DETERMINATION OF SELECTED METALS IN SEDIMENT FROM TERENGGANU AND NERUS RIVER

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by

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DECLARATION

I declare that this thesis entitled “Determination of Selected Metals in Sediment from Terengganu and Nerus River” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :____________________

Name :____________________

Date :____________________

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LIST OF ABBREVIATIONS

EF	Enrichment Factor
CF	Contamination Factor
Igeo	Geoaccumulation Index
PLI	Pollutant load index
SQA	Scottish Qualifications Authority
WHO	World Health Organisation

LIST OF SYMBOLS

%	Percent
<	Less than
>	More than
±	Plus/Minus
≤	Less and equal than
≥	More and equal than
^{o}C	Degree Celsius
µ	Micro
µg	Microgram
µg/g	Microgram / gram
µg/L	Microgram / Liter
g	Gram
Km	Kilometer
mL	Milliliter
mm	Milimiter
Al	Aluminium
Ca	Calcium
Cl	Chlorine
Fe	Iron
K	Potassium
Mn	Manganese
P	Phosphorus
Si	Silicon

S	Sulphur
Ti	Titanium
Zr	Zirconium

Determination of Selected Metals in Sediment from Terengganu and Nerus River

ABSTRACT

Rivers are dominant pathway for trace metals transport. Due to massive anthropogenic activities along Kuala Terengganu and Nerus River, the degree of pollution on surface sediment would increase. The purpose of this study was to determine the selected metals in sediment together with assessing the metal pollution in sediment at Kuala Terengganu and Nerus River. The study about trace metals in sediments were scarce in Malaysia. The sediments location were determine using Global Positioning System (GPS) and the sediments were collected 2 km for each point with 4 cm depth. At Kuala Terengganu and Nerus River, five and three sample of sediments were collected and have been analysed using X-ray Fluorescence (XRF) instrument. The mean concentration of all elements found (mg/g) namely Mn, Fe, Al, Zr, Ca, P, Ti, S, Cl, K and Si were 1.8, 353.4, 152.9, 2.8, 6.6, 9.6, 20.2, 25.4, 24.7, 80.7 and 305.9 respectively. The sediment assessment using Enrichment Factor (EF) indicated Fe, Zr, P, S, and Cl originated from anthropogenic sources and the rest of other elements comes from natural sources. The overall results of Geoaccumulation Index (Igeo) showed the rivers were level of strongly to extremely polluted by elements S and Cl. Moreover, the Pollution Load Index (PLI) of all elements were classified as polluted except for Ca and Si. However the Si is slightly polluted at Kuala Terengganu River. The statistical analysis using Kruskal-Wallis H test proved there were significant different for all elements at Kuala Terengganu and Nerus River. As a conclusion, sediments in this study were contaminated mostly from anthropogenic activity along the river. The recommendation for this study were identify the Total Organic Carbon (TOC), dating of sediment core, determine the water quality and benthic organism as well as identify the concentration of elements during dry and wet season.

Penentuan Logam-Logam Terpilih di Dalam Sedimen daripada Sungai Terengganu dan Sungai Nerus

Abstrak

Sungai adalah laluan dominan untuk pengangkutan logam surih. Oleh kerana aktiviti antropogenik secara besar-besaran di sepanjang Sungai Kuala Terengganu dan Nerus, tahap pencemaran pada permukaan sedimen akan meningkat. Tujuan kajian ini adalah untuk menentukan logam yang dipilih dalam sedimen bersama-sama dengan menilai pencemaran logam dalam sedimen di Sungai Kuala Terengganu dan Nerus. Kajian mengenai logam berat dalam sedimen adalah sukar didapati di Malaysia. Lokasi sedimen di tentukan menggunakan Sistem Kedudukan Global (GPS) dan jarak sedimen ialah 2 km untuk setiap titik dengan kedalaman 4 cm. Di Sungai Kuala Terengganu dan Nerus, lima dan tiga sampel sedimen telah dikumpulkan dan telah dianalisis menggunakan (XRF) alat X-ray pendarfluor. Kepekatan min semua elemen yang terdapat (mg /g) iaitu Mn, Fe, Al, Zr, Ca, P, Ti, S, Cl, K dan Si adalah 1.8, 353,4, 152,9, 2.8, 6.6, 9.6, 20.2, 25.4 , 24.7, 80.7 dan 305.9 masing-masing. Penilaian sedimen menggunakan Enrichment Factor (EF) menunjukkan Fe, Zr, P, S, dan Cl berasal daripada sumber antropogenik dan seluruh unsur-unsur lain datang daripada sumber semula jadi. Keputusan keseluruhan Indeks Geoaccumulation (Igeo) menunjukkan sungai-sungai adalah pada tahap kuat tercemar kepada amat tercemar oleh unsur-unsur S dan Cl. Selain itu, Indeks Pencemaran Beban (PLI) semua elemen diklasifikasikan sebagai tercemar kecuali Ca dan Si. Namun Si sedikit tercemar di Sungai Kuala Terengganu. Analisis statistik menggunakan ujian Kruskal-Wallis H membuktikan terdapat perbezaan yang signifikan untuk semua elemen di Sungai Kuala Terengganu dan Nerus. Kesimpulannya, sedimen dalam kajian ini telah tercemar kebanyakannya daripada aktiviti antropogenik di sepanjang sungai. Penambahbaikan untuk kajian ini ialah mengenal pasti Jumlah Organic Carbon (TOC), mengukur masa teras sedimen, menentukan kualiti air dan bentik organisma serta mengenal pasti kepadatan jisim semasa musim kering dan basah.

CHAPTER 1

INTRODUCTION

1.1 Background of study

Heavy metals pollution is known as great pollution to environment because of toxicity, nondegradable and ubiquitous in the ecosystem (Akoto & Abankwa, 2014). The existence of metal elements in trace amount carry out benefit to human in daily life. However, some metals in appalling concentration do harm human, animals and plants (Husin *et al*., 2015).

Trace metals and heavy metals can be found right through the earth's crust which naturally occurring element (Tchounwou *et al*., 2014). Heavy metals are also called as trace as they fund in trace quantity i.e, 1000 ppm or even lesser in the Earth crust (Tilwankar *et al*., 2016). Heavy metals commonly study at Malaysia include Fe, Mn and Al (Lim & Kiu, 1994; Billah *et al*., 2014; Sim *et al*., 2016).

The effluents of heavy metals in aquatic environments may occur from natural processes and from discharges or leachates from several anthropogenic activities (Adu, 2010). In recent years, human exposure to the environment has dramatically increase and demonstrate pollution in sediment, plant and aquatic life clearly (Kabeer *et al*., 2014). The source of pollution may come from land sources, geogenic and atmospheric sources (Suyarso & Susana, 2010; Wadi *et al*., 2015). Land sources including industries, surface runoff of catchment area, agricultural waste, automobile exhausts and trade waste (Begum *et al*., 2009; Olawale *et al*., 2016).

Rivers are the dominant pathway for metals transport and it is important to protect the water and aquatic ecosystem from exceed contaminant of heavy metals (Jepkoech *et al*., 2013). Sediment is an important component in water system and it plays a significant role in the environmental transport, remobilization of contaminants in aquatic systems under favorable conditions and fate of organic pollutants. Furthermore, it also gave a great effect in interactions between water and sediment (Yang *et al*., 2011; Öztürk *et al*., 2009).

1.2 Problem statement

River in Terengganu which are Kuala Terengganu River and Nerus River received and carries different kinds of liquid and solid wastes from agricultural and massive urban development. According to Chee *et al*., 2008, those environmental pollution generated from mining activities, transportation, and domestic waste that happened in Kuala Terengganu area. High tendency for heavy metals accumulation in the river may occur due to huge anthropogenic activity. The heavy metals concentration such as iron (Fe), manganese (Mn), and aluminium (Al) founded in the river are in low ranges (5.31, 2.04 and 3.23 mg/kg) (Sultan & Shazili, 2010).

The heavy metals presence in the river system has been long acknowledged to pose to the river water. They can be accumulated in the sediment for a long time and therefore pose a further toxic to the whole aquatic environment in contact with water (Liza, 2013). The accumulation of heavy metals in the bed river not only emanate by various fluvial inputs, but also from chemical interaction between metals and sediments. In particular, the adsorption process occur when pollutants are associated with sinking sediment particles and they are bound to organic or inorganic matrices (Ong &Yunus, 2009).

Trace metals concentration present in small amount and not toxic even in low concentration. Most of the trace element concentration originated from the earth crust.

1.3 Objective

1. To determine the selected metals in sediment of Kuala Terengganu River and Nerus River.
2. To assess metal pollution using pollution assessments at Kuala Terengganu and Nerus River

1.4 Significance of study

This study is conducted to provide a baseline data about the heavy metals and trace metals contaminant in Kuala Terengganu and Nerus River to government. This data will help to establish the sediment quality guideline in Malaysia as it is not establish yet (Ikram *et al*., 2010). Apart from that, due to high anthropogenic activity along the river, this study is important to monitor the level of metal contamination in the sediment as it influence the water quality and source of contaminant from environment. Moreover, further study is need in order to get deeper understanding about trace metals and heavy metals pollution in Malaysia aquatic environment (Zulkifli *et al*., 2010).

CHAPTER 2

LITERATURE REVIEW

2.1 River at Terengganu

In Malaysia, there are three large basins in East Cost of Peninsular Malaysia namely Terengganu River basin, Kelantan River basin and Pahang River basin. These three main river basins are influenced by the heavy rainfall from Northeast monsoon. In Terengganu River basin, the total catchment area are respectively 5000km^2 and the length is 100km (Ibrahim *et al*., 2015; Sultan & Shazili, 2010).

The Terengganu River basin located at 4º40'-5º20'N, 102º30'-103º09'E and Kuala Terengganu is the pinpoint at the North Eastern part of Peninsular Malaysia (Khairiah *et al*., 2014). In Terengganu River the stream flowing from the upper watershed at Kenyir Lake and were directly discharge to the South China Sea. The foremost tributaries flowing from Terengganu River are Tersat, Nerus, Berang and Telemung Rivers.

The Nerus River is one of the tributaries of Terengganu River which passes through on Setiu and Kuala Terengganu districts that situated on East Coast of Peninsular Malaysia. The length of Nerus River is about 77km and extend between latitude 103º00' E to 103º06'E and longitude of 05º13'N to 05º23'N. The water is originated from Gunung Sarut and was flow through South Eastern route to the mouth of Nerus River. Henceforth the water from Nerus River were discharges into Terengganu River estuary before permanently discharge to the South China Sea (Chee *et al*., 2008).

The Kuala Terengganu and Nerus River received and carries different kinds of liquid and solid wastes from agricultural and urban development through socio-economical activities. Moreover, these activities contributed pollution to the river where by generated based on agricultural plantation (i.e. palm oil, rubber and coconut), commercial industries, mining activities, transportation, and domestic waste (Chee *et al*., 2008; Suratman *et al*., 2015). In addition, there is a change in river water sources in term of quality and quantity due to human interference in land use and lead to pollution. The demand in clean water influence the degree of metals concentration in sediment, hence there is a need to protect the water resources from pollute (Chee *et al*., 2008).

Furthermore, the seasonal wind patterns with the nature of the local topography influence the rainfall patterns in Malaysia. During the Northeast Monsoon, the critical areas such as the East Coast of Peninsular Malaysia, Sarawak and West Sabah East Coast were exposed with the bouts of heavy rain. At the same time, the rural areas or areas that was protected by mountain is relatively free from the heavy rains. On November until January, most of the areas in East Coast of Peninsular Malaysia receives maximum rainfall due to the Northeast Monsoon while, on June until July are the driest months in these particular areas.

During the last phase of Northeast Monsoon the wind began to blow from all directions and there are some areas were received less rainfall due to the El Nino phenomenon. In addition, according to the Malaysian Metrological Department (MMD) 2016, the Terengganu State has received 60% below than the total average of rainfall per year. Where, the amount of rainfall is recorded 50mm below from the total average rainfall per year compared with other states in East Coast of Peninsular Malaysia. The El Nino phenomenon gave adverse effect to river ecosystem and influence volume of water in Terengganu River. On the contrary to the Northeast Monsoon, Shantakumari *et al*., (2012) proved that the degree of pollutant in the water was recorded highest reading after the rain fall season but still below the permissible limits.

2.2 Sediment in river

Sediment is solid material (soil and rock fragments) transported and deposited by wind, water, or ice; chemically precipitated from solution; or secreted by organisms. Sediment suspended in the water column consists of solid particulate organic and inorganic material (Langland & Cronin, 2003).

Sediments in the river are significant sinks for various pollutants such as heavy metal pollutions. In spite of being place for sink a pollutant, sediment play a big role as a secondary source for identifying a contaminant (Ogendi *et al*., 2014; Yang *et al*, 2011). Therefore, anthropogenic activity can be attestation as the commit to pollution of heavy metal in the sediment.

Sediments, particularly surficial sediments, may serve as a metal pool that released metals to the overlaying water via natural anthropogenic processes. It cause potential adverse health effects to the ecosystems because of their serious toxicity and persistence. Bottom sediments are known to act as a sink for heavy metals introduced to the marine environment. Therefore, benthic organisms, which occupy the bottom layer of the water column, tend to accumulate the highest levels of heavy metals in comparison to pelagic organisms (Sany *et al*., 2011).

Trace metals may adsorb onto sediment but it did not permanently fixed into sediment. The heavy metals have potential effect of bio-toxicity may be accumulate by benthic organism and it might recycle via chemical and biological agent in between water column and sedimentary compartment (Sharmin *et al*., 2010; Akan *et al*., 2010). In circumstances, sediment can recorded the history of pollution from virtually (Sany *et al*., 2013).

Sediment not only act as background for pollution reservoir but it represent the magnitude of pollution in the sediment greater than water (Mendil *et al*., 2010). Saleem *et al*., (2015) indicate there is about 99% of overwhelming metals concentration stored in the sediment and only 1% of the contaminant dissolve in water column which reflect the contaminant load over a period (Shuhaimi-Othman *et al*., 2012). These pollutant can be consume by aquatic life and laterally transferred to human via food chain and give severe effect to human health.

2.3 Metals

2.3.1 Heavy Metals

The highest reading of heavy metals concentration nowadays are well known as dangerous pollutant to the biotic component especially to human life. There are two common sources of heavy metal pollution which are from, natural or anthropogenic activities. The heavy metals pollution can be occur naturally from the soil, rock, vegetation, forest fires and airborne dust by the leaching process that ended to our aquatic system (Ogoyi *et al*., 2011). Meanwhile, the anthropogenic activities can comes from various activities such as mining activity, transportation, agricultural and unsystematically development at industrial and residential areas.

Diverse meaning has been appoint to heavy metals. Heavy metals has been defined in various way and it can be group into density, atomic weight or mass, atomic number, and based on chemical properties (Duffus, 2002). Heavy metals are described as metallic element that have high density than water (Wadi *et al*., 2015). Duruibe *et al*., (2007) has defined heavy metals as any metallic element that has respectively high density and is toxic and poisonous even in low concentration.

In addition, heavy metals are also known as a group of metals and metalloids that possess a density more than 4 g/cm3 or 5 g/cm3 or more (Duruibe *et al*., 2007; Husin *et al*., 2015; Olawale *et al*., 2016). Therefore, any toxic metal possibly called heavy metals based on density and atomic mass (Singh *et al*., 2011). According to Horowitz (1985), chemical factor of heavy metals is important to identify the sample whether have similar bulk chemistries and predicting environmental availability.

