ALUMINIUM POLLUTION IN SEDIMENT OF PERAI RIVER, PENANG

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ALUMINIUM POLLUTION IN SEDIMENT OF PERAI RIVER, PENANG

by

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DECLARATION

I hereby declare that I conducted, completed the research work and written the dissertation entitled “Aluminium pollution in sediment of Perai river, Penang”. I also declare that is has not been previously submitted for the award of any degree or diploma or other similar title of this for any other examining body or University.

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Date:

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LIST OF SYMBOLS

µm	Micron
mm	millimeter
cm	Centimeter
∘	Degree
°C	Degree Celsius
mg/L	Milligram per litre
λ	Lambda
θ	Theta

LIST OF ABBREVIATIONS

XRD	X-Ray Diffraction
USM	Universiti Sains Malaysia
HM	Heavy Metals
Al	Aluminium
H2O2	Hydrogen Peroxide
HCl	Hydrochloric acid
HSO4	Sulphuric acid
ICP-OES	Inductively Couple Plasma – Optical Emission Spectrometry
MR	Main river
PBAPP	Penang Water Supply Corporation
DOE	Department of Environment
WQI	Water Quality Index

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Appendix A Pattern list of x-ray diffraction (XRD) result

ABSTRAK

PENCEMARAN ALUMINIUM DIDALAM MANDAPAN SUNGAI PERAI, PULAU PINANG

Selama berabad-abad, sungai menyediakan pelbagai jenis komponen penggunaan kepada manusia. Kegiatan pembangunan melalui pembuangan efluen dari sumber antropogenik yang berbeza merosakkan kualiti air dan ekosistem akuatik kesihatan. Kajian ini dilakukan untuk menentukan pencemaran aluminium di sedimen sungai Perai, Pulau Pinang dan sumber-sumbernya yang berpotensi sejak ada beberapa berita mengenai pihak yang tidak bertanggungjawab yang membuang sampah mereka ke sungai. Sebanyak 22 sampel (11 sampel untuk setiap bulan Februari dan April) dikumpulkan. Aluminium dan logam berat lain dianalisis dengan menggunakan Spectrometry Emission Optical Plasma Induktif Coupled (ICP-OES) dan difraksi sinar-X. Didapati bahawa kepekatan aluminium lebih tinggi pada musim kemarau daripada musim hujan kerana pencairan air pada musim hujan. Hasilnya akan lebih konkrit jika terdapat sampel yang dikumpulkan pada sumber yang berpotensi. Hasil ini sangat penting untuk memahami pencemaran aluminium di sungai Perai berdasarkan logam berat dan kesannya.

ABSTRACT

ALUMINIUM POLLUTION IN SEDIMENTS OF SUNGAI PERAI, PENANG

For centuries, rivers provide various kinds of utilization components to humans. Development activities through discharge of effluents from different anthropogenic sources deteriorate the water quality and health aquatic ecosystem. The present study was conducted to determine the aluminium pollution in sediments of Perai river, Penang and its potential sources since there has been several news of irresponsible parties that dump their waste into the river. A total of 22 samples (11 samples for each month of February and April) is collected. Aluminium and other heavy metals were analyzed by using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) and X-ray diffraction (XRD). It is found that aluminium concentrations are higher during dry season than wet season due to the water dilution during rainy seasons. The results will be more concrete if there are samples collected at the potential sources. These results are very crucial to understand the aluminium pollution in Perai river based on heavy metals and the effects towards human health and environment.

CHAPTER1

INTRODUCTION

1.1 Background Study

Rivers are the foremost essential freshwater resources for humans. Rivers are the sources of natural water which is a source for drinkable, irrigation, and fishing. Generally, rivers are essential for geology, biology, history, and culture. About 0.0001% of the whole amount of water within the world represents rivers. Rivers provide not just for a habitat, nourishment, and means of transport to most organisms but also as a vital source of valuable deposits of sand, gravels and even for electricity (Anhwange et al., 2012). Rivers are precious not only for humankind but also essential for the ecosystem as a whole.

Perai River is Penang's longest river and is additionally its largest water geographical region. it's been identified as a possible future water source to serve the state's growing water demands and catalyst to Butterworth's urban regeneration. The river's natural charm provides a perfect setting for eco-tourism and recreational opportunities like kayaking and boat tours. However, the pressures of growth and urbanisation has degraded the waters of Perai river to an undesirable level.

Figure 1.1 The view of Perai River (highlighted in blue) in Google Maps.

Perai River is subject to urban development and a crowded area. The river receives point pollution loads from sewage treatment additionally as major industries including textiles and manufacturing factories which are located near the riverbank. The non-point pollution source within the study area contributed to domestic drainage and land run-off. In some places, the streams within the Perai River are used for rubbish dumping sites.

Whol et al. (2015) defines sediment controls the physical habitat of river ecosystems. Changes within the amount and areal distribution of various sediment types cause changes in river-channel form and river habitat. the number and sort of sediment suspended within the water column determines water clarity. Understanding sediment transport and therefore the conditions under which sediment is deposited or eroded from the varied environments in a very river is therefore critical to understanding and managing sediment and sediment-related habitat in rivers.

