlation between Pb and As at 99% confidence level ($r=-.999$, $p<0.01$). The inverse relationship between the amounts of lead and arsenic and the treatment procedure shown by the negative correlation seen in treated leachate. The concentration of one element tends to alter in the reverse direction of the other element's percentage when it grows or decreases. The negative connection would suggest that, albeit perhaps not in exactly the same amounts, the treatment procedures are successful in eliminating or lowering the quantities of lead and arsenic. Significant positive correlation of Ni with both As and Mn were found ($r=.996$, $p<0.01$) and ($r=.986$, $p<0.01$) respectively. The positive associations between Ni and As and Mn indicate that these elements may have comparable origins, behave similarly during treatment, or have similar environmental influences influencing their amounts. There is also significant negative correlation between As and Mn at 99% confidence level ($r=-0.983$, $p< 0.01$), between Pb and Mn ($r=-.983$, $p<0.01$) and between Ni and Pb ($r=-.999$, $p<0.01$). The inverse associations between these components' concentrations are strongly suggested to exist in the setting of treated leachate, based on the negative correlations. When one element's concentration rises, the other element's concentration tends to fall. Significant positive correlation is also found of Cr with Mn, As, Ni ($r = 0.999$, $p<0.01$), ($r=.982$, $p<0.01$), ($r=.989$, $p<0.01$) respectively. The positive correlations indicate that the amounts of chromium and all other components have significant direct interactions in the setting of treated leachate. Manganese, arsenic, and nickel concentrations tend to rise in tandem with increases in chromium concentrations, and vice versa. It is exceedingly improbable that the observed significant positive correlations happened by accident, as indicated by the p-values being below 0.01. Cr has strong negative correlation with Pb ($r=-.984$, $p<0.01$). The inverse associations between these components' concentrations are strongly suggested to exist in the setting of treated leachate, based on the negative correlations. When one element's concentration rises, the other element's concentration tends to fall. The significant correlation between these metals indicates that they might come from similar sources in this study. The metals in both the landfills come from the same sources of waste.

4.9. Statistical comparison between raw and treated leachate

Analysis of variance (ANOVA) is an analysis tool used in statistics that splits an observed aggregate variability found inside a data set into two parts: systematic factors and random factors. The systematic factors have a statistical influence on the given data set, while the random factors do not. Analysts use the ANOVA test to determine the influence that independent variables have on the dependent variable in a regression study. (Will Kenton, 2023)

For One Way ANOVA test the groups assigned were raw leachate and treated leachate in Matuail and in Aminbazar landfill. There must be two hypotheses which are null and alternative hypotheses and based on p value null hypothesis is accepted or rejected. The p value refers to a probability value between 0 and 1. This p value represents the probability of obtaining the observed differences in the outcome measures of the sample, given no difference exists between treatments in the population. P value suggests that there may or may not be significant differences between the values of heavy metal from raw and treated leachate.

The null hypothesis must be accepted when p>0.05 and rejected when p=<0.05. So the significant difference is present or not depends on the value of p from this test. The null hypothesis is that there is no significant difference between the value of heavy metals from raw and treated leachate. The alternative hypothesis suggests that there is a significant difference between the heavy metal values from raw and treated leachate.

For Arsenic found in raw and treated leachate of Matuail landfill the ANOVA test resulted in p value 0.0326 which is less than 0.05 which means that the null hypothesis is rejected, and the alternative hypothesis will be accepted. The alternative hypothesis is that there is a statistically significant difference between the amount of arsenic in raw and treated leachate of Matuail.

For Nickel found in both raw and treated leachate in Matuail landfill the ANOVA test revealed p value is 0.893 which is more than 0.05. It means that the null hypothesis will be accepted, and the alternative will be rejected. So, there is no significant difference between the concentration of Nickel in raw and treated leachate of Matuail.

For Lead present in both raw and treated leachate of Matuail landfill the p value calculated by one way ANOVA test is 0.002 which is a lot less than 0.05 and so the null hypothesis will be rejected and accepting the alternative hypothesis suggests that there is significant difference between the quantity of Lead in raw and treated leachate.