Heavy metals such as Mn, Fe and Al are needed in small amount for plant, animal and human to growth (Tilwankar *et al*., 2016). Other than that, Mn and Fe act as catalyst in enzyme activities at low levels (Akan *et al*., 2010). However, heavy metals absolutely can caused harmful effect to human health depends on quantity of metal ingested and level of exposure (Duruibe *et al*., 2007 ; Akan *et al*., 2010).

Manganese (Mn) with relative atomic mass 24.3 and density 7.20 g cm^(-3) located at Rows 4 through 7 in Groups 3 through 12 of the periodic Table (Scottish Qualifications Authority, 2008). Manganese is classified as transition metal (Newton, 2010). This element occur naturally in rock, soil and water and present about 0.1 % in earth's crust (WHO, 2004). Besides, manganese and iron have similar properties and often occur together in Earth's crust (Newton, 2010). The hazardous and potential effect of Mn to human health are neurodegenerative disorder and Parkinson's disease (Dobson *et al*., 2004).

Iron (Fe) with relative atomic mass 55.8 and density 7.86 g cm^(-3) located at Groups 3 through 12 (Scottish Qualifications Authority, 2008). Iron is classified as transition metal. Iron is element that abundant on earth and it is essential in every living organism (Abbaspour *et al*., 2014). In decade, iron play important role in haemoglobin formation and oxygen transport. Iron normally does not occur as a free element in the earth (Newton, 2010). The effect of excessive iron to human health can cause death and genetic disorder (haemochromatosis) (WHO, 2003).

Aluminium (Al) with relative atomic mass 27.0 and density 2.70 g cm^(-3) located at Row 3, Group 13 of the periodic table (Scottish Qualifications Authority, 2008). Aluminium and its compound contain in the Earth's surface about 8% and it occur naturally in cryolite, bauxite rock and silicates (Krewski *et al*., 2007). It is second to silicon as the most abundant metallic element (Newton, 2010). The effect of aluminium to human health are presenile dementia, senility, Parkinson's disease and Alzheimer's (Akan *et al*., 2010).

Heavy metal pollutions from natural sources come from weathering of minerals, erosion and volcanic activities, forest fires and biogenic source and particle release by vegetation (Weber *et al*., 2013). Soils may inherit heavy metals from parent materials such as those derived from metal-enriched rocks including serpentine and black shale.

2.3.2 Trace Metals

Trace metals can be defined as metals that presence in trace concentration (ppb range to less than 10 ppm) (Tchounwou, 2012). In other literature, Tilwankar *et al.*, (2016) stated that heavy metals also called as trace as they are found in trace quantity i.e. 1000 ppm or even lesser in the Earth crust. In this study, Zr, Ca, P, Ti, S, Cl, K, and Si are categorized as trace metals.

Zirconium (Zr) with relative atomic mass 91.2 and density 6.52 g cm^{-3} located at Row 4 through 7 and between Groups 2 and 13 in the periodic table (Scottish Qualifications Authority, 2008). Zn is classified as one of the transition metals (Newton, 2010). Zirconium contain in selected human tissue such as in liver and gall bladder (Schroeder & Balassa, 1966). Zr compounds are low toxicity and has been used in artificial internal organs (Lee e*t al*., 2010). According to Lee *et al*., (2010), normal human exposed up to 1,000 µg/ml showed no evidence for DNA damages using single-cell gel (comet) assay.

Calcium (Ca) with relative atomic mass 40.0 and density 1.54 g cm^{-3} located at Groups 2 (Scottish Qualifications Authority, 2008). Calcium is an alkaline earth metal and more chemically active than most metals (Newton, 2010). Calcium is important in human body as it serves a vital role in nerve impulse transmission, muscular contraction, blood coagulation, hormone secretion, and intercellular adhesion (Blaine *et al*., 2014). The excessive amount of calcium can cause Hypercalcemia and hypocalcemia indicate serious disruption of calcium homeostasis (Peacock, 2010).

Phosphorus (P) with relative atomic mass 31.0 and density 1.82 g cm^{-3} located at Groups 15 (Scottish Qualifications Authority, 2008). Phosphorus is part of the nitrogen family along with nitrogen, arsenic, antimony and bismuth (Newton, 2010). Phosphorus (P) is an essential element for all life forms (Corell, 1998). Increasingly, studies show that phosphorus intakes in excess of the nutrient needs of a healthy population may significantly disrupt the hormonal regulation of phosphate, calcium, and vitamin D, which contributes to disordered mineral metabolism, vascular calcification, impaired kidney function, and bone loss (Calvo & Uribarri, 2013).

Titanium (Ti) with relative atomic mass 47.9 and density 4.50 $g\,cm^{-3}$ located at group 4 of the periodic table (Scottish Qualifications Authority, 2008). Titanium is classified as one of the transition metal (Newton, 2010). Pure titanium and titanium alloy has been widely used in manufacture dental implants (Campbell *et al*., 2014), spacecraft (Henriques, 2009), automotive industry and medical devices (Veiga *et al*., 2012). However, there is adverse effect to human health such as necropsies, lung inflammation and dermal irritation (Shi *et al*., 2013).

Sulphur (S) with relative atomic mass 32.1 and density 2.07 $g\,cm^{-3}$ located at Group 16 of the periodic table (Scottish Qualifications Authority, 2008). Sulphur is classified as chalcogen family (Newton, 2010). Sulfur in abundance in earth crust about 0.05 % (Newton, 2010). It is more abundant than carbon, but less abundant than barium or strontium. The less amount of sulphur intake gave certain health problem such as itchy and flaking skin and improper development of hair and nails (Newton, 2010).

Chlorine (Cl) with relative atomic mass 35.5 and density 0.0032 $g\,cm^{-3}$ located at Group 17 of the periodic table (SQA, 2008). Chlorine is classified as halogen family (Newton, 2010). Numerous amount of chlorine have been used as disinfectants and bleach for both domestic and industrial purposes used in (WHO, 2003). Moreover, in our daily life, chlorine had been used to ensure the safety of drinking water (Zyara *et al.*, 2016). However, there is side effect to human health such as bladder cancer from long term exposure (Villanueva *et al*., 2003).

Potassium (K) with relative atomic mass 39.1 and density 0.86 g cm^{-3} located at Group 1 of the periodic table (Scottish Qualifications Authority, 2008). It always occurs in compounds and combined with other element because it is so active alkali metals (Newton, 2010). Potassium is an abundance element in earth's crust about 2.0 to 2.5% and it is also essential element in all living organism (WHO, 2009; Newton, 2010). The high amount of potassium intake give good benefit to human health such as reduces blood pressure in people with hypertension and has no adverse effect on blood lipid concentrations, catecholamine concentrations, or renal function in adult (Weaver, 2013).

Silicon (Si) with relative atomic mass 28.1 and density 2.33 g cm^{-3} located at Group 14 in the periodic table (SQA, 2008). Silicon is abundance in earth's crust about 27.6%, the second most abundant element exceeded only by oxygen and it is always present in combined with one or more other elements as a compound (Newton, 2010). In recent year, Silicon has been widely used in semiconductor industry (Mangolini, 2013) and invasive medical sensors (Engels & Kuypers, 1983). In human health, silicon play an important role in the formation of cross-links between collagen and proteoglycans as well as essential element for bone formation (Price *et al.*, 2013).

2.4 Previous study of heavy metals and trace metals

There is previous study about heavy metals in Malaysia and international countries shown in table 2.4. In Malaysia, the most elements of heavy metals study is arsenic (As), copper (Cu), cadmium (Cd), iron (Fe), manganese (Mn), mercury (Hg) and lead (Pb) (Idris & Ahmad, 2015; Khairiah *et al*., 2013; Koh *et al*., 2015; Sany *et al*., 2011). However, there is little study about trace metals in Malaysia study.

Meanwhile, in international study, the study about heavy metals and trace metals are equivalent (Tiimub, 2013; Olatunji & Osibanjo, 2012; Harikishnan *et al*., 2015; Cardoso *et al*., 2008; Odukoya & Akande, 2015). The heavy metals and trace metals study by previous researcher include arsenic (As), copper (Cu), cadmium (Cd), iron (Fe), manganese (Mn), mercury (Hg) and lead (Pb), zicronium (Zr), calcium (Ca), phosphorus (P), titanium (Ti), sulphur (S), chlorine (Cl), potassium (K), and silicon (Si).

Previous study in Malaysia by Sultan & Shazili (2015) reported that there is abundance element of metals in sediment from Terengganu river basin such as Al, Fe, K, Na, Mg, Ca, Mn, Ba, Cr, Zr, Ni, Sr, Zn, Y, Li, Cu, Mo, Nb, Th, Co, Ga, W, Ta, Be, Ti, Ge, Se, Bi, Te, Sc and Re. The concentration of element such as Mn, Fe, Cr, Ba, Ni, Zn, Cu, Mo, Co and Se has exceed the environmental guideline values (Sultan & Shazili, 2015).

Shaari *et al*., 2015 reported the heavy metals found at the East Coast of Peninsular Malaysia are Al, Fe, Mn, Zn, Cu, and Co. The study was compared with previous study such as regional study and it showed diverse pattern of heavy metals concentration (Shaari *et al*., 2015).

Another previous study in Malaysia at Baleh River, Sarawak by Sim *et al*., 2016 reported that the heavy metals found was Mn, Fe, Al, Cu, Pb, and Zn. The concentration of heavy metals showed that the concentration reading is below the world average value as well as in the range of literature review used by the Sim *et al*., 2016.

From Sim *et al*., 2014, reported that the heavy metals and trace metals found at Batang Ai Reservoir and Ai River such as Na, K, Mn, Cr, Ni, Zn, Mg, Fe, Sn, Al, Ca, As, Se, and Hg. The study showed the concentration of trace metals in sediment was lower than other previous study and other reported study (Sim *et al*., 2014).

Another previous study in Malaysia reported by Suhaimi-Othman *et al*., (2012), the heavy metals found in sediment at Sungai Sedili Kecil are for Na, K,Mn, Cr, Ni, Zn, Mg, Fe, Sn, Al, Ca, As, Se, and Hg. The concentration of metals was compared with interim sediment quality guideline (ISQG) and probable effect value (PEL) and it showed that the concentration is lower than ISQG and PEL limits.

Besides, the previous study in international countries showed by Gatti *et al*., (1999) found the heavy metals and trace metals in sediment at Infernao Lake, Southen Brazil such as Al, Mn, Fe, Si, P, S, Cl, K, Ca, Ti, V, Cr, Ni, Cu, Zn, Rb, Sr, Zr, Ba, and Pb. The sediment concentration was compare with Earth's Crust in sedimentary rock and the result showed that Al, P, Ti, V, Cr, Fe, Cu and Pb has exceed the sedimentary rock value (Gatti *et al*., 1999).

Furthermore, in rivers of Kososvo, Gashi *et al*., (2009) reported that the heavy metals and trace metals found in sediment such as Al, Mn, Fe, Ca, K, P, and S. The concentration of elements were compared with sediment quality by SMSP, Falconbridge and earth's crust value Gashi *et al*., 2009).

For concentration of Lima River, Portugal, Cardoso *et al*., (2008) reported that the heavy metals and trace metals founds in the sediment such as Mn, Fe, Al, Zr, Ca, Ti, S, Cl, K and Si. The concentration was reported in percentage. The concentration of metals in sediment was compare with reference value for non-polluted soil (Cardoso *et al*., 2008).

In other previous study about sediment reported by Han *et al*., (2012) found that at Wei River, China, the heavy metals and trace metals such as Mn, Fe, Al, Zr, Ca, Ti, K and Si. The concentration of metals in Wei River was compared with the larger river at China (Han *et al*., 20012).

Similarly with Minho River reported by Mil-Homens *et al*., (2013), the concentration of metals found in the sediment such as Al, Fe, Ca, K, Ti, Mn and Si. The fine grained sediment influence the metals concentration and the concentration was compared with other previous study.

2.5 Sediment pollution assessment

In order to identify the degree of pollution in sediment or quantitative indexes (Ho *et al*., 2010), there are several parameter used as pollutant indicator known as enrichment factor (EF) and geoaccumulation index (I_{geo}) (Ghani, 2015). Henceforth for the pollution load index (PLI) also state as parameter used to assess sediment pollution (Salah *et al*., 2012).

Additionally, all of the parameters using background value or reference value in the calculation and mostly from earth's crust whether average crustal value or average shale (Abrahim & Parker, 2008). The background value is known as normalizer value or reference value (Yusoff *et al*., 2015; Ong &Yunus, 2009).

2.5.1 Enrichmrnt Factor (EF)

Enrichment factor was used to analyse the pollutant whether the metal input from natural or anthropogenic (Ong *et al*., 2015). Other than that, the degree of sediment composition could be identify by using EF calculation on account of linear relationship between background value and measured value (Sultan &Shazili, 2010). In this study, Al has been choose as normalizer because the anthropogenic activity produce Al is low compare from natural resources (Ho *et al*., 2010; Apkan & Thompsan, 2010).

The result obtain from previous study at estuary of Vietnam reported by Ho *et al*., 2010 showed that the heavy metals such as As was ranked from “severe enrichment” to “extreamly enrichment”. The study using three reference materials which comes from average sedimentary rock, upper continental crust and average continental crust and it has been classified based on enrichment level (Ho *et al*., 2010).

Apkan & Thompsan (2013) reported that the metals contaminant in sediment at Cross River, Nigeria was from minimal enrichment to significant enrichment. The river was polluted by nickle (Ni) origin from anthropogenic activity mainly from agricultural (Apkan & Thompson, 2013).

Other study about assessing metal contaminant in sediment was in Balok River, Pahang that has been reported by Abdullah *et al*., (2015). The enrichment value was classified from deficiency to minimal enrichment to significant enrichment. The heavy

Table 2.1: Previous study from Malaysia and International countries in mg/g.

	Malaysia Study					International countries				
Element	Terengganu river basin	EEZ of the Coast of Peninsular Malaysia	Baleh River, Sarawak	Batang Ai Reservior and Ai River, Sarawak.	Sedili Kecil River, Johor	Infern~ao Lake, in Southern Brazil	Rivers of Kosovo	Lima River, Portugal	Wei River, China	Minho River, China
Mn	0.02724	0.27342	0.793	0.27386	0.1905	129	1.33865	0.315	0.55767	0.26
Fe	0.0017	75.6	37.823	3.38745	33.3894	32274	28.41	28.6	26.5	12
Al	0.00633	42.3	100.879	10.63263	17.1187	66947	14.66	75.2	58.2	45.7
Zr	0.00909	–	–	–	–	60.3		0.258	0.29118	–
Ca	0.00008	–	–	0.32179	–	371	36.275	2.9	49.9	1.4
P	–	–	–	–	–	654	0.5805	–	–	–
Ti	0.00056	–	–	–	–	4342	–	3.5	3.6893	1.6
S	–	–	–	–	–	1089	0.4745	3.9	–	–
Cl	–	–	–	–	–	88.5	–	4.2	–	–
K	0.00242	–	–	0.84207	–	2976	1.645	27.7	19.4	26.8
Si	–	–	–	–	–	91966	–	264	297.3	368.3
Sources	Sultan & Shazili, 2010	Shaari *et al.*,2015	Sim *et al.*, 2016	Sim *et al.*, 2014	Suhaimi-Othman *et al.*, 2012	Gatti *et al.*, 1999	Gashi *et al.*, 2009	Cardoso *et al.*, 2008	Han *et al.*, 2012	Mil-Homens *et al.*, 2013

metals such as lead (Pb) and zinc (Zn) was reveal comes from anthropogenic activity associated by fisheris and boating activity (Abdullah *et al*., 2015).