1.2 Problem Statement

In May 2021, three rivers in Seberang Perai were covered in what looks like thick brown mud, and a green group here has raised the alarm over potential heavy metal pollution there. They believe the "sludge" is a by-product of a major water treatment plant which supplies water to 80% of Penang. The Penang Water Supply Corporation (PBAPP) which runs the plant was swift to deny the claim, but the Penang sustainable natural heritage association (LEKAS) is standing its ground, saying the pollution has to be investigated.

Lately, people can determine just by watching the river, the standard of the river has deteriorated. Therefore, a study must be conducted to see the number of heavy metals within the water, sediment and therefore the total solids of the Perai River and to conclude if the weather of the river is highly polluted until it's unsuitable for the consumption of living things. PBAPP said the brown sludge was essentially residual aluminium resulting from one amongst their treatment plants and wasn't hazardous to health and therefore the aquatic environment. It said if it absolutely was indeed dangerous, then these rivers would be depleted of marine life.

Rivers are most vulnerable to pollution since they became an easy passage for the discharge of varying domestic, commercial, industrial and agricultural effluents due to their natural function as drainage channels. For the last three decades, Malaysia has developed very rapidly with urbanisation increasing many folds in all major cities and towns. The river systems become overstressed, resulting from of those developments. Swift development has produced enormous amounts of human wastes also as from anthropogenic activities like agriculture, industrial, commercial, and transportation wastes. this instance causes the exacerbation of the occurrence of low flows. As a result, many rivers are polluted, to some extent of not rehabilitating (Huang et al., 2015).

Water pollution are often defined because the condition of a body of water containing various elements. By measuring and studying the weather contained in water, it is possible to spot water as pure, clean and contaminated. (Nasir et al., 2012). A river is claimed to be polluted when pollutants affect the standard of the water involved. Contamination defined as environmental quality changes caused by human activity that produce adverse effects (Hodges, 1973).

River pollution nationwide increased slightly by 2% in 2017, compared with 2013, per a study by the Department of Environment. Eleven percent of main river basins were considered polluted from 189 main river basins in 2017. Irrigation and Drainage Department (DID) Malaysia launched the Integrated basin Management programme nationwide. This programme aims to form sure that there's enough clean water, additionally as reduce the danger of floods and increase environmental conservation (The Star, 2018).

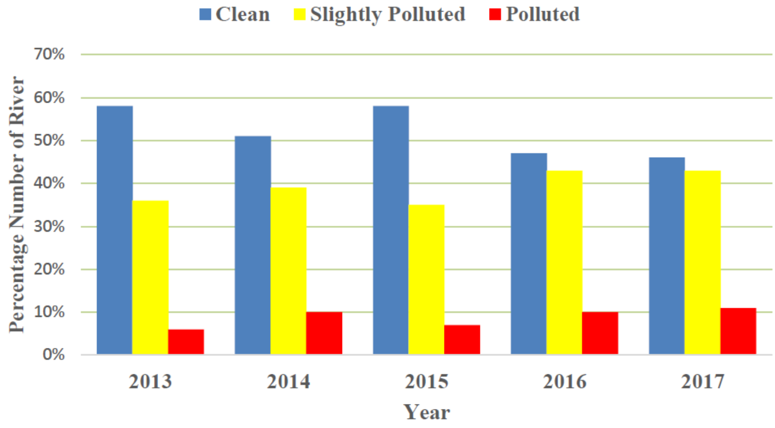

Figure 1.2Malaysia River Water Quality Index (WQI) Trend for 5 years period. [Source: Environmental Quality Report 2017 by DOE]

Usually rivers in Malaysia, especially located in geographical region are heavily polluted with pollution by chemicals, organics and solid wastes. The disturbances and contamination of this pollution will eventually flow right down to the estuaries and accumulate before moving into the ocean. The Department of Environment (DOE) continues the river water quality program to see the status of river water quality and to detect changes in river water quality.

1.3 Objectives

1.3 (a) To study the aluminium distribution in Sediments of Perai River.

1.3 (b) To identify the sources of aluminium pollution of Perai River by relating to the aluminium distribution in sediments of Perai River.

1.4 Thesis Outline

In this thesis, it will be methodically divided into several parts. Chapter 1 is the introduction to the thesis of the current problem at the targeted location which is Perai River. It will also highlight the objectives that need to be fulfilled in this research.

In Chapter 2, will be focusing on the literature review which focused on the past research of the current problem with reference of various media including scientific articles, journals and press media. This includes the properties and impacts of aluminium pollution to the sediment in rivers, and the potential sources of the pollution. This chapter will also link with the history of pollution in Perai river after several media news reported. Chapter 2 will be the supporting root of this study.

Moving to Chapter 3, the actual research will be conducted with scientific methodologies based on Chapter 2. This includes sample collection, preparation of the samples which are grinding and acid digestion before proceeding to the analysis methods which are X-Ray diffraction (XRD) and inductively coupled plasma (ICP).

Following the analysis, Chapter 4 will present the results of the conducted experiments and discussing the relativity based on the objectives and hypothesis mentioned in Chapter 1. The results of XRD and ICP will determine the potential source of the pollution based on the amount of Aluminium of each sample location.