For Chromium present in both raw and treated leachate of Matuail landfill the p value is 0.023 and again this value rejects the null hypothesis because it is less than 0.05. The decision is that there is no statistically significant difference between the amount of Chromium in raw and treated leachate of Matuail.

For Manganese in raw and treated leachate the value of p is 0.000243 which is a lot less than 0.05 and based on the p value calculated through ANOVA test it can be said that these is no statistically significant difference between the concentrations of Manganese between raw and treated leachate of Matuail because the p value suggests that the null hypothesis will be rejected, and alternative hypothesis will be accepted.

For Arsenic present in both raw and treated leachate of Aminbazar landfill the ANOVA test resulted in p value 7.44x10-9 which is a lot less than 0.05 which means that the null hypothesis is rejected, and the alternative hypothesis will be accepted. The alternative hypothesis is that there is a statistically significant difference between the amount of arsenic in raw and treated leachate of Aminbazar.

For Nickel found in both raw and treated leachate in Aminbazar landfill the ANOVA test revealed p value is 0.00167 which is less than 0.05. It means that the null hypothesis will be rejected, and the alternative will be accepted. So, there is a significant difference between the concentration of Nickel in raw and treated leachate of Aminbazar.

For Lead present in both raw and treated leachate of Aminbazar landfill the p value calculated by one way ANOVA test is 3.85x10-5 which is a lot less than 0.05 and so the null hypothesis will be rejected and accepting the alternative hypothesis suggests that there is significant difference between the quantity of Lead in raw and treated leachate.

For Chromium present in both raw and treated leachate of Aminbazar landfill the p value is 0.0235 and again this value rejects the null hypothesis because it is less than 0.05. The decision is that there is no statistically significant difference between the amount of Chromium in raw and treated leachate of Aminbazar.

For Manganese in raw and treated leachate the value of p is 0.016 which is a lot less than 0.05 and based on the p value calculated through ANOVA test it can be said that these is no statistically significant difference between the concentrations of Manganese between raw and treated leachate of Aminbazar because the p value suggests that the null hypothesis will be rejected and alternative hypothesis will be accepted.

Thus most of the p value of heavy metal groups of raw and treated leachate suggest that there is no statistically significant diffenrece between between the concentrations of heavy metals in raw and treated leachate except for Nickel in Matuail landfill which suggested there is a significant diffenrece.

4.10. Microplastic removal approaches:

Table 16: Advantages and disadvantages, type of MPs removed and efficiencies of various current approaches for the removal of MPs. (Anik et al., 2021)

Types	Approaches	Types of MP removed	Efficiency	Advantage	Disadvantage
Physical	Adsorption on green microalgae	20–500 nm polystyrene MPs	~94.5% removal efficiency. However, the sorption of positively more efficient than negatively charged ones.	Lofty aptitude of the surfaces to adsorb weeny MPs fragments, selectivity based on MPs surface infusion	It is not a recyclable method, chemical adhesion of the MPs causes poisoning onto its surface
	Membrane bioreactors	Polymeric debris and MPs of any size	99.9% removal efficiency	It is conducted through using associated commenced treatment methods with porous membranes	It might cause frequent clogging in MBR
	Combined membrane bioreactor – conventional activated sludge	MPs from municipal wastewater	99.4% removal efficiency	It can treat a large range of influent and also applicable in large extent, sturdy, cost-effective, malleable	Lengthy retention times in the tank, massive surface area is required for sedimentation, the high expense of energy and operating, and settlement of sludge
	Soil and sand bed filtration	MPs from wastewater	Rapid sand filter: 97% (from 0.7 to	More feasible mix treatment processes, low expenses for	MPs trapped into sand layers can clog and reduce performance. Backwashing process of

			0.02 MP/L), Dissolved air	maintaining, facile operation	the sand layers is also challenging to conduct
Chemical	Electro-coagulation	Polyethylene MPs	90–90.24% removal efficiency	Compatible for the divergence of nano-particles, No chance of secondary pollution, small sludge volume, energy efficient, cost-effective, automation pliancy	Periodic necessity for the replacement of sacrificial anode, cathode passivation, useless in the fields except for electricity
	Classic coagulation and agglomerat-ion methods	Polyethylene MPs (for Fe and Al based salts)	Efficiency can increase from 25.83% to 61.19% with 15 mg/L	It can remove tiny micro-particles, adjustable operational conditions	MPs might decrease the availability of coagulants/flocculants requiring more chemicals