2.5.2 Geoaccumulation Index (I_{geo})

Geoaccumulation Index was used to estimate the enrichment of metal concentrations above background or baseline concentrations is to calculate the geoaccumulation index (Igeo) as proposed by Müller (1969) (Abrahim & Parker, 2008). In addition, the Igeo value can be used to compare between the control level with the current concentration of the metals (Abdullah *et al*., 2015)

The assessment of Geoaccumulation Index at Euphrates River in sediment reported by Salah *et al*., (2012) showed that all sampling site were unpolluted. The Igeo value indicate the mean concentration of heavy metals are lower than surface rock average (Salah *et al*., 2012).

The study by Varol & Sen (2012) reported that the Igeo class values in sediment at Tigris River were polluted. The range of heavy metals (Cd, Co, Cu, Ni, Pb and Zinc) under present that the range of sediment from “moderately polluted to very highly polluted” based on the station taken along the river (Varol & Sen, 2012).

2.5.3 Pollution load Index (PLI)

Pollution load index is one of the parameter that can be used to estimate the metal contamination status and the necessary action that should be taken (Likuku *et al*., 2013). In other words, pollution provide simple but comparative means for assessing a site quality (Salah *et al*., 2012).

The previous study at Yellow River, China reported by Ren *et al*., 2015 showed that all sample point along the river was polluted in the rank of moderately polluted. Other researcher such as Salah *et al*., (2012) reported that PLI is also used to identify whether the site is suffer from contamination or not.

CHAPTER 3

MATERIALS AND METHOD

3.1 Study site

Kuala Terengganu River and Nerus River are located at Terengganu, the East Coast of Peninsular Malaysia. The source of Kuala Terengganu river originated from Kenyir Lake and ended to South China Sea (Ong & Yunus, 2009). The total catchment area of Kuala Terengganu is 500 km^2 with 100 km length (Ibrahim, 2015). Meanwhile, the total catchment area of Nerus River is 851 km^2 with 77km length and originated from Gunung Sarut (Chee *et al*., 2008).

At Kuala Terengganu, the main tributaries include Berang River, Tersat River, Nerus River and Telemong River. In particular at Nerus River, the tributaries include Tepuh River, Pelung River, Telemong River, Las River, Tong River, Linggi River, Tayur River, Temiang River and Semelang River (Chee *et al*., 2008).

The pollution in Kuala Terengganu and Nerus River were influenced by anthropogenic activities that happen at surrounding area such as from soil mining activity, residential waste, ecotourism activities, and transportation activity along the river bank (Koh *et al*., 2015). Apart from residential area, urbanization and land use, aquaculture, urban and rural settlement and forest was contribute to the pollution in the river (Suratman *et al*., 2015).

3.2 Sample collection

The Global positioning System (GPS) was used to determine the actual coordinate of the sampling stations and to reconfirm the location of stations during the subsequent sampling periods (Abdullah *et al*., 2015). The difference between each sampling point is 2 km. Where the sediment sample was collected by using Ekman grab sampler at each sampling locations at 4cm depth (Wan *et al*., 2013). This is because since it provides information on the most recently deposited sediment materials and it is able to determine the horizontal variation in sediment properties as well as the distribution of contaminants (Simpson *et al*., 2005). The sediment was kept into clean polythene bag and an icebox at 4°C to decrease biological and chemical reactions. Then the sample was stored in the laboratory for further analysis (Sany *et al*., 2013). Figure 3.2a showed the general map for sampling. The sample were taken for each river showed in Figure 3.2b and Figure 3.2c. The sediment sample were collected as shown in Table 3.1. The analytical procedure for metals in sediment can be seen in Figure 3.1.

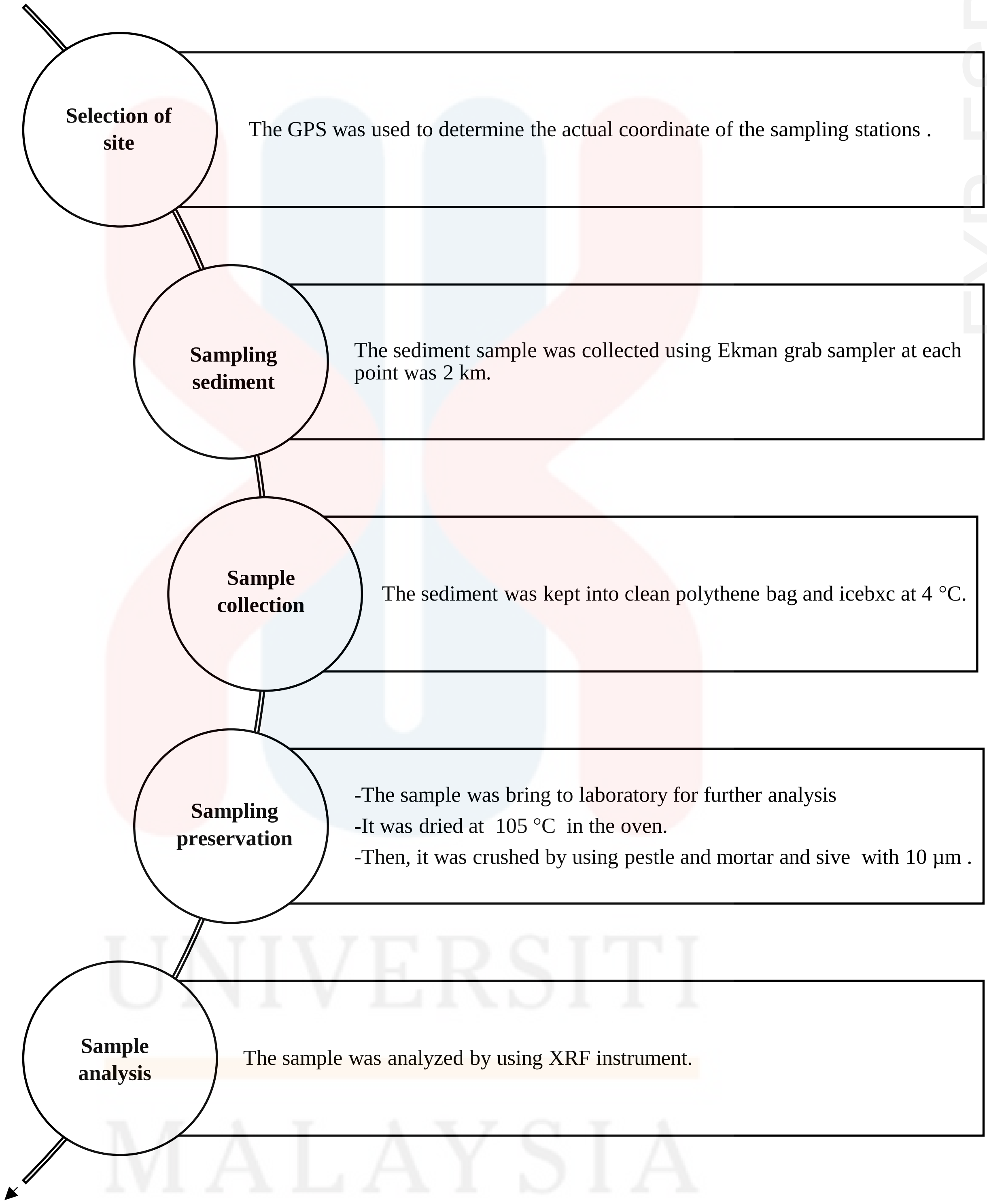

Figure 3.1: Analytical procedure for metals in sediment

3.2a The map of sampling collection

3.2b Nerus River

3.2c Kuala Terengganu River

Figure 3.2: a) The map of sample collection, b) Nerus River, and c) Kuala Terengganu River.

Source by Google Earth (2016).

Table 3.1: The geographical position and description of sampling locations.

		Geographical description		
Station	Location	Latitude (North)	Longitude (East)	Description
SKT 1	Kuala Terengganu River	N 05° 18’ 10.7 "	E 103° 05’ 15.3"	Nearby to bushes
SKT 2	Kuala Terengganu River	N 05° 18’ 55.2"	E 103° 05’ 17.9"	Residential Area Mangrove Swamp
SKT 3	Kuala Terengganu River	N 05° 19’ 53.0"	E 103° 06’ 47.2"	Residential Area Road Bridge
SKT 4	Kuala Terengganu River	N 05° 20’ 17.4 "	E 103° 07’ 50.7 "	Boat Parking at Marina heritage
SKT 5	Kuala Terengganu River	N 05° 20’ 42.3 "	E 103° 08’ 11.7"	Jetty Seberang Takir
SN 1	Nerus River	N 05° 20’ 26.0 "	E 103° 05’ 27.7"	Boat Parking Thick Bushes
SN 2	Nerus River	N 05° 20’ 03.4 "	E 103° 06’ 05.8"	Masjid Bukit Tunggal Residential Area
SN 3	Nerus River	N 05° 19’ 34.4"	E 103° 06’ 00.3"	Mining Area

SKT: Kuala Terengganu River
SN: Nerus River

3.3 Sediment sampling

The sediment samples were collected at 8 different points which 5 samples along Kuala Terengganu River and 3 samples along Nerus River. The number of sample collected at Kuala Terengganu and Nerus River, namely as indicated in Table 3.1. The total of 8 samples in this study represents the Kuala Terengganu and Nerus River. At Nerus River, due to bad weather, only 3 sample was able to collect.

3.4 Sample preparation

This sample was analysed in the Environmental Lab of Universiti Malaysia Kelantan. The sample was dried in the oven at 105 °C until there is no excessive water in the sample. Then, the sample was crushed by using pestle and mortar to homogenize. The homogenized sample was sieved with 10 µm and packed with zip lock bag. The dried sediments were weighed in 15g using electronic balance Model AAA Adam Co limited (Muiruri, 2013).

3.5 XRF preparation

The dry sample was weighed 15g approximately and it was filled in 15 mL falcon tube. Then the sample has been analysed by using X-ray Fluorescence (XRF) instrument located at University Malaysia Kelantan in powder form. . The result that has been analysed was in mg/kg.

3.6 Sediment Quality Assessment

To detect heavy metals in sediment, some parameter was used to identify the pollution. In order to clarify geochemical data, the selection of background value plays a powerful contribution. The level of contaminant can be evaluated by deciding the enrichment factor (EF), geoaccumulation index (I_{geo}) and pollution load index (PLI).

3.6.1 Enrichment factor

Enrichment factor is a parameter used to determine the pollution by using pollution index as stated. The enrichment factor was calculated using the formula originally introduced by Buat-Menard and Chesselet (1989) as shown in equation (1). The concentration of earth's crust reported by Wedehpohl (1995) as shown in Table 3.2.

Table 3.2: The concentration of metals in continential crust

Metals	Cocentration in Continential Crust (%)
Manganese(Mn)	0.0716
Iron(Fe)	4.32
Aluminium(Al)	7.96
Zirconium(Zr)	0.0203
Calcium(Ca)	3.85
Phosphorus(P)	0.0757
Titanium(Ti)	0.401
Sulphur(S)	0.0697
Chlorine(Cl)	0.0472
Potassium(K)	2.14
Silicon(Si)	28.8

Source: Wedepohl (1995)

$$EF = \frac{(C_n / C_{ref})_{sample}}{(B_n / B_{ref})} \quad (1)$$

Where,

C_n (sample) = the concentration of the examined chemical element in the examined environment.

C_{ref} (sample) = the concentration of the examined chemical element in the reference environment.

B_n = the concentration of the reference chemical element in the examined environment.

B_{ref} = the concentration of the reference element in the reference environment.

Enrichment categories were listed in the Table 3.3.

Table 3.3: Enrichment factor categories

Enrichment factor (EF)	Enrichment factor (EF) Categories
EF < 1	No enrichment
1 < EF < 3	Minor enrichment
3 < EF < 5	Moderate enrichment
5 < EF > 10	Moderate severe enrichment

(Source: Yusoff *et al*., 2015)

3.6.2 Geoaccumulation Index (Igeo)

The function of this index approximately to make a comparison between the current levels of metal concentration and the original pre-industrial concentrations in the soils has been suggested by Müller shown in equation (3). The sediment qualification can be refer at Table 3.4.

$$I_{geo} = \log_2 \left[\!\left[\frac{C_m\ Sample}{1.5 \times C_m\ Background} \right]\!\right] \qquad (3)$$

The factor of 1.5 is introduced to minimize the effect of possible variations in the background values, *C*m Background, which may be attributed to lithogenic variations in soils.

Table 3.4: Qualification of sediment based on Igeo value

Igeo Value	Class	Qualification of sediment
≤0	0	Unpolluted
0-1	1	From unpolluted to moderately polluted
1-2	2	Moderately polluted
2-3	3	From moderately polluted to strongly polluted
3-4	4	Strongly polluted
4-5	5	From strongly polluted to extremely polluted
>6	6	Extremely polluted

Source: Salah *et al*., (2012)

3.6.3 Pollutant load index

Tomlinson *et al*., (1980) has proposed how to calculate the pollution load index by using the same thing but different as shown in equation (2).

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \ldots CF_N)^{1/N} \quad (2)$$

Where,

N = the number of metals studied and

CF = the contamination factor

The *PLI* is able to give an estimate of the metal contamination status and the necessary action that should be taken can be shown in Table 3.5.

Table 3.5: Estimation of metal contamination status.

Pollution Load Index	Sediment Qualification
PLI < 1	Denote perfection
PLI = 1	Present that only baseline levels of pollutants are present
PLI > 1	Indicate deterioration of site quality
PLI value of ≥1	Indicates an immediate intervention to ameliorate pollution;
0.5 ≤ *PLI* < 1	Suggests that more detailed study is needed to monitor the site
PLI < 0.5	There is no need for drastic rectification measures to be taken.

Source: Likuku *et al*., (2013)

3.7 Statistical Analysis

The data was analysed using software @IBM SPSS Statistics 21. Based on the sample taken at Kuala Terengganu and Nerus River, this data was classified as non-parametric data because the sample number is not equivalent and less than thirty. The statistical analysis used was Kruskalwalis test.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Concentration of metals in sediment from Kuala Terengganu and Nerus River.