Finally, the thesis is concluded in Chapter 5 whether the objectives have achieved or not and future recommendation for subsequent improvement on the related work

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this literature review, the focus in on the properties of aluminium as a heavy metal and how it can pollute the river as well as its effects to the environment based on past researches. It will also contain the never-ending history of the pollution of Perai river where there have been several media news about the dumping of waste into it by irresponsible parties. Other than that, this chapter will introduce how river sampling is done and why it is important to the environment and research.

2.1 Aluminium as Heavy Metals

Aluminium is categorised as a heavy metal not only due to its specific gravity but also potential toxicity especially when it is in compound form. Although many water treatment plants use alum or aluminium sulphate as a coagulant, the improper disposal of alum into rivers can lead dangerous effects. Many places in Perai river have been polluted by various heavy metals and the presence of these HMs increase the concentration of aluminium present in sediments (Foo YZ et al., 2020).

2.1.1 Definition of Heavy Metals

Heavy metals, HM are naturally occurring elements that have a high atomic number, high atomic weight and a specific gravity greater than 5.0. Some lighter metals and metalloids are toxic such as arsenic (As) and, thus, are termed heavy metals though some heavy metals, such as gold, typically are not toxic Heavy metals include some metalloids, transition metals, basic metals, lanthanides, and actinides. Although some metals meet certain criteria and not others, most would agree the elements such as mercury, bismuth, and lead are toxic metals with sufficiently high density (Tchounwou et al., 2012).

Examples of heavy metals include lead, mercury, cadmium, sometimes chromium. Less commonly, metals including iron, copper, zinc, Aluminium, beryllium, cobalt, manganese and arsenic may be considered heavy metals.

In recent years, environmental and global public health concerns associated with these metal pollutions have increased. In addition, the use of HM is increasing exponentially due to its use in industrial, agricultural, household, and technical applications. Reported sources of heavy metals in the environment include geological, industrial, agricultural, pharmaceutical, domestic wastewater, and atmospheric sources. (Kochian, 2001).

Although heavy metals are naturally occurring elements that are found throughout the earth's crust, most environmental contamination and human exposure result from anthropogenic activities such as mining and smelting operations, industrial production and use, and domestic and agricultural use of metals and metal-containing compounds (He et al. 2005). In support of this statement, Nriagu (1989) stated that environmental contamination can also occur through metal corrosion, atmospheric deposition, soil erosion of metal ions and leaching of heavy metals, sediment re-suspension and metal evaporation from water resources to soil and ground water. Weathering and volcanic eruptions which are natural phenomena have also been reported to significantly contribute to heavy metal pollution.

Heavy metals are one of the more serious pollutants in our natural environment due to their toxicity, persistence and bioaccumulation problems (Balachandran et al. 2005; Caeiro et al. 2005; Tam & Wong 2000). Following the introduction of heavy metal contaminants into a river, whether via natural or anthropogenic sources, they partition between aqueous (pore water, overlying water) and solid phases (sediment, suspended particulate matter and biota) (Prudencioa et al. 2007; Zhang et al. 2007). Depending on hydrodynamics, biogeochemical processes and environmental conditions (redox, pH, salinity and temperature) of rivers, sediments are recognized as an important sink of heavy metals in aquatic systems as well as a potential non-point source which may directly affect overlying waters (Pekey 2006).

2.1.2 Properties of Aluminium

Aluminium (Al), is a chemical element, a light-weight silvery bearing metal of main Group 13 (IIIa, or boron group) of the tabular array. Aluminium is that the most abundant metal in Earth’s crust and therefore the most generally used non-ferrous metal. because of its reactivity, aluminium does not occur naturally within the style of metals, but its compounds are more or less present in the majority rocks, plants and animals. Aluminium is concentrated 10 miles outside the Earth's crust, accounting for about 8 weight percent. Quantitatively, only oxygen and silicon outperform it. The name aluminium comes from the Latin word alumen, used to describe potash alum, or aluminium potassium sulphate, KAl(SO4)2·12H2O (Encyclopaedia Britannica, 2022, March 13).

Aluminium is present altogether natural waters and water services. It can occur within the sort of organic and inorganic compounds in dissolved and insoluble form, and a key factor affecting the shape of development is pH. it's amphoteric, combining with both acid and bases to make, respectively, aluminium salts and aluminates. The chemical nature of aluminium in water is basically the chemistry of $Al(OH)_3$ that has an amphoteric character and tendency to make complex ions and polymerise. Evidence has been provided by chemical modelling that in solutions with a pH below 5 aluminium exists predominantly as Al(H2O)63+, with rising pH an insoluble $Al(OH)_3$ complex forms at circumneutral pH that re-dissolves at higher pH because the Al(OH)4− (aluminate) complex. the amount of aluminium in natural waters varies from 0.0001 to 1 mg/dm, and in acidic waters (pH < 5) the concentration of aluminium may even exceed 100 mg/dm^3. Aluminium compounds show low solubility within the pH range of 6–8, therefore in surface and subsurface waters the concentrations of aluminium are very low and are classified within the range of 60 to 300 $\mu g/dm^3$ (Kravchenko O.V. et al., 2005).