Membrane bioreactors are the most efficient of all these removal techniques, outperforming other treatment methods and typical activated sludge. (Anik et al., 2021) At present in both landfills there is only coagulation and flocculation treatment present to remove organic and inorganic matters among all the treatments mentioned in the table 15. This process is primarily used to remove inorganic materials like silt but the removal rate of MPs is very low according to the table 15, only 25.83% to 61.19%. So, this is not enough to treat MPs present in leachate. Sufficient and feasible treatment method is required and membrane bioreactor have such potential to remove MPs significantly.

4.11. Heavy metal removal approaches:

There are various methods to remove heavy metals from landfill leachates and some of the processes are given in the tables below:

(i) Precipitation: Precipitation is a process where different types of precipitating agents are used to remove various metals. The list of metals, their removal efficiencies, precipitating agents, their advantages and disadvantages according to different studies is given in the table below:

Table 17: Percentages of heavy metal removal through precipitation with advantages and disadvantages (Flórez and Gallo, 2019)

Heavy metals	Removal rate (%)	Precipitating agents	Advantages	Disadvantages
Cr, Ni	> 99	Ferric chloride	• Technological availability • Applicability in different areas • Successful experiences • Known kinetics	• Costly and inefficient methods • The active agent can not be recovered for later reuse • Sludge with a high concentration of metals, which makes it difficult to eliminate
Cr	99.7	$Ca(OH)_2$ + NaOH + $FeCl_3$		
Mn	99.9	NaOH		
Cr	98.2	Na_3PO_4 and NaOH		

According to various literature, Cr, Ni can be removed through ferric chloride more efficiently than any other precipitating agent. Mn requires NaOH to be removed efficiently but none of these agents are being used in the landfills discussed in this paper currently. Therefore, there's a possibility that if these agents are used Cr, Ni and Mn can be removed and reduced to permissible limits.

(ii) Adsorption: In adsorption various adsorbents are used to reduce heavy metals, these adsorbents, the metals they remove and removal percentage with advantages and disadvantages are listed below:

Table 18: Percentages of heavy metal removal through adsorption with advantages and disadvantages (Flórez and Gallo, 2019)

Heavy metals	Uptake (mg/g)	Adsorbent	Advantages	Disadvantages
Pb	172.43	Activated charcoal from plum seeds	• Technological availability • Applicability in different areas • Successful experiences Known kinetics	• Costly and inefficient methods • The active agent can not be recovered for later reuse • Sludge with a high concentration of metals, which makes it difficult to eliminate
Ni	63.74	Activated charcoal from plum seeds		
Pb	27.53	Activated carbon from European Black Pine		
Cu	126	Silica mesoporous		
Pb	130	Silica mesoporous		

According to table 18, few metals have been studied by adsorption process for their removal and among these Pb had maximum removal rate through adsorption by activated chcarcoal from plum seeds. Very few studies have achieved sufficient removal of heavy metals through adsorption technique.

(iii) Phytoremediation: Various studies have shown the removal of heavy metals through phytoremediation and some of them had prominent results which are listed below:

Table 19: Percentages of heavy metal removal through phytoremediation with advantages and disadvantages (Flórez and Gallo, 2019)

Heavy Metals	Removal rate (%)	Plants	Advantages	Disadvantages

Cr	70.3	Rice seedlings	• Low costs. • Ease of implementation • High rate of removal • Does not require chemical or electrical currents • Does not produce by-products or toxic sludge	• The removal rate is lower, when heavy metal concentration is higher • The leachate pollutants, can generate toxicity microorganisms and plants • In all cases, the implementation of biological processes has been carried out at a laboratory scale and not a real-life scale in
As	89.5	*Micranthemum umbrosum*		
Pb	96.4	*Lemba minor*		
Cr	94.8	*Lemba minor*		

Table 19 shows few of the metals that have been removed from landfill leachates in a significant amount through different kinds of plants.