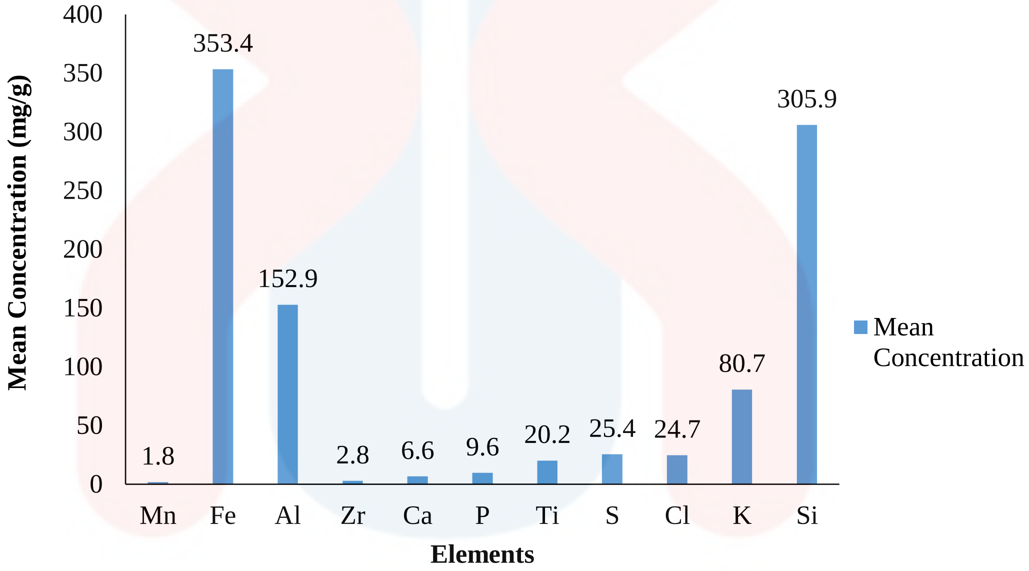

Figure 4.1: Mean concentration of each elements in Kuala Terengganu and Nerus River.

Figure 4.1 showed the mean concentration of selected metals in Kuala Terengganu and Nerus River. According to the mean value, it was arranged from the highest mean value to the lowest mean value as follow, Fe > Si > Al > K > S > Cl > Ti > P > Ca > Zr > Mn respectively for both river.

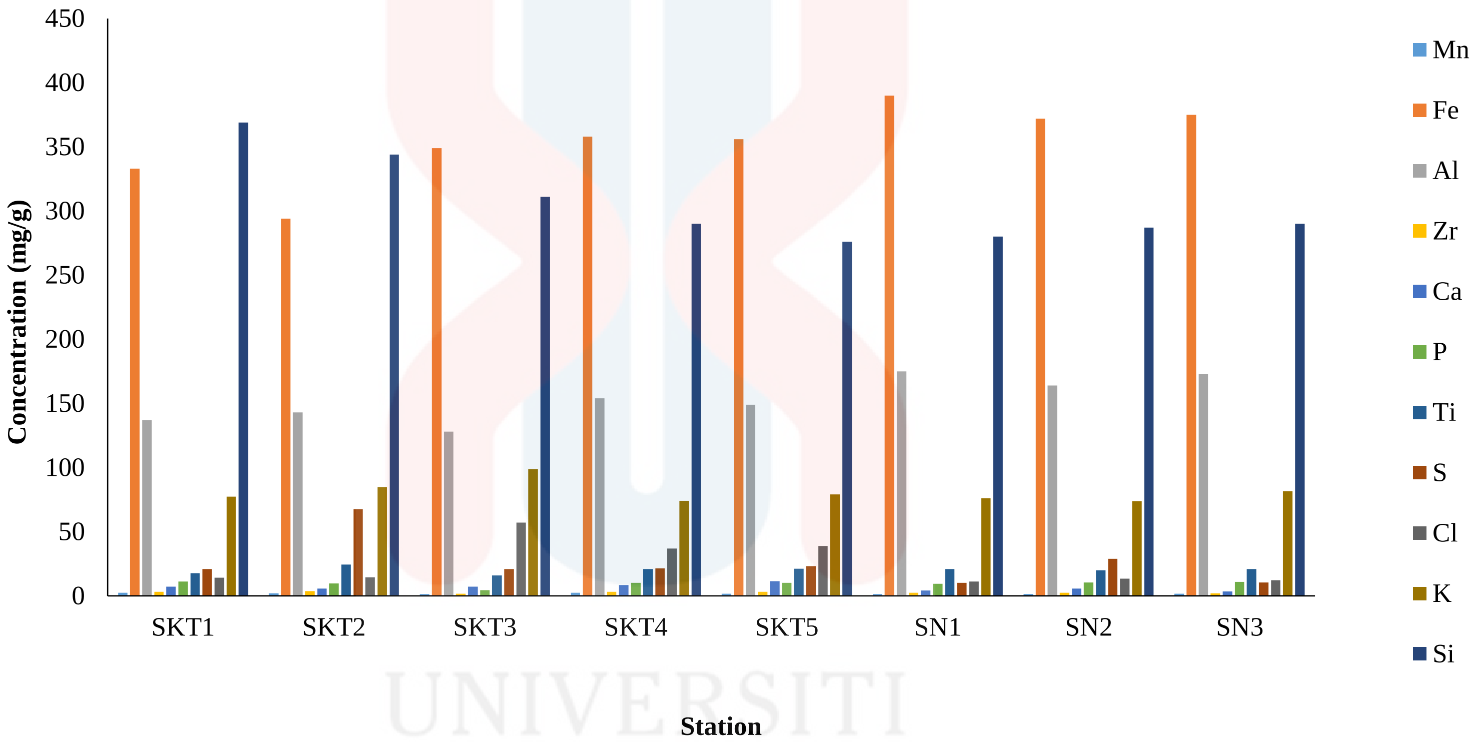

Figure 4.2: Concentration of all elements at Kuala Terengganu and Nerus River

SKT: Kuala Terengganu River
SN: Nerus River

It was clear that Fe represent the highest value among other element in the sediment sample. Meanwhile, Mn represent the lowest concentration of mean value. The highest amount of Fe reveal at station SN1 with value 390 mg/g which is sample from Nerus River. For the Mn concentration, the lowest value was observed at the same station which is SN1 with value of 1.4 mg/g. Figure 4.1 and Figure 4.2 showed the mean concentration of all elements from Kuala Terengganu and Nerus River.

The trace metals from present study was compared with other regional study and international study to make sure the result was between the range since the sediment quality guideline for trace element in sediment is not published yet. Conversely, the studies about trace metals in sediment at Malaysia were not as much of worldwide study. Presently, the metals in concern with Malaysia study including Mn, Fe and Al. Therefore, other metals were compared with other international study as shown in Table 4.1.

In this study, the concentration of all elements were discussed to know the highest and lowest concentration of elements contamination for every station. It is important to know the possibility of element source comes from and factor that affect the element concentration.

Table 4.1: Comparison between the present study and previous study in mg/g.

Location	Mn	Fe	Al	Zr	Ca	P	Ti	S	Cl	K	Si
Present Study											
Kuala Terengganu River	1.50-2.50	294.00-358.00	128.00-154.00	1.80-3.80	5.60-11.30	4.40-11.10	17.70-24.50	20.80-67.50	14.10-57.10	74.00-98.80	276.00-369.00
Nerus River	1.4-1.8	372.00-390.00	164.00-175.00	2.00-2.50	3.40-5.70	9.40-10.90	19.80-20.80	10.20-28.80	11.10-13.30	73.90-81.70	28.00-29.00
Malaysia studies											
Terengganu River Basin[1]	0.03	0.00	0.01	0.01	0.00	–	0.00	–	–	0.00	–
EEZ of the Coast of Peninsular Malaysia[2]	0.27	75.60	42.30	–	–	–	–	–	–	–	–
Baleh River, Sarawak[3]	0.79	37.82	100.88	–	–	–	–	–	–	–	–
Batang Ai Reservior and Ai River, Sarawak.[4]	0.27	3.39	10.63	–	0.32	–	–	–	–	0.84	–
Sedili Kecil River, Johor[5]	0.19	33.39	17.12	–	–	–	–	–	–	–	–
International studies											
Infernao Lake, in Southern Brazil[6]	129.00	32274.00	66947.00	60.30	371.00	654.00	4342.00	1089.00	88.50	2976.00	91966.00
Rivers of Kosovo[7]	1.34	28.41	14.66	–	36.28	0.58	–	0.47	–	1.65	–
Lima River, Portugal[8]	0.32	28.60	75.20	0.26	2.90	–	3.50	3.90	4.20	27.70	264.00
Wei River, China[9]	0.56	26.50	58.20	0.29	49.90	–	3.69	–	–	19.40	297.30
Minho River, China[10]	0.26	12.00	45.70	–	1.40	–	1.60	–	–	26.80	368.30

Sources: [1]Sultan & Shazili, 2010; [2]Shaari *et al.*, 2015; [3]Sim *et al.*, 2016; [4]Sim *et al.*, 2014; [5]Suhaimi-Othman *et al.*, 2012; [6]Gatti et al., 1999; [7]Gashi *et al.*, 2009; [8]Cardoso *et al.*, 2008; [9]Han *et al.*, 2012; [10]Mil-Homens *et al.*, 2013.

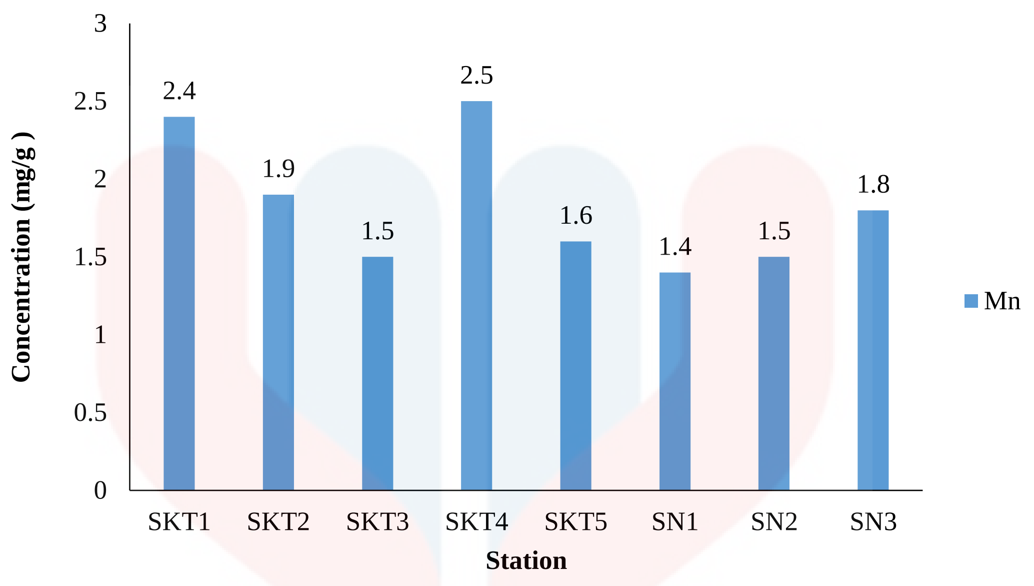

Figure 4.3: Concentration of manganese at all station from Kuala Terengganu and Nerus River.

SKT: Kuala Terengganu River
SN: Nerus River

Figure 4.3 showed the concentration of Mn at each station from Kuala Terengganu and Nerus River. The highest reading for all stations was observed at station SKT4 with value of 2.5 mg/g. Meanwhile the lowest concentration was observed at station SN1 with the reading 1.4 mg/g. The mean concentration of Mn was 1.8 mg/g as shown in Figure 4.1.

The highest concentration of Mn in sediment at SKT4 was associated by the anthropogenic activity nearby such as boat parking at Marina heritage. Besides, the highest concentration of Mn at SKT (2.5 mg/g) and SN (1.8 mg/g) have exceed the reading from previous study at Terengganu River Basin (0.02724 mg/g) that reported by Sultan & Shazili (2010) in Table 4.1.

The Mn concentration at present study is in the range (1.4-2.5 mg/g). The concentration of Mn in sediment was compared with previous study from Malaysia

Study, EEZ of the Coast Peninsular Malaysia (Shaari *et al*., 2015). The result showed that the concentration of Mn from the present study was higher than EEZ of the Coast Peninsular Malaysia. As well as when it compared with other reading showed in Table 4.1 was greater than other Malaysian studies reported by Sim *et al*., (2016), Sim *et al*., (2014), and Suhaimi-Othman *et al*., (2012).

The study was also compared with international study from Infernao Lake in Southern Brazil showed that the concentration of Mn in sediment was lower than the concentration reported by Gatti *et al*., (1999). Nonetheless, the concentration of Mn was greater than other study reported by Gashi *et al*., (2009), Cardoso *et al*., (2008), Han *et al*., (2012) and Mil-Homens *et al*., (2013) in Table 4.1. This showed the present study was contaminated with metal Mn from anthropogenic activity.

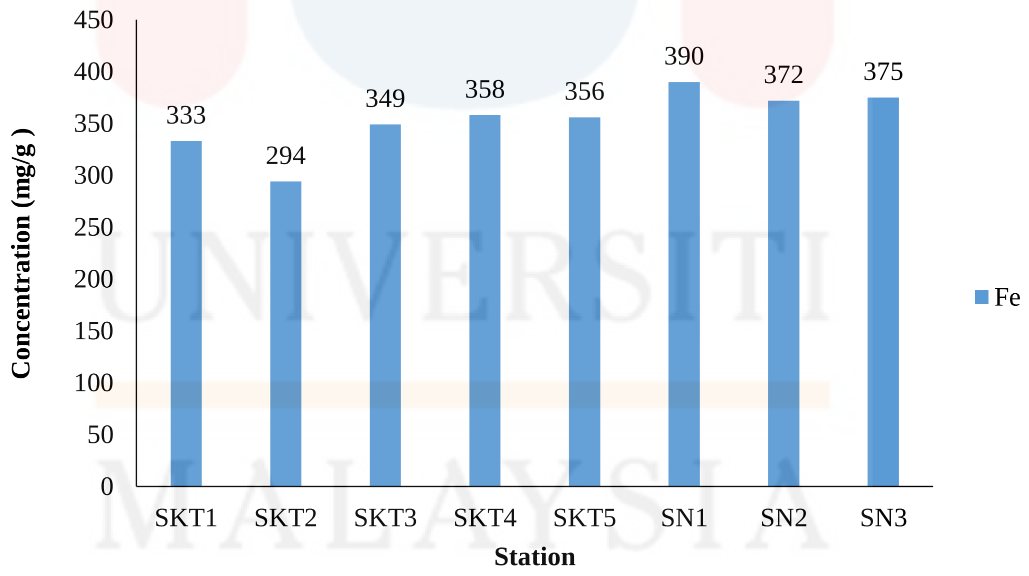

Figure 4.4: Concentration of iron at all station from Kuala Terengganu River and Nerus River.

SKT: Kuala Terengganu River
SN: Nerus River

The concentration of Fe in Figure 4.4 showed the highest concentration reading in sediment was found at station SN1 which is 390 mg/g. In addition, the lowest value of Fe occurred at station SKT2 which is Kuala Terengganu River with the value of 29.4 mg/g. The mean concentration of Fe was 353.4 (mg/g) as shown in Figure 4.1.

The concentration of iron at SKT 4 was influenced by the anthropogenic activity. The source of Fe probably due to boat activity as the sediment taken at station SKT 4 was closed to boat parking at Marina heritage. In addition, according to Sultan & Shazili (2010), the human settlement may also influence the Fe concentration in sediments. In this study, most of the land use along the river were residential house and the waste from the house hold probably contribute to Fe contaminant.

The Fe concentration of recent study in range between (294 -390 mg/g) as shown in Table 4.1. The highest concentration of present study (SKT: 2.5 mg/g and SN: 1.8 mg/g) was compared with the concentration from Terengganu River basin reported by Sultan & Shazili, (2010). It showed the concentration of Fe in sediment wss out of ranges from Terengganu River basin. Afterward, all the previous study from Malaysia studies reported by Suhaimi-Othman *et al*., (2012), Shaari *et al*., (2015), Sim *et al*., (2016) and Sim *et al*., (2014) in Table 4.1 showed the present study contain higher concentration of Fe in sediment. The factor influence the concentration of Fe in sediment was due to anthropogenic activity.