Noor Muhammad et al. in 2019 stated alums are applied as fertilizer in tea plantations. Other Aluminium compounds are applied in paper production. Alloys like dialuminium are applied because these are stronger than aluminium itself. Aluminium foam is applied in tunnels as soundproofing material. Other samples of aluminium application include aluminum chloride use in cracking processes, aluminium oxide as an abrasive or for production of inflammable objects, aluminium sulphate use as a basic material in paper glue, tanners, mordants and artificial rubber, and aluminium hydrogen as a reduction and hydration agent. Aluminium occurs as an aerosol in oceanic surface layers and in waters. this can be because aluminium dust lands up in water. Particles end up in water through surface run-off or atmospheric transport. Generally, aluminium concentrations increase with increasing water depth.

2.1.3 Aluminium in Sediments

Aluminium forms during mineral weathering of feldspars, such as and orthoclase, anorthite, albite, micas and bauxite, and subsequently ends up in clay minerals. A number of gemstones contain Aluminium, examples are ruby and sapphire. Aluminium salts are often added to water to start precipitation reactions for phosphate removal. Consequently, sewage sludge in water purification with a pH value between 6.8 and 7.3 is present as hydroxides.

Surface water bodies act as filters by retaining pollutants flowing into them from catchment areas. Accumulation of pollutants takes place in the tissues of living organisms and in bottom sediments, which under stable conditions are accumulated and do not pose a threat to the aquatic environment. However, they can be released into the water during floods, volcanic eruptions, earthquakes, or human construction work in the catchment area or in the riverbed itself. In flowing waters of mountainous sections, sediment deposition takes place to a rather small extent. Too fast water current does not allow to capture organic and mineral matter. The accumulation of its scanty amount within the mountainous section of the river in summer and autumn along with spring thaws is washed out when large masses of water flow down the river often with great force. The formation and maintenance of sediment is feasible only within the lowland section, when the water current becomes slower and also the sedimentation process is visible. the underside sediment that accumulates within the river bed acts as a sort of pollution store. It contains dead plant and animal remains, but also chemical compounds flowing with the water. River beds are subject to modifications, most frequently distributed in sub-mountain areas and in towns. Regulation covers not only the river bed, but also the banks. Rivers are excessively straightened, water flows fast, which does not favour the build-up of bottom sediments are particularly important because water from them is obtained for the Lower Silesian urban agglomerations. These rivers differ, among others, in their length and catchment structure (Srinivasan and Viraraghavan, 2002).

The presence of organic and mineral compounds within the bottom sediments in numerous proportions is sometimes recorded. the extent of mineral compounds in water reservoirs depends on their content within the catchment but may be the results of their release from bottom sediments. Aluminium compounds occupy a substantial amount within the sediments, which under natural conditions don't have a negative impact on the life within the reservoir and on the standard of the water obtained from it.

Aluminium is an amphoteric element, meaning it has both an acidic and a basic character. The pH is of decisive importance for the discharge of Aluminium from soil and water. Therefore, in surface waters with extreme values of pH, it can occur in elevated concentrations. This condition could also be because of natural causes or as a result of anthropogenic activities. The presence of Aluminium in water is not indispensable, and it would not to be considered a very harmless element for aquatic organisms. However, at the turn of the 20th century, the primary reports of its toxicity appeared within the 1950s, aluminium was shown to enter surface water from acidified soil solutions. Therefore, it should be present in water, especially if collected from areas with acid rocks or soil. (Guibaud and Gauthier, 2003).

In addition, water may be enriched with aluminium as a results of water pipes contamination. Aluminium is additionally used as a water conditioner for water and in wastewater treatment processes. Aluminium levels within the ambient air reflect the natural dustiness that increases in urbanized areas (coal burning, metallurgical industries). Because Aluminium occurs in bottom sediments as complexes of organic compounds, fluorides, and sulphates, it is present in water at low concentrations—less than 1.0 mg/dm^3 (De la Fuente J.M. et al., 1997).

McLachalan et al. (1985) states that aluminium is instantly absorbed by bottom sediments within the variability of metastable compounds. As water acidity increases, it can become activated. Only a change in pH caused by, among others, air pollution can dissolve minerals and release Al into the water. When the pH is acidic, elevated concentrations of aluminium are recorded, reaching up to 5 mg/dm3. The natural level of aluminium in water has increased significantly in many cases with the event of civilization. Aluminium is additionally to the following degree available to living organisms and perceived as a natural component are treated as pollution.

2.2 Environmental impacts of Aluminium

In general, most HMs have adverse effects to the environment if cannot treated properly. Some heavy metal ions activate with water, making the ions produce toxic properties, and some dissolve directly to the living things.

2.2.1 Impacts of Aluminium to Rivers

Aluminium may negatively affect terrestrial and aquatic life in numerous ways. Regular aluminium concentrations in groundwater are about 0.4 ppm, because it's present in soils as water insoluble hydroxide. At pH values below 4.5 solubility rapidly increases, causing aluminium concentrations to rise above 5 ppm. this may additionally occur at very high pH values. Dissolved Al3+ ions are toxic to plants; these affect roots and reduce phosphate intake. As was mentioned above, when pH values increase aluminium dissolves. This explains the correlation between acid rains and soil aluminium concentrations. At increasing nitrate deposition, the aluminium amount increases, whereas it decreases under large heather and agricultural surfaces. In forest soils it increases (Affinity Chemical, n.d.).

Aluminium is not a dietary requirement for plants, but it should positively influence growth in some species. it is preoccupied by all plants due to its wide distribution in soils. Grass species may accumulate aluminium concentrations of above 1% dry mass. air pollution dissolves minerals in soils, and transports these to water sources. this could cause aluminium concentrations in rivers and lakes to rise (R.B. Clark, 1977).