There are few more approaches to remove heavy metals effectively from landfill leachates but all these processes including the three procedures mentioned above didn't have significant removal rate for every heavy metal found in leachates. Precipitaion achieved a strong remediation rate for Cr, Ni and Pb while adsorption achieved a higher degree of removal for only Pb and phytoremediation had significant removal rate for Cr, As, Pb. The aspect that needs to be focused on is which process has more advantages than disadvantages. The precipitation and adsorption process have similar advantages and disadvantages. Comparing the merits and demerits of the three process it can be said that precipitation and adsorption are more feasible options that can effectively remove few of the heavy metals than phytoremediation and so these approaches can be adopted to increase the efficiency of the leachate treatment facility. Still more studies need to be conducted to discover a more inclusive approach that can remove majority of heavy metals.

CHAPTER V

CONCLUSION

5. Conclusion

This study has been conducted focusing on the efficiency of leachate treatment facility of Matuail and Aminbazar landfills through measuring the removal rate of microplastic and heavy metals in leachate. To assess the efficiency of leachate treatment facility, raw and treated leachate were sampled and analyzed. Physical, chemical characterization as well as the concentration of heavy metals and microplastics were analyzed in raw and treated leachate to determine the effect of leachate on surrounding water bodies. Landfill leachate is a complicated liquid that contains high levels of both biodegradable and nonbiodegradable substances, such as phenols, organic matter, phosphate, nitrogen, ammonia, heavy metals, and sulfide. Landfill leachate may percolate across soils and subsoils, negatively affecting receiving waterways, and might be an imminent source of contamination for groundwater as well as surface water if improperly managed and disposed of.The physiochemical parameters of both raw and treated leachate from Aminbazar and matuail landfills varied. Mean pH, DO, salinity for both Matuail and Aminbazar landfills' leachates were below the range set by WHO, ECR but the difference between raw and treated leachate was minimum indicating that the treatment facility isn't efficient in removing these parameters in considerable amount. The mean amount of microplastics in treated leachate in Matuail landfill is 28.5 MPs/0.1L which is not very low compared to raw leachate's which is 31.5 MPs/0.1L. It indicates that the leachate treatment system doesn't remove microplastics significantly and it is a huge drawback of the treatment plant because this treated leachate goes into surface water and may also contaminate groundwater due to improper lining which can cause significant microplastic pollution in both surface and groundwater. For the Aminbazar landfill the mean abundance of raw leachate is 30MPs/0.1L and the abundance of treated leachate is 22.5MPs/0.1L which depicts that the treatment plant didn't significantly reduce the microplastic volume and it is a drawback of the treatment plant. Though the difference between the amount of microplastics in raw and treated leachate is less than Matuail, the difference isn't significant to state that the leachate treatment plant is Aminbazar is working well than Matuail. The amount of Mn, Cr, Ni is little lower in treated leachate than raw ones in Aminbazar landfill but As is remarkably lower which stipulated that the treatment facility is only good at removing arsenic in significant amount and below the limit set for surface water. Pb on the other hand is much higher in treated leachate than raw ones. At Matuail landfill Pb and Ni concentration is higher in treated than raw ones. As, Mn, Cr concentration is lower in treated leachate than raw ones but none was notably lower to stipulate that the treatment facility is efficient in removing heavy metals in significant amount. The quantity of all the heavy metals is lower than the standards set for heavy metal in surface water except for Cr. the HPI of raw and treated leachate of Aminbazar landfill are 71.46 and 59.29. Both of these falls in the HPI range of 51-75 for water which indicates poor quality for water. It means that the leachate is not suitable to be mixed in water or lese it might affect or raise the HPI of water deeming it unhealthy for ecosystem. The HPI for raw and treated leachate at Matuail falls in the range of 76-100 for water. The is range indicates very poor quality of water but as this discussion is about leachate the result interprets that if the raw or the treated leachate gets mixed with the water around the area the water may get unsuitable for any purpose.