The concentration of Fe in present study is lower than other international study, specifically from Infernao Lake (Gatti *et al*., 1999)). However, other study reported by Cardoso *et al*., (2008), Gashi *et al*., 2009; Han *et al*., (2012) and Mil-Homens *et al*., (2013) showed that the concentration of Fe were lower than the present study. The anthropogenic activities occur at international study were different from the present as well as the origin of the natural source. Those gave different reading from every place.

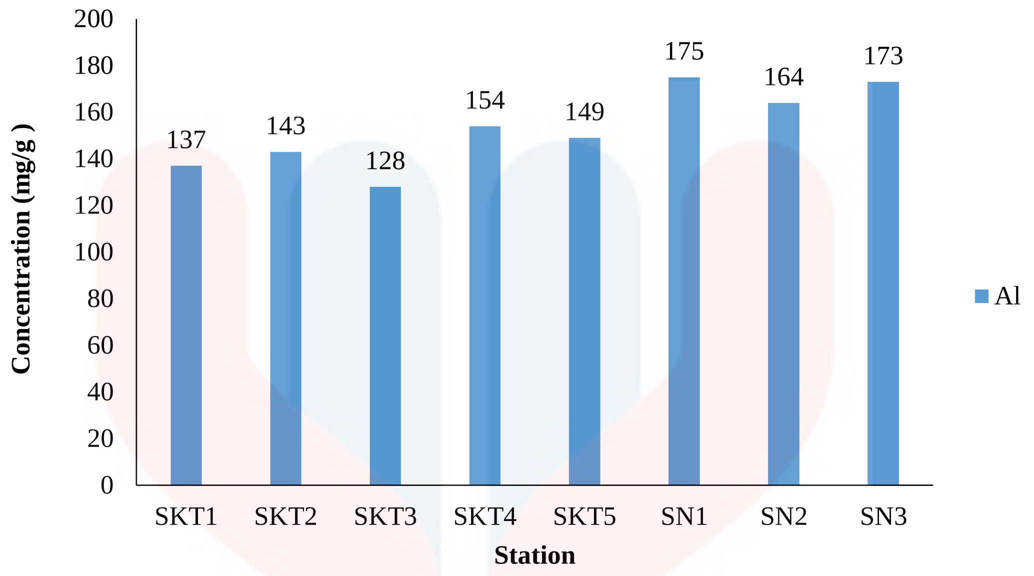

Figure 4.5: Concentration of aluminium at all station from Kuala Terengganu and Nerus River.

SKT: Kuala Terengganu River
SN: Nerus River

Based on Figure 4.5, concentration of Al is higher at station SN1 with the concentration about 175 mg/g respectively which located at Kuala Terengganu River. However, the concentration of SKT3 showed the lowest reading about 128 mg/g which located at the same river. The mean concentration of Al was 152.9 mg/g as shown in Figure 4.1.

Heavy metal of Al may contribute from socio-economic activity such as boat parking near the sampling collection. Also, the present of Al in sediment sample may probably come from natural sources such as from cyolite, bauxite rock and silicate (Krewski *et al.*, 2007). As the main activity along the river was human settlement (Google Earth, 2016), it may affect the present of Al as effluent from residential house.

Formerly, the Al concentration at present study within the range of (128-175 mg/g) as shown in Table 4.1. The regional study from Terengganu River basin, EEZ of the Coast of Peninsular Malaysia, Sedili Kecil River, Baleh River and Ai River have relatively low concentration compare to present study (SKT: 154 mg/g and SN: 175 mg/g) (Sultan & Shazili, 2010; Shaari *et al*., 2015; Sim *et al*., 2016; Sim *et al*., 2014; Suhaimi-Othman *et al*., 2012).

As compare with international studies as shown in Table 4.1, the concentration of Al in sediment at Infernao Lake (66947 mg/g) reported by Gatti *et al*., (1999) was greater than concentration from present study. However, the result from present study was higher than other international study reported by Gatti *et al*., (1999), Gashi *et al*., (2009), Cardoso *et al*., (2008), Han *et al*., (2012) and Mil-Homens *et al*., (2013).

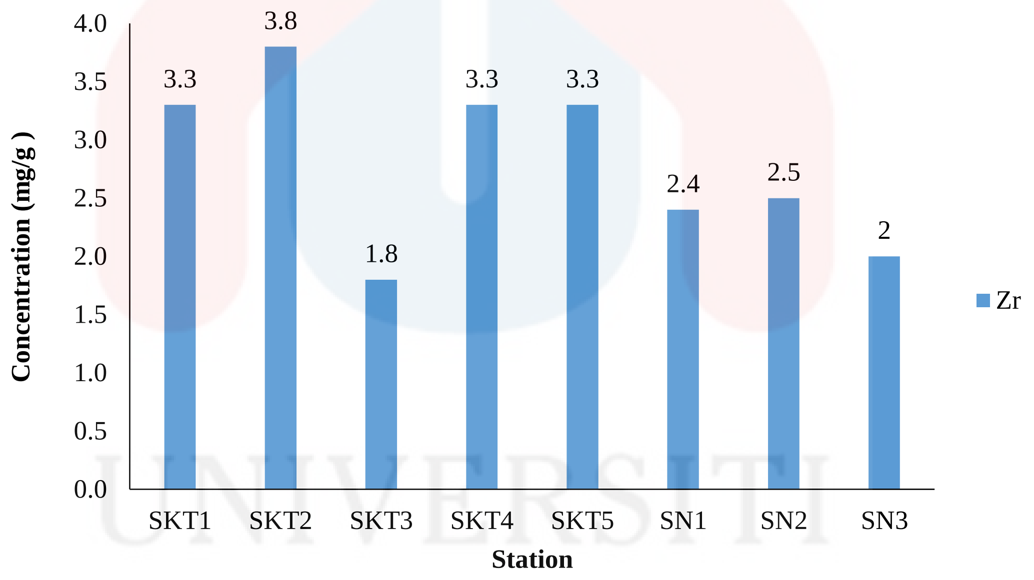

Figure 4.6: Concentration of zirconium at all station from Kuala Terengganu and Nerus River.

SKT: Kuala Terengganu River
SN: Nerus River

Based on Figure 4.6, the concentration of zirconium in sediment was higher at station SKT2 which was from Kuala Terengganu River with the value of 3.8 mg/g. The lowest concentration observed at station SKT3 which is next to station SKT2 at

Kuala Terengganu River with value of 1.8 µg/g. The mean concentration of zirconium was 2.8 mg/g as shown in Figure 4.1.

The present study showed that at station SKT2, there were mangrove swamp suggested to be the contributor of trace metals for Zr in the sediment. This showed the trace metal Zr may be originated from natural sources. The fine grain sediment that contained silicates exhibited the concentration of Zr in sediment at all station (Ayari *et al*., 2016; Dominika, 2016). However, there was possibility for anthropogenic activity from residential areas in introducing Zr element in the sediment sample. The product that contain Zr include antiperspirant and deodorant.

The concentration of Zr in sediment at present study was within the range of (1.8-2.5 mg/g). Only Terengganu River Basin showed the data concentration about Zr (Sultan & Shazili, 2010) as shown in Table 4.1. The concentration of Zr at present study (SKT: 3.8 mg/g and SN: 2.5 mg/g) was higher than Terengganu River Basin. The diverse anthropogenic activity at the present study has increased the trace metal Zr availability in the sediment.

For comparison with other international countries, the concentration of Zr at Infernao Lake is higher than the present study at both river as shown in Table 4.1. Even though the study of trace metals element Zr is numerous, however the selected international study respectively from Kosovo River (Gashi *et al*., 2009), Lima River (Cardoso *et al*., 2008), and Wei River (Han *et al*., 2012) showed the concentration of Zr was lower than present study. The contamination of element Zr may come from residential area along the river plus with the boat activity.

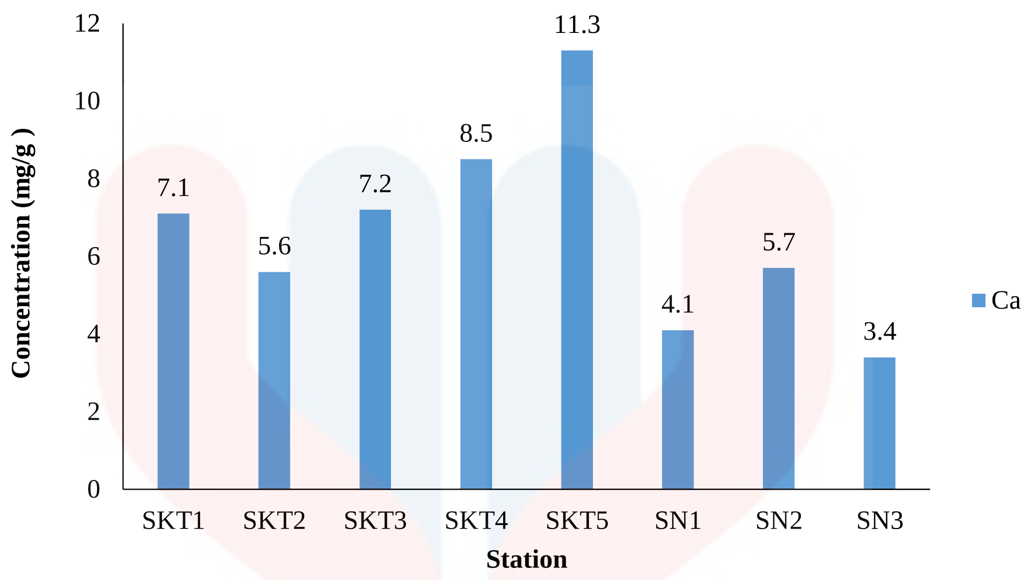

Figure 4.7: Concentration of calcium at all station from Kuala Terengganu and Nerus River.

SKT: Kuala Terengganu River
SN: Nerus River

The concentration of Ca shown in Figure 4.7 indicate the higher concentration occurred at station SKT5 was 11.3 mg/g located at Kuala Terengganu River. In the meantime, the lowest concentration of Ca occurred at station SN3 with the value of 3.4 mg/g which located at Nerus River. The mean concentration of trace metals in sediment was 6.6 mg/g as shown in Figure 4.1.

The result of the present study showed the lowest concentration of Ca probably originated from natural sources in the sediment. The higher Ca concentration most likely transported by the weathering and current river generated by anthropogenic activity. The possibility of Ca present in sediment may come from cleaning activity and effluent from residential house.

Next, the concentration of Ca in sediment at present study was within the range of (3.4 – 11.3 mg/g) as shown in Table 4.1. In the selected regional study, only Terengganu River basin and Air River reported by Sultan and Shazili (2010) and Sim *et al*., (2014) present the concentration of Ca. The concentration of both previous study was lower than present study (SKT: 11.3 mg/g and SN: 5.7 mg/g). The origin source of Ca may come from natural resource.

There were contradiction between the concentrations of Ca in sediment from international study. All of the selected international study reported contain Ca concentration more than present study which from Infero Lake, Kosovo River, and Wei River (Gatti *et al*., 1999; Gashi *et al*., 2009;; Han *et al*., 2012). The different can be observed from Minho River and Lima River (Mil-Homens *et al*., 2013; Cardoso *et al*., 2008) where the concentration of Ca was lower than the recent study.

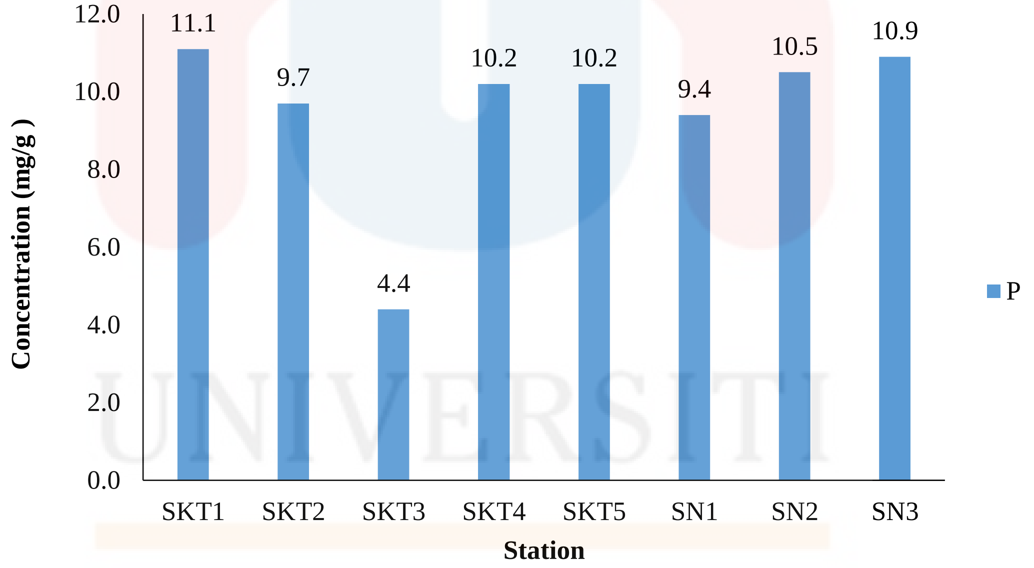

Figure 4.8: Concentration of phosphorus at all station from Kuala Terengganu and Nerus River.

SKT: Kuala Terengganu River
SN: Nerus River

From Figure 4.8, the result showed the highest concentration of trace metal P was 11.1 mg/g at station SKT1 from Kuala Terengganu River. Meanwhile, 4.4 mg/g indicate the lowest concentration of P in sediment sample at station SKT3. The mean concentration of P was 9.6 mg/g as shown in Figure 4.1.

The amount of trace metals P was higher at SKT 1 maybe because it come from natural resources as the sample was taken nearby the bushes. The availability of P in sediment may also come from anthropogenic activity such as surface run off from agricultural land use. Moreover, there were catfish and tilapia farm at Kuala Terengganu and Nerus River implies important susceptibility the source of P probably inherent from this activity (Lio-Po *et al*., 2014)

The P concentration in sediment at recent study indicates the range was within (4.4 – 11.1 mg/g) as shown in Table 4.1. There were no result about concentration P in selected Malaysia study. Therefore, concentrations of P were compared with international study. The concentration of present study (SKT: 11.0 mg/g and SN: 10.9 mg/g) was lower than Infernao Lake (Gatti *et al*., 1999) but higher than Kosovo River (Gashi *et al*., 2009). Other international study did not have the result for concentration P. For the reason, the result still in the range.