Aluminium naturally occurs in waters in very low concentrations. Hermann (1985) found that higher concentrations derived from mining waste may negatively affect aquatic biocoenosis. aluminium is toxic to fish in acidic, unbuffered waters starting at a degree of 0.1 mg/L. Simultaneous electrolyte shortages influence gull permeability, and damage surface gull cells. Aluminium is principally toxic to fish at pH values 5.0-5.5. Aluminium ions accumulate on the gulls and clog these with a slimy layer, which limits breathing. When pH values decrease, aluminium ions influence gull permeability regulation by calcium which increases sodium losses. Calcium and aluminium are antagonistic, but adding calcium cannot limit electrolyte loss. This mainly concerns young animals. An Aluminium concentration of 1.5 mg/L clad to be fatal to trout. The element also influences growth of freshwater fish. One might assume that concentrations of aluminium would be uniform throughout the surface of sediments, but Perrollaz et al. (1990) state that not all matrix-bonded aluminium is within the style of silicates. Industrially produced aluminum oxide residues are released into the water. a number of the aluminium in these residues becomes available when digested with strong acids and might increase the degree of present aluminium.

2.2.2 Impacts of Aluminium to Sediments

Depending on hydrodynamics, biogeochemical processes and environmental conditions (redox, pH, salinity and temperature) of rivers, sediments are recognized as an important sink of heavy metals in aquatic systems as well as a potential non-point source which may directly affect overlying waters (Pekey 2006). Aluminium can absorb into the sediments, resulting the increase acidity of the soil. This effects the growth of aquatic plants and support the growth of algae.

Aluminium in sediments can also result the discolouration of the river water which leads to the unsuitability of water for everyday uses for living things.

2.3 Pollution of Perai River, Penang

River pollution has been an environmental problem of the world as humans progressively populate the planet. This is because since water flows by the current and gravity in the rives allows as a transportation medium for river-based transportation such as boats and rafts. Irresponsible humans took advantage of it by dumping waste into the river in hopes it will flow to another place not knowing the trash has polluted the water and sediment and affected the ecosystem in it.

2.3.1 Importance of Perai River

Historically, Perai river acted as a natural physical boundary between Province Wellesley (formerly Southern Kedah) and therefore the state of Kedah when Province Wellesley was separated to the East India Company within the year 1798 (Malay Mail, 2017).

Perai river obtained its name supported two sources of data. because of the word 'Border' also indicates the border or end of an area, it is also referred to as the 'end' of Kedah government land. As Kedah was also influenced by the Siamese government at the time, 'Prai' means 'End' in Thai. From another source, land Government at that point named the river as ‘Prye’ thanks to its long physical river. Hence the name ‘Perai’ or some recognise it as ‘Prai’. (Seberang Perai Heritage, 2015)

Now, Perai river is that the longest river in Penang and also the community has beneficiated from it in their daily lives. The river is home to several faunas including over 100 species of aquatic creatures that's also the most source of income for fishermen who lived nearby. Nowadays, the river has transformed into an agrotourism destination to extend the income of the community nearby where tourists can venture the everyday lives of the villagers and even have an opportunity to attend workshops and take a look at fishing using traditional methods.

Perai river has also the chance to become an alternate fresh water resource for the residents in Seberang Perai area under PBAPP scheme Sungai Perai water supply Scheme (SPWSS). The SPWSS is geared toward tapping Sungai Perai as a further raw water resource for Penang. Previous water engineering studies have indicated that raw water from this river might not be safely treated using conventional water treatment technology. The SPWSS will explore the viability of bringing into play more advanced technologies to effectively treat water from this river for safe consumption (PBAPP, October 2021) Therefore, it is important that the river must not be increasingly polluted to make sure the scheme is going to be realised soon.

2.3.2 History of Pollution of Perai River

YZ. Foo et al 2021 IOP Conf. Ser.: Earth Environ. Sci. 944 012052, has done a heavy metal distribution in the sediments of Perai river in 2021. The results shown the sediments contain heavy metals which are zinc Zn, chromium Cr, copper Cu, cadmium Cd, lead Pb, lithium Li and aluminium by using the Enrichment factor. The Enrichment Factor (EF) is a favoured evaluation that identifies and quantifies human interference to the element cycle (Karageorgis et al., 2012) The EF differentiates between the metals originating from anthropogenic sources and the anthropogenic influence based on the degree of natural process. The EF of the heavy metals can be derived using the formula:

Enrichment Factors (EF) = (Element concentration / background concentration) sample/

(Element concentration / background concentration) background

Upon analysis, it is found out that zinc comes from port activities such as loading and unloading materials from fishing boat as well as waste from mining activities that also produces gangue materials such as SiO_2, Al_2O_3 and $CaCO_3$, agriculture and urban runoff. Chromium originated from the mineral weathering but also anthropogenic sources such as industrial activities, laundry activities and boat paintings which use anti-rust paintings that contain chromium which also is the leading source for copper and cadmium. The usage of gasoline for boats and the fact the road is close to the river is the main anthropogenic source of lead in the sediments. The findings of lithium and aluminium in sediments deduced that the two elements are geochemical normalizer in Perai river surficial sediments. Although Foo et al. conclude that the EF values ranging from 0.14 to 0.50 are relatively low, some of the stations they sampled show a relatively high concentration of metals. This might cause by external sources such as the emission from the industry activities and runoff from the nearby urban area.