Thus the leachate treatment facility isn’t sufficient to reduce microplastics and heavy metals in remarkable amount. To remove microplastics and heavy metals various methods were gathered from list of papers that mentioned significant removal rates of microplastic and heavy metals to increase the efficiency of leachate treatment facilities. In addition to problems with leachate treatment effectiveness, sanitary landfills always have a chance of leachate release into the surrounding region because of the impact of heavy rainfall or surface runoff. The landfill liner's failure risk should also be closely watched since natural deterioration can cause it to break easily or leak. Hence, constant observation at the leachate treatment plant discharge point and at the nearby waterway is necessary to prevent these inhibitory events.

6. References:

Abir Mahmud, Mustafa Md Wasif, Hridoy Roy, Fareen Mehnaz, Tasnim Ahmed, Md. Nahid Pervez,Vincenzo Naddeo and Md. Shahinoor Islam, (2022). Aquatic Microplastic Pollution Control Strategies: Sustainable Degradation Techniques, Resource Recovery, and Recommendations for Bangladesh. Water 2022, 14(23), 3968; https://doi.org/10.3390/w14233968

Ana L.P. Silva, Joana C. Prata, Armando C. Duarte, Amadeu M.V.M. Soares, Damia Barcelo, Teresa Rocha-Santos, (2020). Microplastics in landfill leachates: The need for reconnaissance studies and remediation technologies. Case Studies in Chemical and Environmental Engineering Volume 3, June 2021, 100072; https://doi.org/10.1016/j.cscee.2020.100072

Ana-Maria Schiopu, Maria Gavrilescu, (2010). Options for the Treatment and Management of Municipal Landfill Leachate: Common and Specific Issues. CLEAN - Soil Air Water 38(12):1101 – 1110; DOI:10.1002/clen.200900184

David John Lawrence Thomas, Sean Ferguson Tyrrel, Richard Smith, Steve Farrow, (2008). Bioassays for the Evaluation of Landfill Leachate Toxicity. Journal of Toxicology and Environmental Health, Part B, Volume 12, 2009 - Issue 1, Pages 83-105; https://doi.org/10.1080/10937400802545292

Fahmida Parvin and Shaf M. Tareq, (2021). Impact of landfll leachate contamination on surface and groundwater of Bangladesh: a systematic review and possible public health risks assessment. Applied Water Science 11(6); DOI:10.1007/s13201-021-01431-3

Fahmida Parvin, Md Morshedul Haque, Shafi M Tareq, (2022). Recent status of water quality in Bangladesh: A systematic review, meta-analysis and health risk assessment. Environmental Challenges, Volume 6, January 2022, 100416; https://doi.org/10.1016/j.envc.2021.100416

Kashif Mahmud, Md. Delwar Hossain, Shahriar Shams, (2011). Different treatment strategies for highly polluted landfill leachate in developing countries. Waste

Management, Volume 32, Issue 11, November 2012, Pages 2096-2105; https://doi.org/10.1016/j.wasman.2011.10.026

Lan Wang, Hui Wang, Qiujie Huang, Changfu Yang, Luochun Wang, Ziyang Lou, Qian Zhou, Tiantian Wang and Chengqi Ning, (2023). Microplastics in Landfill Leachate: A Comprehensive Review on Characteristics, Detection, and Their Fates during Advanced Oxidation Processes. Water 2023, 15(2), 252; https://doi.org/10.3390/w15020252

Martijn van Praagh and Bettina Liebmann, (2021). Microplastics in landfill leachates in three Nordic countries. Conference: detected) 14th International Conference on Environmental Effects of Nanoparticles and Nanomaterials (ICEEN 2019), 1-4 Sept 2019, Vienna, Austria; DOI:10.6027/TN2018-557

MD. Azim, M. Mahabubur Rahman, Riaz Hossain Khan and A.T.M.M. Kamal, (2011). Characteristivs of leachate generated at landfill sites and probable risks of surface and groundwater pollution in the surrounding areas: A case study of Matuail landfill site, Dhaka. Journal of Bangladesh Academy of Sciences 35(2):153-160; DOI:10.3329/jbas.v35i2.9418

Md. Rezaul Karim, Megumi Kuraoka, Takaya Higuchi, Masahiko Sekine, Tsuyoshi Imai, (2017). Assessment of heavy metal contamination from municipal solid waste open dumping sites in Bangladesh. International Journal of Environment and Waste Management Vol. 19, No. 3, pp 191-202; https://doi.org/10.1504/IJEWM.2017.084297