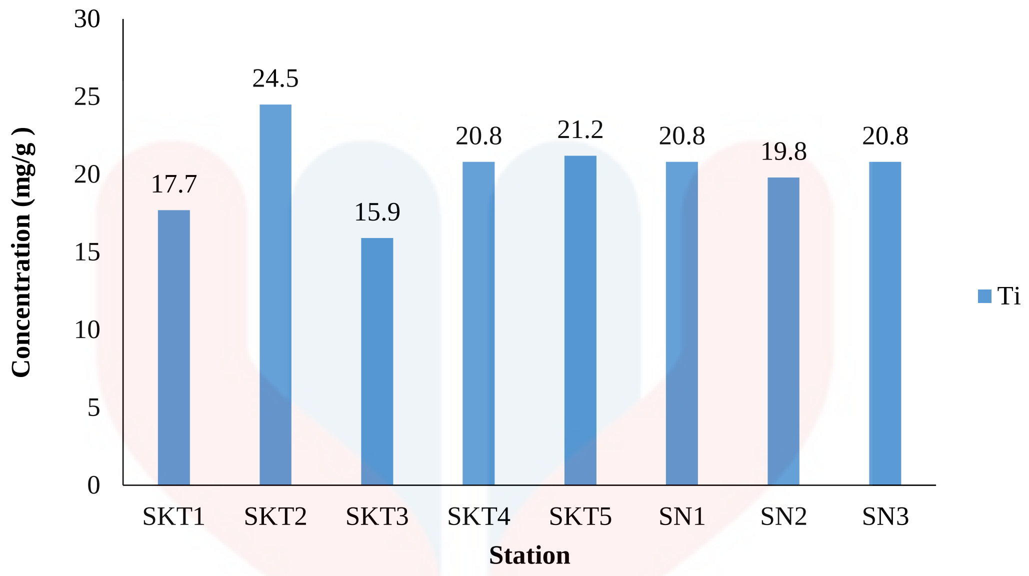

Figure 4.9: Concentration of Titanium at all station from Kuala Terengganu and Nerus River.

SKT: Kuala Terengganu River
SN: Nerus River

The result shown in Figure 4.9 indicate the highest trace metals Ti was 24.5 mg/g at station SKT2 represent the Kuala Terengganu River. As the lowest concentration of Ti was 15.9 mg/g at station SKT 3 next to SKT 2. The mean concentration of metals of trace metals Ti was 20.2 mg/g as shown in Figure 4.1.

The concentration of Ti in sediment sample is higher at SKT2 because of anthropogenic activity occur at the station. Activity such as residential waste may contribute the Ti availability in the sediment. Trace element Ti may also come from geogenic activity as the sediment sample collection was near to mangrove swamp.

As for Ti, the range concentration from recent study was within (17.7 – 24.5 mg/g). The concentration of present study for Kuala Terengganu and Nerus River (24.5 mg/g and 20.8 mg/g) were greater than Terengganu River (Sultan & Shazili, 2010). Other regional study do not analysed the present of Ti in sediment as shown in Table

4.1. The Kuala Terengganu and Nerus River maybe contaminated from boat activity and residential waste.

The international study from Infernao Lake contain higher concentration of Ti than recent study at Kuala Terengganu and Nerus River as shown in Table 4.1(Gatti *et al*., 1999). The other international study reported by Cardoso *et al*., (2008), Han *et al*., (2012) and Mil-Homens *et al*., (2013) have lower concentration than present study.

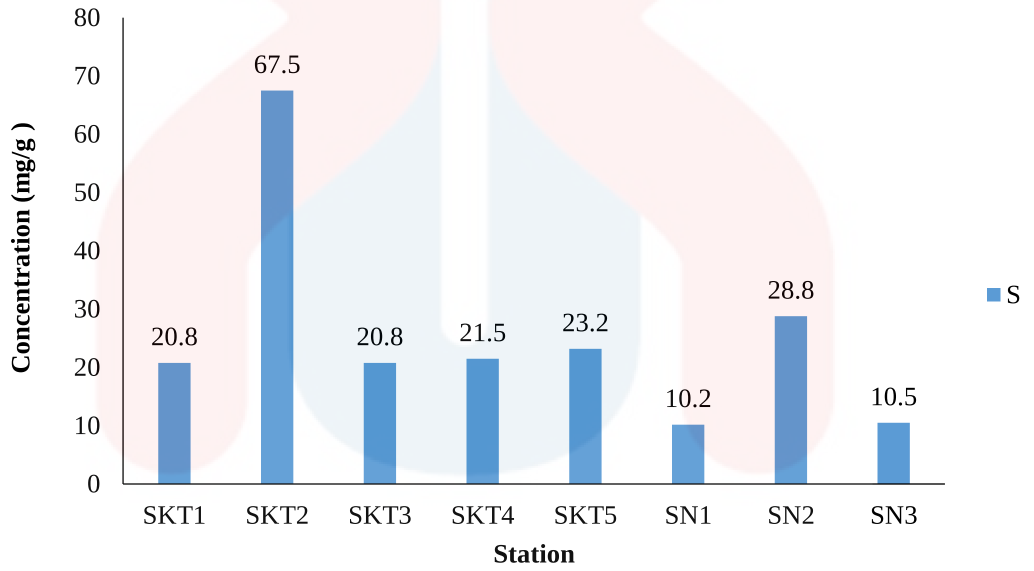

Figure 4.10: Concentration of sulphur at all station from Kuala Terengganu and Nerus River.

SKT: Kuala Terengganu River
SN: Nerus River

As shown in Figure 4.10, the highest concentration of element S located at station SKT2 which is 67.5 mg/g from Kuala Terengganu River. Then, station SN 1 indicate the lowest concentration of S at Nerus River with the value of 10.2 mg/g. The mean concentration of S was 25.4 mg/g as shown in Figure 4.1. There was huge different between concentration of S at station SKT2 with the other station.

The concentration of trace metal S may come from anthropogenic activity at station SKT 2 which influence by massive residential area. The source from residential waste such as textile, pesticide and medicines. Down the river, the catfish farm may inherent the source of S. The other point of view may come from natural resource as the sample taken near by the mangrove swamp. The surface run off also probably contributed the contaminant of S.

Consequently, the concentration S in sediment at present study was within the range of (10.2 – 67.5 mg/g). There was no selected regional study that can be compared with current study. In this case, the concentration of S were compared with international study so that it can be comparable. The concentration of S at Lima River and Kosovo River indicate the concentration from present study (SKT: 67.5 mg/g and SN: 28.8 mg/g) was higher than Lima River (Cardoso *et al*., 2008; Gashi *et al*., 2009). The contradiction can be observed where the concentration of present study was lower than Infernao Lake (Gatti *et al*., 1999). The source of contaminant may come from agriculture and surface run off.

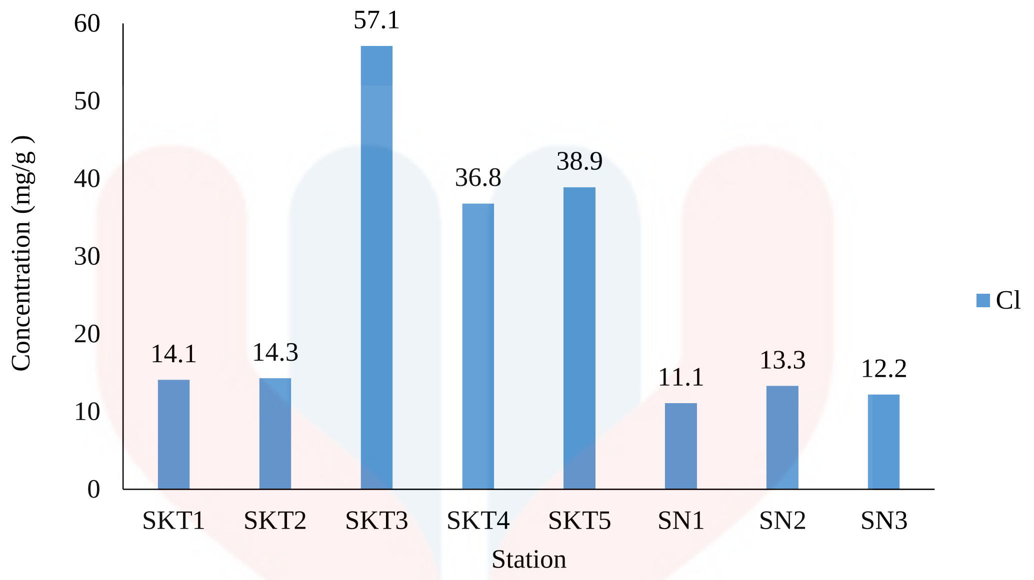

Figure 4.11: Concentration of chlorine at all station from Kuala Terengganu and Nerus River.

SKT: Kuala Terengganu River
SN: Nerus River

The trace metal concentration of Cl based on Figure 4.11 showed that the highest concentration reveal at station SKT3 which was 57.1 mg/g from Kuala Terengganu River. Then, the lowest concentration of trace metal Cl can be observed at station SN1 which was 11.1 mg/g from Nerus River. The mean concentration for trace metals chlorine was 24.7 mg/g as shown in Figure 4.1.

The source of trace metal Cl may come from point source of residential area through residential waste such as washing and bleach. Other than that, the sample collection was near to road bridge where typically make river as disposable site. The availability of Cl in sediment at SKT3 was come from anthropogenic activity.

The concentration of Cl at present study was within the range of (11.1 – 57.1 mg/g). There was no data that can be compared with regional study. The data were compared with international study from Infernao Lake and Kosovo River as shown in Table 4.1. The concentration of present study (SKT: 57.1 and SN: 13.3) was lower than concentration from Infernao Lake (Gatti *et al.*, 1999). In circumstances, the concentration of Ca from Lima River was lower than the concentration of Cl in sediment at present study both at Kuala Terengganu and Nerus River (Cardosa *et al.*, 2008).

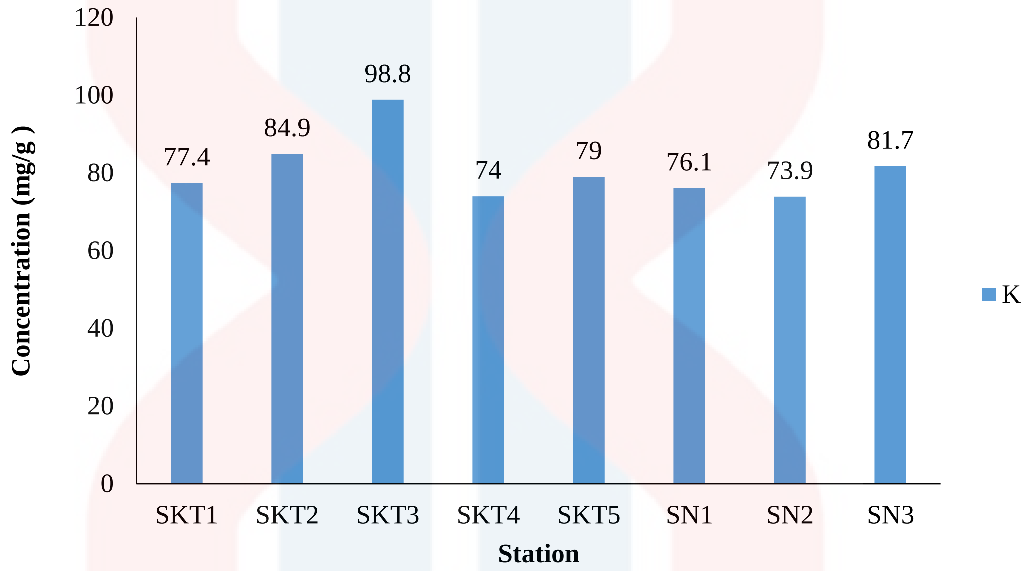

Figure 4.12: Concentration of potassium at all station from Kuala Terengganu and Nerus River.

SKT: Kuala Terengganu River
SN: Nerus River

Figure 4.12 represent the concentration of K at Kuala Terengganu and Nerus River. The highest concentration of K observed at SKT3 with the value of 98.8 mg/g from Kuala Terengganu River. Meanwhile the lowest concentration occur at station SKT 4 with the value of 74 mg/g. The mean concentration of trace metals K was 80.7 mg/g as shown in Figure 4.1

The point source of pollution may come from residential area which located along the station SKT 2 and SKT 3. Other than that, it may come from natural sources such as composition of organic material from mangrove swamp. Additionally, road bridge also play a role in introducing the K to the sediment.

Next, the concentration of K in sediment at Kuala Terengganu and Nerus River was within the range of (73.9 – 98.8 mg/g). The regional study which was Terenganu River Basin and Ai River showed that the concentration of K in present study (SKT: 98.8 mg/g ang SN: 81.7 mg/g) was higher than previous regional study reported by Sultan & Shazili (2010) and Sim *et al.*, (2014). In compare with international study, the concentration of K in present study was higher rather than concentration of K at Kosovo River, Lima River, Wei River and Minho River (Gashi *et al.*, 2009; Cardoso *et al.*, 2008; Han *et al.*, 2012 and Mil-Homens *et al.*, 2013). Otherwise, it was lower than Infernao Lake, Kosovo Rivers (Gatti *et al.*, 1999).

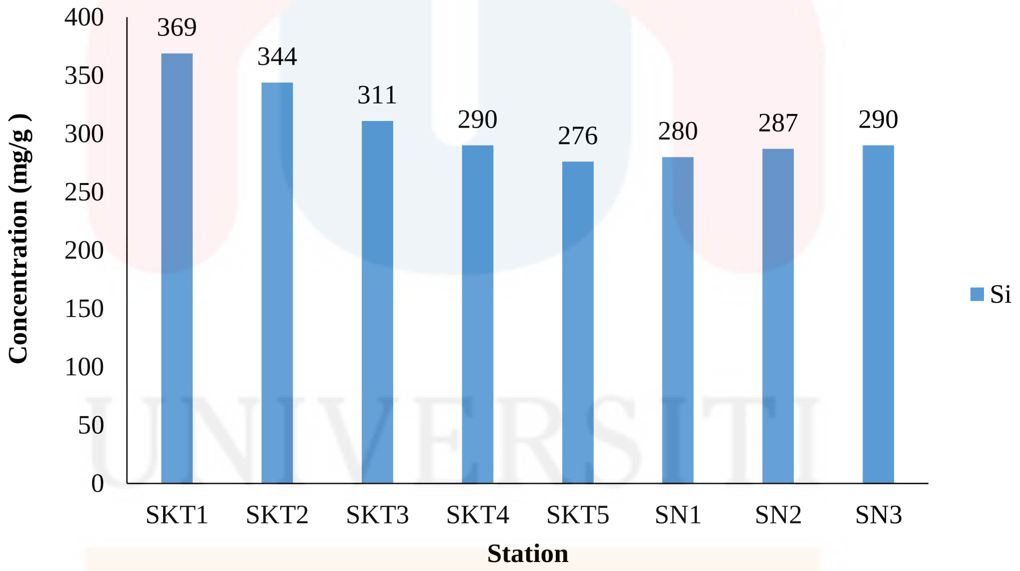

Figure 4.13: Concentration of silicon at all station from Kuala Terengganu and Nerus River.

SKT: Kuala Terengganu River
SN: Nerus River

The present study about Si showed in Figure 4.13 explained the highest concentration occur at station SKT1 about 369 mg/g. For the present, the lowest concentration of trace metals Si located at station SKT5 about 276 mg/g. The mean concentration of Si was 305.9 mg/g as shown in Figure 4.1.

The sample collection at station SKT 1 was nearby to bushes. The anthropogenic activity probably contribute to the present of Si was from residential area. This is because along the river, there was a lot of residential area which may produce waste directly to the river. Urbanization

Lastly, the concentration of Si in Kuala Terengganu and Nerus River were in range within (28 – 369 mg/g). There was no data found about Si concentration at regional study. The comparison was made between present study and international study. The present study (SKT: 369.0 mg/g and SN: 29.0 mg/g) has lower concentration compared to Infernao Lake (Gatti *et al*., 1999) but higher than Lima River, Wei River and Minho River (Cardoso *et al*., 2008; Han *et al*., 2012 and Mil-Homens *et al*., 2013). The anthropogenic activity has contributed to the contamination of Si at present study.