2.3.3 Sources of pollution of Perai River

According to Penang Water Quality in 2021 (interim), data released by the state Department of Environment (DOE), 26 out of 33 tributaries that flow into the seven main rivers in Penang are either slightly polluted supported the Water Quality Index (WQI). Five of Perai river tributaries are slightly polluted and one is polluted.

Moreover, in May 2021, Perbadanan Bekalan Air Pulau Pinang (PBAPP) is criticised to dump alum sludge which is that the by-product produced by the water purification and wastewater treatment plants when Al salts are used during the coagulation process (Dassanayake et al. 2015). Wet sludge makes up to five within the total quantity of processed water and it is difficult and expensive to treat.

Penang sustainable natural heritage association (LEKAS)'s chief, Zikrullah Ismail said the direct discharge of the "alum sludge" from the treatment plant into the tributaries of Sungai Perai was "concerning" and urged the authorities, like the PBAPP and also the environment department to hold out studies immediately. He also mentioned that Sungai Merbau Kudong, Sungai Perai Mati and Perai river are suffering from the alum sludge. This was because a large discharge drain from the treatment plant at Sungai Dua is taking the sludge into these rivers.

Sungai Dua Water Treatment Plant (SDWTP) is found at Seberang Perai and occupies about 13 hectares of land. SDWTP is that the most vital WTP within the Penang because it supplies 80% of the whole volume of treated water to Penang. SDWTP was first commissioned within the year 1973 and after series of upgrading in 1994, 1999, 2004, 2011 and 2013, it now has the look capacity of 1,113,792 m3/day. SDWTP usually draws water from Muda River as a primary source and Mengkuang Dam because the secondary source which is that the largest dam within the Penang. Currently, the Mengkuang Dam is temporarily decommissioned since February 2014 to facilitate its expansion project.

The Al pollution can also be related to the waste disposal of nearby factories. In Figure, the Perai area of Penang is known for its industrial area that accommodates various industries such as manufacturing, processing, handling and distribution. A good amount of these companies is also located near Perai river (Figure 2.1) which can be a cause of aluminium pollution. Coincidentally, in February 2021, a food company in Seberang Perai has been fined by DOE due to disposal of chemical waste into Perai River. Director of Penang DOE, Sharifah Zakiah Syed Sahab stated that the river was polluted with white foam and there were many dead fish floated on the water surface. Therefore, the potential Al pollution can also be found from Industrial factories.

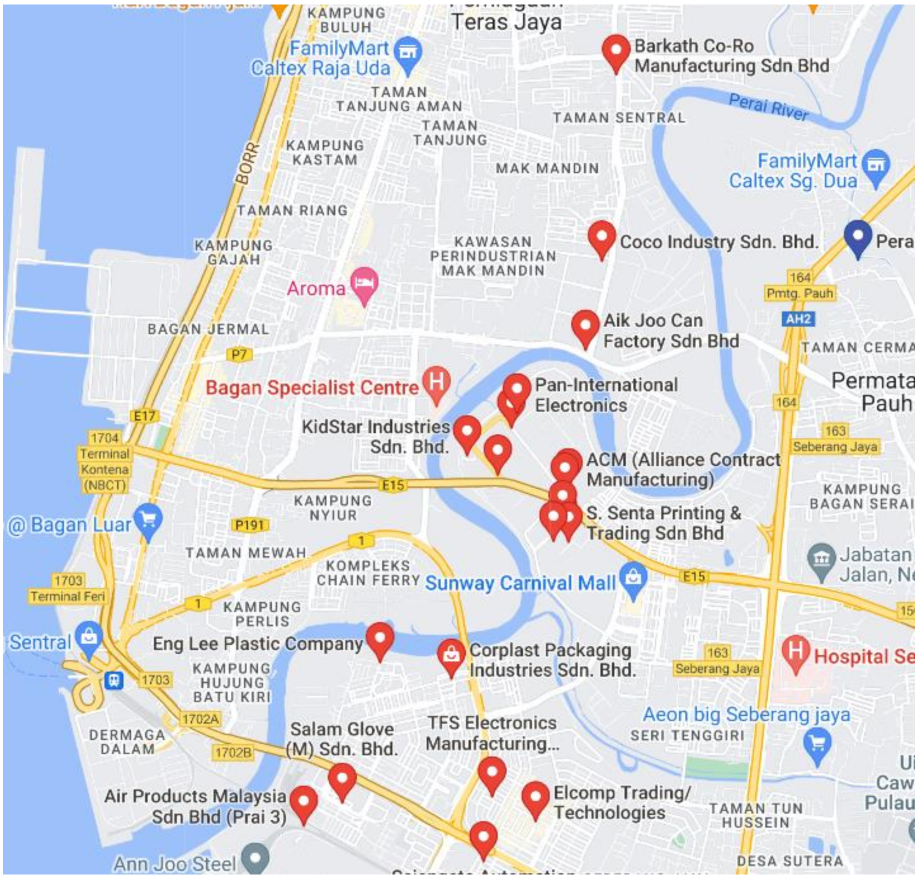

Figure 2.4.1 Map of industrial companies (marked with red pins) near Perai river.