Muhammad Umar, Hamidi Abdul Aziz, Yusoff Mohd Suffian (2010). Variability of Parameters Involved in Leachate Pollution Index and Determination of LPI from Four Landfills in Malaysia. International Journal of Chemical Engineering, Volume 2010 | Article ID 747953 | https://doi.org/10.1155/2010/747953

Nurhasanah, Muhammad Reza Cordova, Etty Riani, (2021). Micro- and mesoplastics release from the Indonesian municipal solid waste landfill leachate to the aquatic environment: Case study in Galuga Landfill Area, Indonesia. Environmental Engineering, Marine Pollution Bulletin 163:111986; DOI:10.1016/j.marpolbul.2021.111986

Rafiul Alam, Zia Ahmed, M. Farhad Howladar, (2020). Evaluation of heavy metal contamination in water, soil and plant around the open landfill site Mogla Bazar in Sylhet, Bangladesh. Environmental Engineering, Groundwater for Sustainable Development 10(9):100311; DOI:10.1016/j.gsd.2019.100311

S. De, S.K. Maiti, T. Hazra, A. Debsarkar, A. Dutta, (2018). Leachate characterization and identification of dominant pollutants using leachate pollution index for an uncontrolled landfill site. Global Journal of Environmental Science and Management, Volume & Issue: Volume 2, Issue 2 - Serial Number 6, 2016, Pages 95-207; https://doi.org/10.7508/gjesm.2016.02.008

S. Mahesh, Nisarga K. Gowda and Sahana Mahesh, (2023). Identification of microplastics from urban informal solid waste landfill soil; MP associations with COD and chloride. Water Sci Technol (2023) 87 (1): 115–129. https://doi.org/10.2166/wst.2022.412

Sadia Afrin, Md. Khabir Uddin, Md. Mostafizur Rahman, (2020). Microplastics contamination in the soil from Urban Landfill site, Dhaka, Bangladesh. Heliyon, Volume 6, Issue 11, November 2020, e05572. https://doi.org/10.1016/j.heliyon.2020.e05572

Salma Akter Urmi, Marzuka Ahmad Radia, Rfiul Alam, Mohammed Uzzal Chowdhury, Shahriar Hasan, Shakil Ahmed, Hasna Hena, Saeamohammed, Syful Islam, Delufa Tuz Herin, Prianka Sultana, Hema Monybur Rahman, A.K.M. Mazharul Islam, Mohammed Tanvir Hasan, Zahidul Quayyum, (2021). Dhaka landfill waste practices: addressing urban pollution and health hazards. Build Cities. 2021; 2(1): 700–716. doi: 10.5334/bc.108

Sumaiya Abdul Hameed Al Raisi, Hameed Sulaiman, Fakhr Eldin Suliman, and Osman Abdallah, (2014). Assessment of Heavy Metals in Leachate of an Unlined Landfill in the Sultanate of Oman. International Journal of Environmental Science and Development, Vol. 5, No. 1, doi:http://www.ijesd.org/papers/451-P014.pdf

Sumaiya Akter, Mashura Shammi, Yeasmin Nahar Jolly, Abid Azad Sakib, Md. Mostafizur Rahman, Shafi M. Tareq, (2021). Characterization and photodegradation pathway of the leachate of Matuail sanitary landfill site, Dhaka South City Corporation, Bangladesh.

Heliyon, Volume 7, Issue 9, September 2021, e07924; https://doi.org/10.1016/j.heliyon.2021.e07924

S. Y. Rikta, Shaf M. Tareq, M. Khabir Uddin, (2018). Toxic metals (Ni2+, Pb2+, Hg2+) binding afnity of dissolved organic matter (DOM) derived from diferent ages municipal landfll leachate. Applied Water Science 8(1); DOI:10.1007/s13201-018-0642-9

Zhongjian Zhang, Yinglong, Jundong Zhu, Jianhong Shi, Huang Huang, Bing Xie, (2020). Distribution and removal characteristics of microplastics in different processes of the leachate treatment system. Waste Management, Volume 120, 1 February 2021, Pages 240-247; https://doi.org/10.1016/j.wasman.2020.11.025