4.2 Enrichment factor (EF)

In order to assess the anthropogenic sources of an area, the parameter such as enrichment factor (EF) can be used to identify the contamination level. Table 4.3 represent the EF value for all stations at Kuala Terengganu and Nerus River and the contamination level is shown in Figure 4.14.

The highest EF value at all stations from Kuala Terengganu and Nerus River was trace metal Cl as shown in Figure 4.14. The range of EF value was higher than 3 except at station SN1 and SN3. The highest Cl reading was recorded at SKT3 with the EF value 14.97 as shown in Table 4.3. Likewise, SKT4 and SKT5 has approximately similar EF value which is 9.41 and 10.00. The station of SKT3, SKT4 and SKT5 has been classified within $5 < EF > 10$ indicate it was considerable moderate severe enrichment. While the concentration of Cl at station SKT1, SKT2 and SN2 was categorized within $3 < EF < 5$ as shown in Figure 4.14. The stations were classified as moderate enrichment. Despite of that, station SKT1 showed the EF value was 2.60 and it has been classified within $1 < EF < 3$. The degree of contaminant was minor enrichment. Therefore, there is evidence that the source of S at Kuala Terengganu and Nerus River from anthropogenic activity.

Table 4.3 represent the highest EF value for trace metal S occur at station SKT2 (14.23). The enrichment of SKT2 was categorized within the range $5 < EF > 10$. It showed the enrichment was moderate severe enrichment. For the meantime, EF value for all station except station at SKT2, SN1 and SN3, the enrichment values have been categorized within $3 < EF < 5$ showed moderate enrichment. While station SN1 and SN3 showed the EF value within the range $1 < EF < 3$ showed minor enrichment. Hence, the contaminant of S may come from anthropogenic activity especially for station SKT2. The sample sediment was contaminated by anthropogenic activity such as boat activity, residential waste and surface run off.

For Zr, all station showed there was minor enrichment happen as represent in Table 4.3. The higher EF value occur at SKT 2 (2.75) and the lowest at SN3. The EF value was classified within 1< EF < 3 as shown in Figure 4.14. The enrichment represent Kuala Terengganu and Nerus River have minor enrichment from trace metal Zr. The source of Zr may come from effluent from residential area.

The data showed that most of element Cl, S, and Zr were found at the station due to anthropogenic activity occur at the station or before the station which in turn contribute to the enrichment. The activity such as boat parking, residential waste and agriculture probably the major contributor for the element to accumulate in sediment.

Other element such as Mn, Fe, Al, Ca, P, Ti, K, and Si are below the EF value 1 indicate the degree of contaminant is no enrichment. These elements may come from natural resources and bedrock sediment.

Table 4.3: Enrichment value for Kuala Terengganu and Nerus River.

Element	EF Value							
	SKT1	SKT2	SKT3	SKT4	SKT5	SN1	SN2	SN3
Mn	0.43	0.39	0.26	0.42	0.27	0.22	0.24	0.28
Fe	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Al	0.22	0.26	0.20	0.23	0.23	0.24	0.24	0.25
Zr	2.11	2.75	1.10	1.96	1.97	1.29	1.41	1.11
Ca	0.02	0.02	0.02	0.03	0.04	0.01	0.02	0.01
P	1.90	1.88	0.72	1.63	1.64	1.37	1.61	1.66
Ti	0.57	0.90	0.49	0.63	0.64	0.57	0.57	0.60
S	3.87	14.23	3.69	3.72	4.04	1.62	4.80	1.74
Cl	3.88	4.45	14.97	9.41	10.00	2.60	3.27	2.98
K	0.47	0.58	0.57	0.42	0.45	0.39	0.40	0.44
Si	0.17	0.18	0.13	0.81	0.12	0.11	0.12	0.12

SKT: Station at Kuala Terengganu River
SN: Station at Nerus River

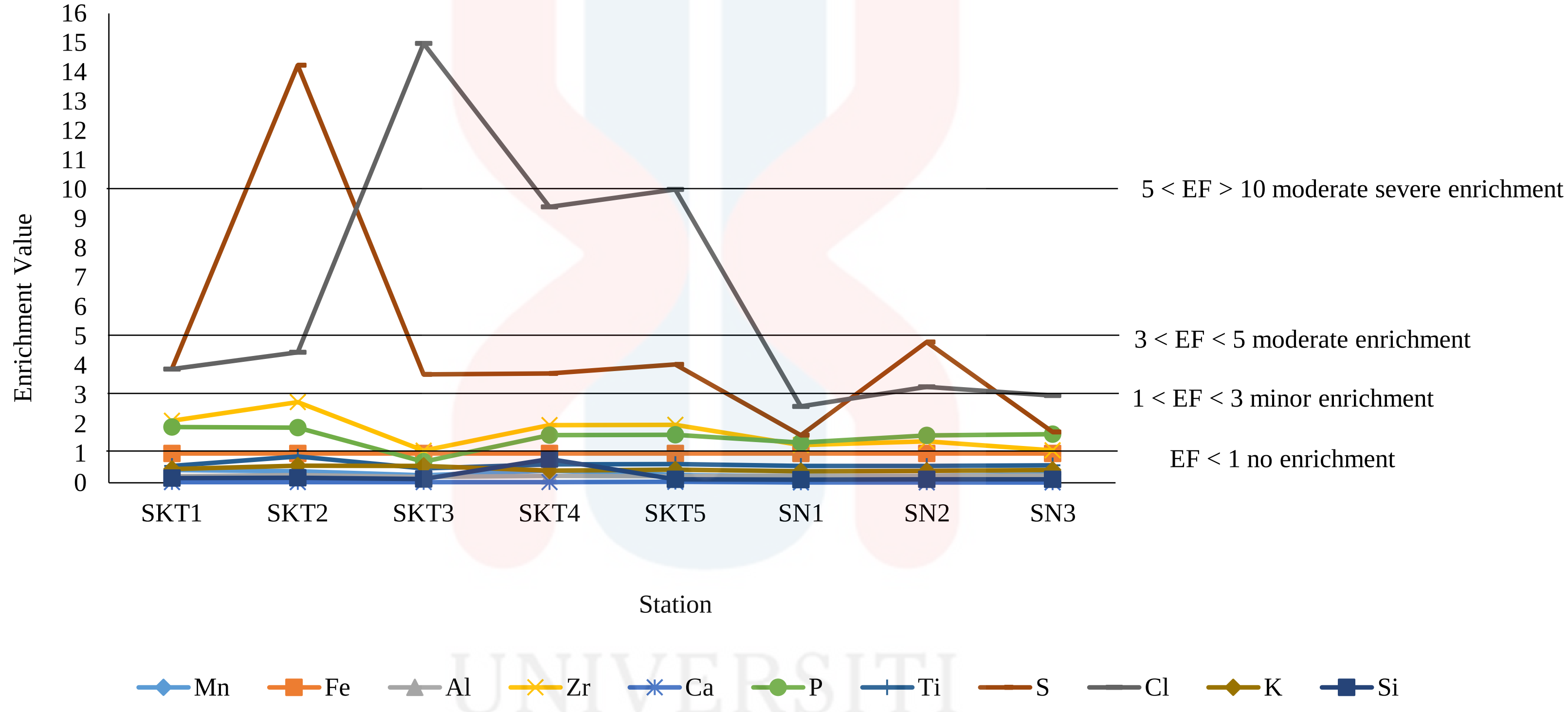

Figure 4.14: The enrichment factor value for all elements in sediment at Kuala Terengganu and Nerus River.

4.3 Geoaccumulation index (Igeo)

Geoaccumulation index (Igeo) was one of the parameter used to estimate the degree of contaminant in sediment. Abdullah *et al*., (2015) reported the current study can be compared with control level. The measured Igeo value were compared with Igeo class value shown in Table 4.4 and the class of pollution shown in Figure 4.4.

Element Cl showed the Igeo value was extreamly polluted (Igeo class 6) at station SKT3, SKT4 and SKT5 which located at Kuala Terengganu River. Besides, the Igeo value from strongly polluted to extreamly polluted (Igeo class 5) occur at station SKT1, SKT2, SN2 and SN3. Whereas at SN1, the Igeo value showed strongly polluted. Hence, Kuala Terengganu and Nerus River were polluted with Cl contaminant.

Element S showed the Igeo class value was 6 at SKT2. This indicated the degree of pollution was extreamly polluted. Besides, station at SKT1, SKT3, SKT4, SKT5, SN2 and SN3 showed the Igeo value were from strongly polluted to extreamly polluted. Whereas, at station SN1, the Igeo value showed Kuala Terengganu and Nerus River have strongly polluted by trace metal S contaminant and it happen at all station.

For Zr element, four station have been polluted, namely SKT1, SKT2, SKT4, and SKT5 with Igeo class value stated strongly polluted (Igeo class 4) as shown in Figure 4.15. Moreover, station at SKT3, SN1, SN2 and SN3 showed the Igeo value were from moderately polluted to strongly polluted (Igeo class 3). Henceforth, Kuala Terengganu and Nerus River have been polluted by Zr contaminant.

Element P represent in Table 4.4 showed the Igeo class value (Igeo class 4) at all station was strongly polluted at SKT1, SKT4 and SKT5 as shown in Figure 4.15. Despite, the degree of contaminant P can be observed at SKT2, SN1, SN2 and SN3 whereby the Igeo class value were from moderately polluted to strongly polluted. The station at SKT3 showed moderately polluted. The data point out that Kuala Terengganu and Nerus River have been polluted with P contaminant.

By means of referring Figure 4.15, all station were polluted with Fe contaminant from moderately polluted to strongly pollute. However, at station SKT5, the Igeo class value was moderately polluted. Similar to element K and Ti, the Igeo class value were moderately polluted at all station. In spite of that, Mn showed moderately polluted at station SKT1 and SKT4. The Al element was categorized from unpolluted to moderately polluted at all station. Under this circumstances, Kuala Terengganu and Nerus River were polluted by Fe, Al, K, Ti and Mn contaminant. Only Si and Ca found not class as polluted contaminant where originated from natural resource.

Based on the Table 4.4 and Figure 4.15, the source of trace metals contaminant in sediment undoubtedly from anthropogenic activity. For instance, the contaminant of Cl, S, Zr, P, Fe, Al, K, Ti and Mn entered the river from mining area, agricultural runoff, boat activity residue, domiciliary waste water had deposited and remain on surface sediment. In consequence, the trace metals that have availability to accumulate in particulate sediment may contribute to pollution for benthic life and consecutively gave adverse effect in human consumption.

Table 4.4: Igeo value in all points of Kuala Terengganu and Nerus River.

Element	Measured Igeo value								I geo class value							
	SKT1	SKT2	SKT3	SKT4	SKT5	SN1	SN2	SN3	SKT1	SKT2	SKT3	SKT4	SKT5	SN1	SN2	SN3
Mn	1.16	0.81	0.47	1.21	0.56	0.37	0.47	0.74	2	1	1	2	1	1	1	1
Fe	2.36	2.18	2.43	2.46	1.20	2.59	2.52	2.53	3	3	3	3	2	3	3	3
Al	0.20	0.26	0.10	0.37	0.32	0.55	0.46	0.53	1	1	1	1	1	1	1	1
Zr	3.45	3.66	2.58	3.46	3.45	3.00	3.00	2.73	4	4	3	4	4	3	3	3
Ca	-3.02	-3.37	-3.00	-2.76	-2.35	-3.82	-3.34	-4.09	0	0	0	0	0	0	0	0
P	3.28	3.08	1.95	3.16	3.16	3.04	3.20	3.26	4	3	2	4	4	3	3	3
Ti	1.56	2.03	1.40	1.79	1.82	1.79	1.72	1.79	2	2	2	2	2	2	2	2
S	4.31	6.00	4.31	4.35	4.47	3.28	4.78	3.32	5	6	5	5	5	4	5	5
Cl	4.32	4.34	6.34	5.70	5.79	3.98	4.24	4.11	5	5	6	6	6	4	5	5
K	1.27	1.40	1.62	1.20	1.30	1.24	1.20	1.34	2	2	2	2	2	2	2	2
Si	-0.23	-0.33	-0.47	-0.57	-0.65	-0.63	-0.59	-0.57	0	0	0	0	0	0	0	0

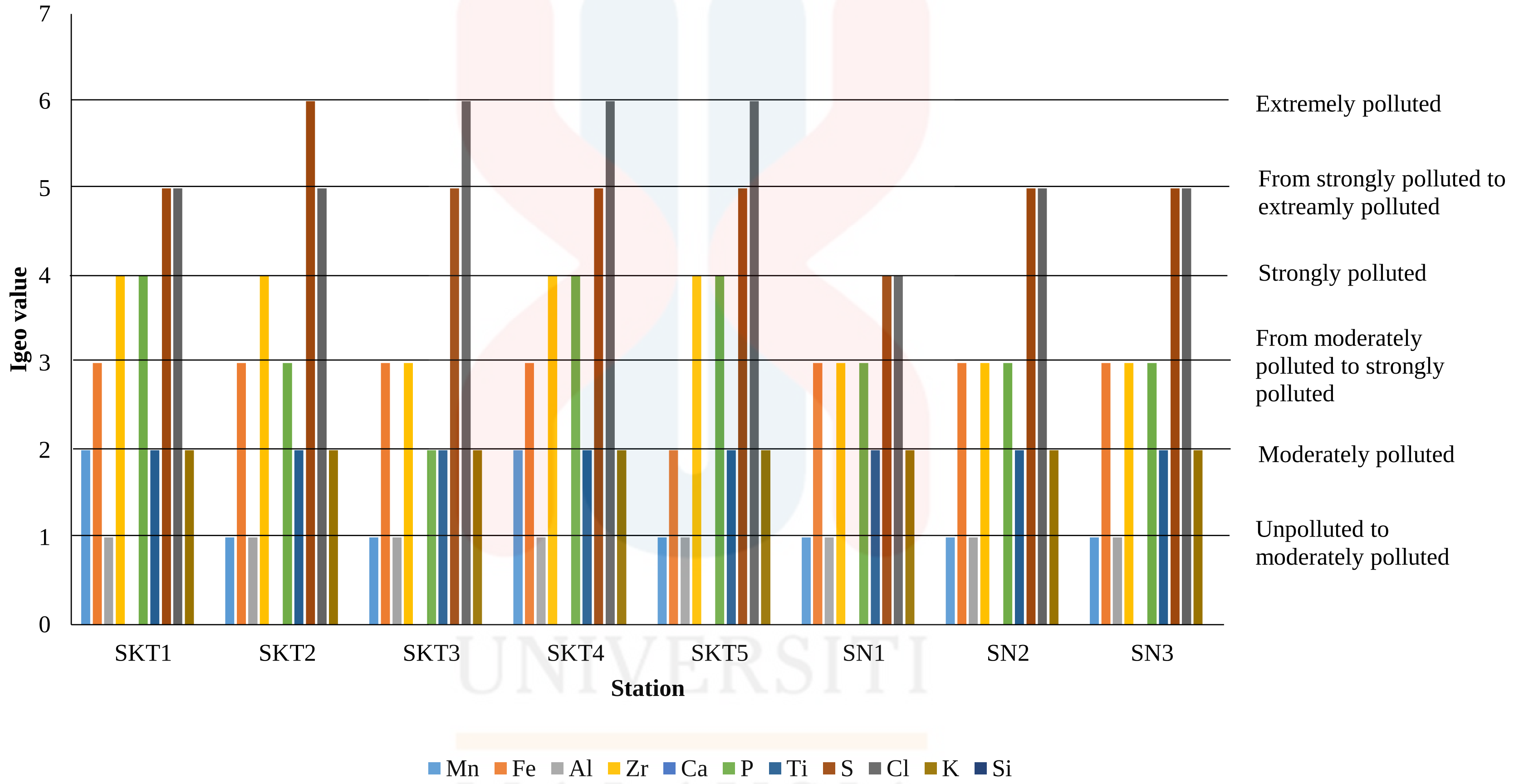

Figure 4.15: Igeo value of all elements in Kuala Terengganu and Nerus River.