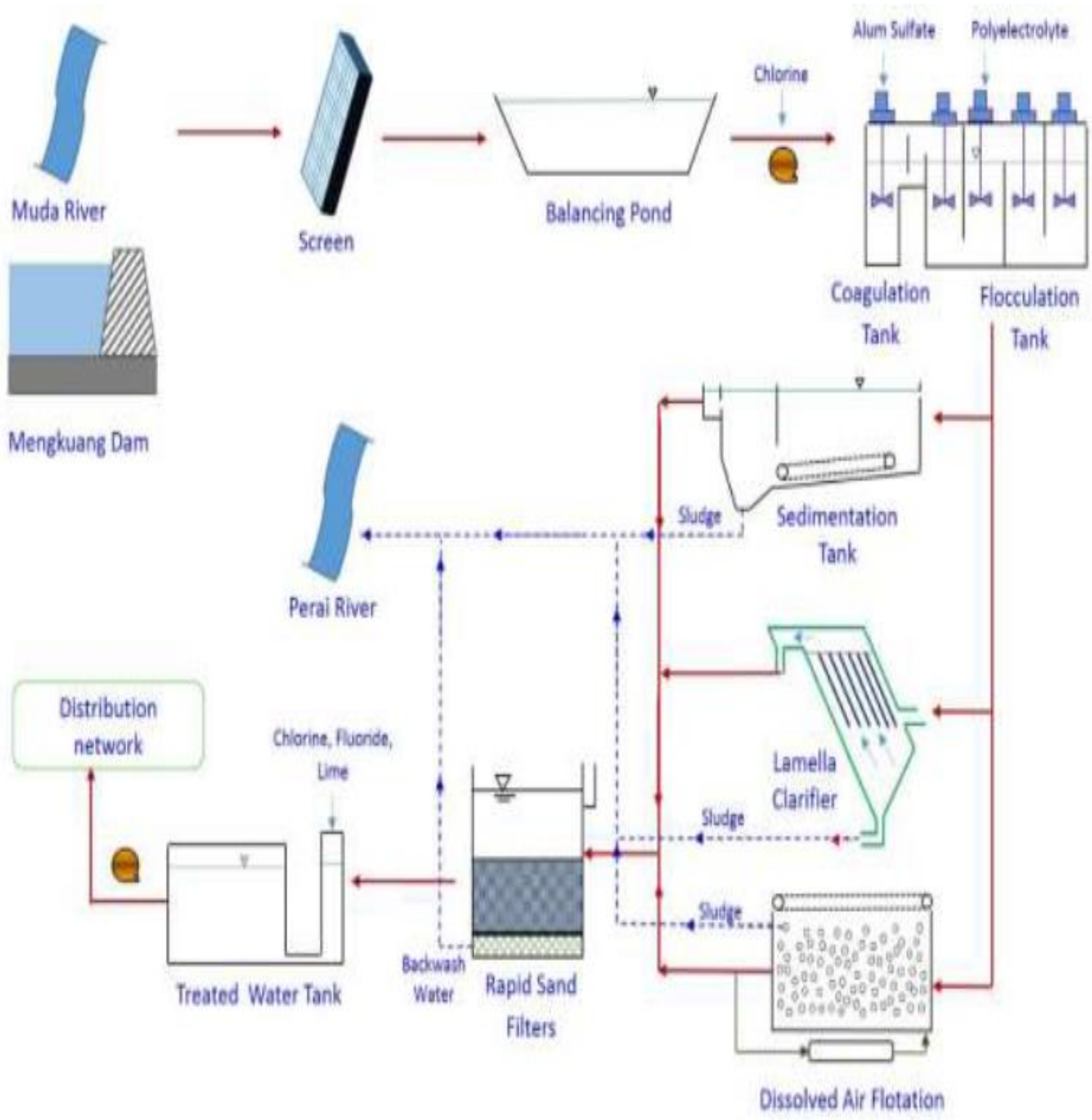

Figure 2.4.2The process flow diagram of each water treatment process at SDWTP

[Source: NewTap, 2016]

2.4 Sampling of Rivers

The majority of river water quality monitoring is performed by collecting discrete grab samples at single points within the channel. they're commonly obtained by filling a container held just beneath the water surface, usually at the mid-point of the channel cross section. the recognition of this sampling method is thanks to the actual fact that it's cheap and straightforward to perform. However, particularly for water bodies that water quality fluctuates over relatively short periods of your time with relation to the frequency, grab samples is also inappropriate for characterizing conditions within the river (other than at the time when the samples are collected). Increasing oftenest can often overcome a number of the issues related to grab sampling. Nevertheless, if sample collection and analysis are expensive or time consuming, then the hassle required may become prohibitive (A. Facchi et al. 2007).

2.4.1 Characteristics of a River (Water, Sediment and Total Suspended Solids)

According to the National Resources and Environment Ministry's Malaysia Environment Quality Report in 2015, there are 477 rivers in Malaysia. All rivers have a start line where water begins its flow. in line with the National Geographic Society in 2022, This source which called the headwater can come from rainfall or snowmelt in mountains, but it also can rise up from groundwater or form at the sting of a lake or large pond. the opposite end of a river is termed its mouth, where water empties into a bigger body of water, like a lake or ocean. Along the way, rivers may undergo wetlands where plants weigh down the water and strain pollutants. The water that flows in rivers is fresh, meaning that it contains but common fraction salt. However, rivers still carry and distribute important salts and nutrients to support plant and animal life. For this reason, a number of the foremost biodiverse habitats on our planet may be found around rivers.