4.4 Polution Load Index (PLI)

In order to identify contamination in sediment, pollution load index (PLI) can be used to assess the site quality in simple way (Salah, 2012). The sediment qualification was determine shown in Figure 4.16.

The element Cl showed the highest PLI value at Kuala Terengganu and Nerus River. Formost, the PLI value at Kuala Terengganu River is higher than Nerus River about 7.668 and 2.65 respectively. Therefore the pollution load index for element Cl contaminant is $PLI \geq 1$. The sediment qualification indicate an immediate intervention to ameliorate pollution.

Based on element S, the highest PLI value also at Kuala Terengganu River about 6.223 and 2.488 at Nerus River. Those, the pollution lod index for element K was found $PLI \geq 1$. Therefore, an immediate intervention to ameliorate pollution is needed. In the midst of all trace element in this study, element Ca was under the range of PLI value ($PLI < 1$). This indicate Kuala Terengganu and Nerus River did not polluted by Ca contaminant. The source of Ca originated from natural source or shell.

The PLI value for the trace elements Cl, S, Zr, P, Fe, Ti, K, Mn, and Al proved the sediment at Kuala Terengganu and Nerus River were polluted and originate from massive anthropogenic activity along the river. The other element such as Ca and Si denote the perfection of sediment qualification as the pollution load index was less than 1. Surprisingly, the Si element have approximately PLI = 1 indicate the pollution at sediment is at baseline level.

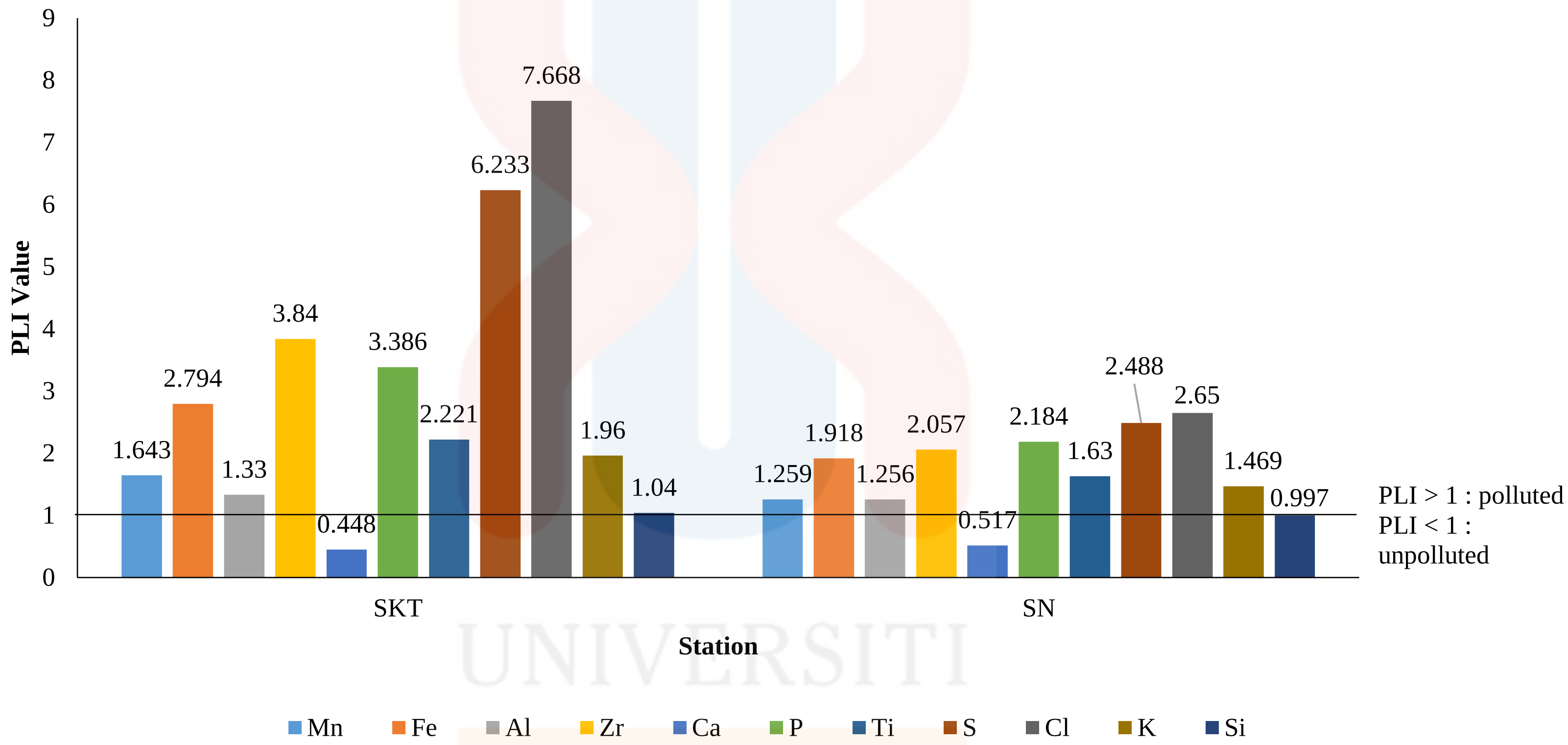

Figure 4.16: PLI value in sediment for Kuala Terengganu and Nerus River

4.5 Statistical Analysis

In this study, the Kruskal Wallis test was used to identify the significant of element at each river. Based on Table 4.5a and 4.5b, there were significant difference for all elements at Kuala Terengganu and Nerus River since the $P < 0.05$.

Table 4.5: The statistical analysis for a)Kuala Terenggnu and b)Nerus River using Kruskal Wallis Test. (N = 3,5)

a) Kuala Terengganu River

Test Statistics[a,b]

	Concentration
Chi-Square	52.156
df	10
Asymp. Sig.	.000

a. Kruskal Wallis Test

b. Grouping Variable: Element

b) Nerus River

Test Statistics[a,b]

	Concentration
Chi-Square	31.103
df	10
Asymp. Sig.	.001

a. Kruskal Wallis Test

b. Grouping Variable: Element

This statistical analysis proved Kuala Terengganu and Nerus River were approximately affected with heavy metals and trace metals. The highest pollutant was Cl as mentioned in enrichment factor (EF) and geoaccumulation index (Igeo). The EF for Kuala Terengganu and Nerus River showed the moderate severe enrichment was trace metals Cl as shown in Figure 4.14. The source of Cl contaminant probably originated from anthropogenic activities such as residential waste, boat activity and road bridge.

The next evidence was geoaccumulation index (Igeo) showed the degree of pollution for trace metal Cl was categorized as extreamly polluted as shown in Figure 4.15. Furthermore, Figure 4.16 represent the pollution load index (PLI) for trace metal

Cl was more than 7 indicate the Kuala Terengganu and Nerus River were polluted by trace metal Cl. The other heavy metals (Mn, Fe, Al) and trace metals (Zr, P, Ti, S, Cl, K) showed the same sign of pollution. This implies meaningful proven that sediments of Kuala Terengganu and Nerus River had been effected by these elements.

However, there were two elements classify as unpolluted as mentioned in EF and Igeo. The elements were Ca and Si, indicated even there is significant different of all element towards the sediment in the river, the elements of Ca and Si did not effect the sediment widely. Although the mean concentration of Si placed in second highest, but it was still under the level of pollution. Same goes to Si and it was just slightly polluted at Kuala Terengganu River as been mentioned in PLI (Figure 4.16).

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The mean concentration of metals in sediment from Kuala Terengganu and Nerus River are between 1.8-305.9 mg/g. The external factor influence the sediment morphology in the river as well as the pollution introduced by human to the river. The pollution source known as non-point source and point source play vital role in determining the element distribution in the sediment at Kuala Terengganu and Nerus River.

The highest pollutant contaminated the sediment at Kuala Terengganu and Nerus River were Cl followed by S > Zr > P > Fe > Ti > K > Mn > Al > Si > Ca. The source of pollution may come from socio-economic activity have been identified probably introduced by effeluent from residential area, catfish farm, boat activity and mining area. The natural run off from agriculture and road bridge under no circumtances entered the river and brought the pollution which in turn deposited and accumulate on surface sediment.

Therefore, there is a need to identify the degree of contaminant on surface sediment as it represent the pollution of the river. The quantitative indexes such as enrichment factor, geoaccumulation index and pollution load index able to assess the degree of contaminant on the surface sediment. Base on this parameter it concluded that Kuala Terengganu and Nerus River have been polluted with all elements except

Ca and Si . This source suggested comes from anthropogenic activity along the river as the sediment morphology depend on the tide of the river.

The statistical analysis showed there were significant different for Kuala Terengganu and Nerus River. The data from Kruskal Wallis test proved the rivers were contaminated with metals Cl, S, P, ,Zr, Fe, Al, K, Mn, Ti . The trace metals Ca and Si proved comes from natural sources. Thus the selected metals in the sediments had been identified along with the assessment of sediments.

5.2 Recommendation

The recommendation that can be done for further study from this thesis were assessment of water quality, increase the sample size and identify the metals in benthic organism. The reason is sediment stored 99% of pollutant deposited whereas only 1% dissolved in water (Saleem *et al*., 2015). Increasing sample size can gain data more accurate.

In addition, other further study can be done were dating of sediment core. By doing the dating, the time for the contaminat deposited can be identify as well knowing the source of pollutant origin. The total organic carbon (TOC) analysis can also be made. Apart from that, the study of metals in sediment can be assess by comparing the concentration between the dry season and wet season.

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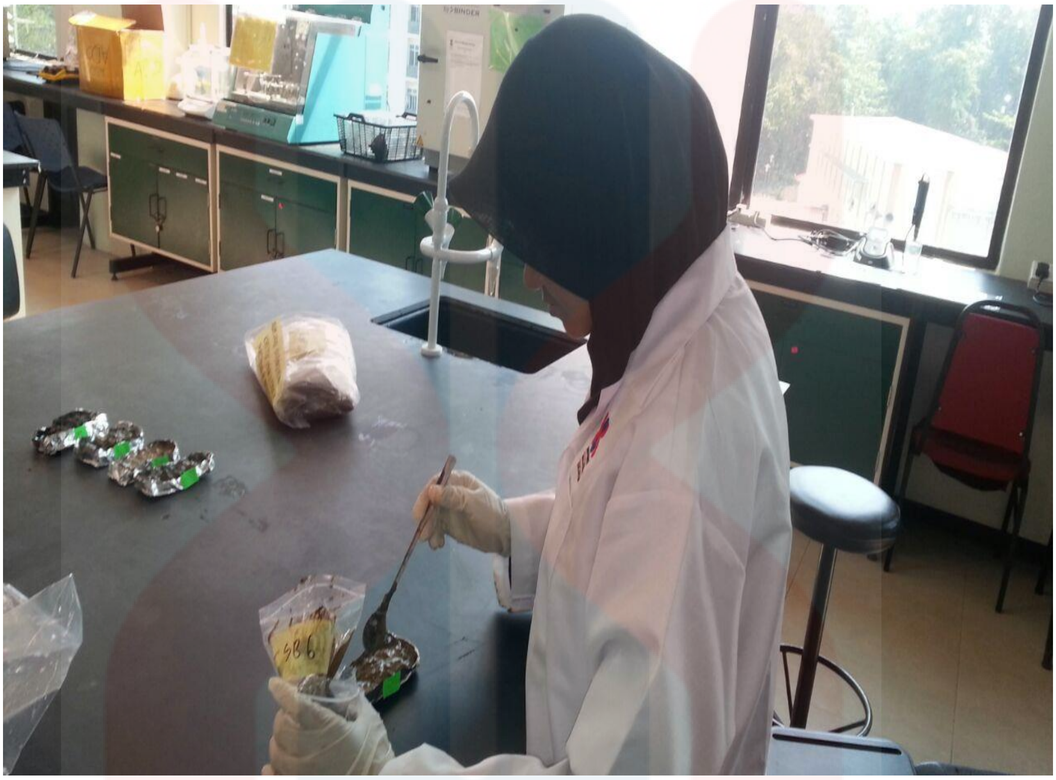
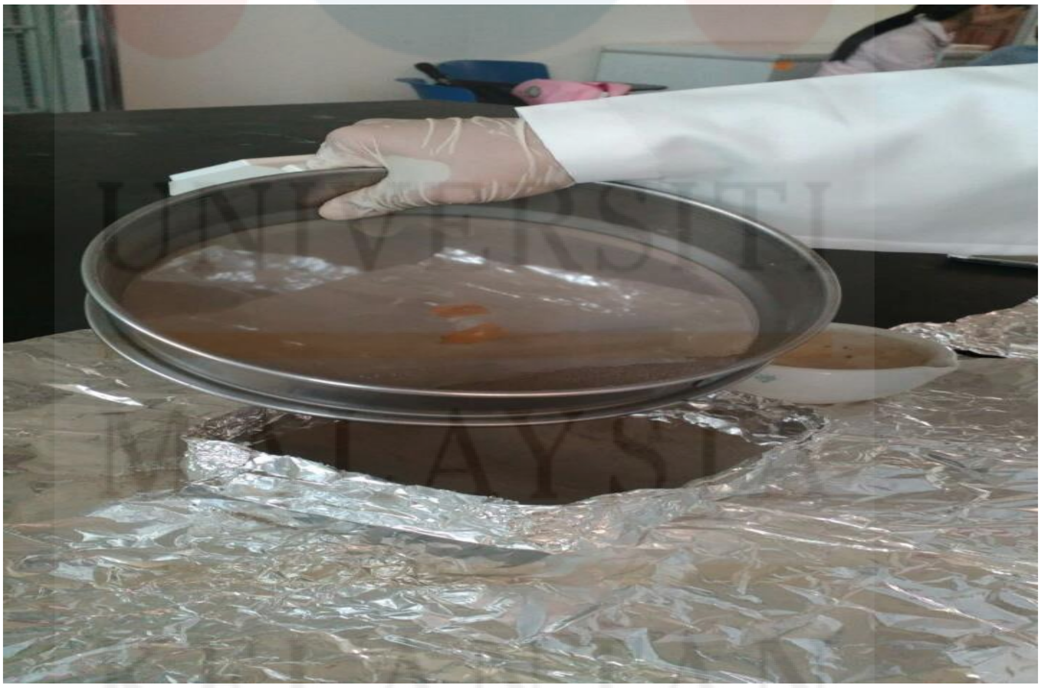
APPENDIX A



Preparing to dry the wet sediment.



The dry sediment was sieved using 10 πm sieve.

The fine sediment ready to be analysed.