Parker in 1976 stated that sediments are a natural a part of a stream, lake, or river, and also the type and amount found in streams are influenced by the geology of the encircling area. Natural processes that raise sediments in waterways include instream scouring of the river bed and banks and erosion of sediments from the encircling catchment from natural slips and any exposed soils. Sediments can enter streams from alongside a reach or from upstream via the myriad smaller interconnecting streams that form a river network within a drainage basin.While sediment movement may be a natural a part of a functioning freshwater ecosystem, human activities around a waterway (such as dam or building or land use change from native forest to pasture) can greatly increase the quantity of sediment that enters the system. this could have considerable effects on water quality and therefore the plants and animals that live there. The addition of sediment to rivers and streams above normal levels may be a serious issue. Sediments in waterways travel downstream in suspension when water velocity is high or turbulent. When there's a decrease in velocity, especially in pools and deep areas of a stream/river, sediments will eventually settle and might be seen as deposits of fine material or by the formation of sand bars on the river or stream bed. Sediments in suspension can have a major impact on the water quality of a waterway because sediments decrease water clarity, which reduces visibility. Water clarity is typically measured as turbidity. Turbid waters prevent the expansion of aquatic plants and algae (because plants need light for photosynthesis) and reduce the flexibility of fish to seek out food or to detect predators and prey, thereby increasing stress. Sediments may smother stream invertebrates which are a very important food source for fish. Excessive sediment deposits on the river/stream bed can significantly alter and degrade habitat. Some animals are passionate about the rocky bottoms of streams, while others board deep sandy pools or around woody debris. Sediments fill the spaces between stones that invertebrates sleep in, and in extreme cases can bury woody debris, stony substrates (gravels and cobbles), and root mats, and fill pools and channels. This reduces the number of invertebrate habitat and canopy and spawning grounds (a place to get eggs) for fish. a rise within the amount of sediment deposited on the river/stream bed may also significantly change the flow and depth of rivers or streams over time and infill lakes and estuaries. Natural cleaning processes - where the water flows through the gravel bed of a stream and interacts with the microbes living on stone surfaces, removing nutrients and a few pollutants - also can be short-circuited by excessive sediment deposits.

Campbell B. in 2020 TSS stands for total suspended solids, and refers to waterborne particles that exceed 2 microns in size. Any particle that's smaller than 2 microns, on the opposite hand, is taken into account a complete dissolved solid (TDS). the bulk of total suspended solids comprise of inorganic materials; however, algae and bacteria may additionally be considered TSS. TSS might be anything that floats or “suspends” in water, including sand, sediment, and plankton. When certain water sources are contaminated with decaying plants or animals, the organic particles released into the water are usually suspended solids. While some sediment will settle at the underside of a water source, other TSS will float on water’s surface or remain suspended somewhere in between. TSS affects water’s clarity, that the higher a water source’s TSS content, the less clear it will be. the foremost common material in TSS is bacteria which is usually found in H2O source. Besides that, the presence of clay, gravel, sand and silt gives the water the cloudy appearance and disrupts the smell and taste of freshwater. the rise of TTS in rivers can congregate into sediments.

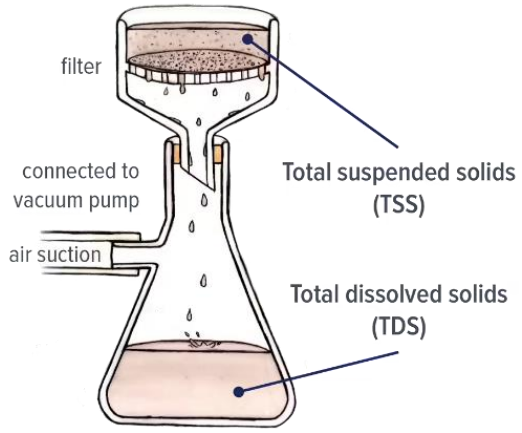

Figure 2.5.1 Method to collect total suspended solids (TSS) [Source: DataStream, n.d]

2.4.2 Water Quality Parameters

Water quality parameters include chemical, physical, and biological properties and may be tested or monitored supported the specified water parameters of concern. Parameters that are frequently sampled or monitored for water quality include temperature, dissolved oxygen, pH, conductivity, oxidation-reduction potential (ORP), and turbidity. However, water monitoring can also include measuring total algae, ISEs (ammonia, nitrate, chloride), or laboratory parameters like biochemical oxygen demand (BOD), titration, or total organic carbon (TOC) (Nayla Hassan Omer, 2020).

Table 2.5. 1DOE Water Quality Index Classification

PARAMETER	UNIT	CLASS				
		I	II	III	IV	V
Ammoniacal Nitrogen	mg/l	< 0.1	0.1 - 0.3	0.3 - 0.9	0.9 - 2.7	> 2.7
Biochemical Oxygen Demand	mg/l	< 1	1 - 3	3 - 6	6 - 12	> 12