Leaflet No. 15/2022

The Republic of the Union of Myanmar
Ministry of Natural Resources and Environmental Conservation
Environmental Conservation Department

Assessment of Heavy Metals in Sediment of the Taungthaman Lake, Mandalay Region, Myanmar

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February, 2023

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Abstract

There are many health risks towards people and animals near and around the lakes because of acute or chronic processes of toxic metals in the lake sediment. In lake sediments, most metals came from anthropogenic sources. To investigate the contamination of heavy metals such as Arsenic (As), Copper (Cu), Cadmium (Cd), Lead (Pb), and Chromium (Cr) in the sediment of the Taungthaman Lake, 15 sediment samples and 1 water sample were collected at the Inlet of the Lake, Residential area-1, Residential area-2, Outlet of the lake and Agricultural area, respectively. Mandalay Industrial Zone discharged waste water to the lake with untreated condition. According to concentration of heavy metals, their mean values ranked in the decreasing order as Pb >Mn> Cu > Cr > Cd > As. Values of Pb, Cd and Cu were greater than their critical values in the earth crust whereas Cr and As values were less than critical values. According to geo-accumulation index, the sediment was highly polluted with Pb and Cd, whitely moderately to strongly polluted with Cu and little polluted with Cr and As. The enrichment factor of the lake sediment was high for Pb and Cd (EF>40), and these metals were likely originated from anthropogenic sources. Cu, Cr and As were absent of contamination in bed sediment of the lake, which were impacted by natural sources. The mean Contamination Factor (CF) values of Pb, Cd, Cu, Cr and As were 148.11, 21.77, 2.24, 0.27 and 0.004 respectively, suggesting various contamination levels. The Inlet point of the Lake, Residential area-1, Outlet point of the lake and Agricultural area were suffer from heavy metals contamination because the value of pollution load index (PLI) is more than 1. Residential area-2 was not contaminated by heavy metals as the PLI value is less than 1. The control measures and management of heavy metal contamination should be conducted by optimization of industrial structures near the lake and treatment of wastewater from Mandalay Industrial Zone. For better control of the pollution, wastewater discharges from industrial sources also need to be monitored more effectively.

Keywords: Anthropogenic sources; Bed sediment; Heavy Metals contamination; Wastewater

မြန်မာနိုင်ငံ၊ မန္တလေးမြို့၏ တောင်သမန်အင်းအတွင်းရှိ ကန်အနည်များတွင် ပါဝင်နေသော Heavy Metals ကို လေ့လာဆန်းစစ်ခြင်း

ကြည်လွင်၊ လက်ထောက်ညွှန်ကြားရေးမှူး
ပတ်ဝန်းကျင်ထိန်းသိမ်းရေးဦးစီးဌာန

စာတမ်းအကျဉ်း

ကန်အတွင်းရှိ အနည်အနှစ်များတွင်ပါဝင်သည့် ထိခိုက်နိုင်မှုကို ချက်ချင်းသိသာစေသော သို့မဟုတ် အချိန်ကြာမြင့်မှသာ သိသာနိုင်သော အန္တရာယ်ဖြစ်နိုင်သော သတ္တုများကြောင့် ရေကန်များ အနီးပတ်ဝန်းကျင်ရှိလူနှင့် တိရစ္ဆာန်များအတွက် ကျန်းမာရေးအန္တရာယ် များစွာရှိနိုင်ပါသည်။ တောင်သမန်အင်း၏ အနည်အနှစ်များတွင် ပါဝင်နေသော ကန်အတွင်း ညစ်ညမ်းစေသည့်အန္တရာယ်ဖြစ်နိုင်သော (အာဆင်းနစ်၊ ကြေးနီ၊ ကဒ်မီယမ်၊ ခဲ နှင့် ခရိုမီယမ်) သတ္တုများ၏ ကန်အနည်နမူနာ ၁၅ ခုနှင့် ရေနမူနာ ၁ ခုတို့အား ကန်၏ ရေအဝင်နေရာ၊ လူနေဧရိယာ-၁၊ လူနေဧရိယာ-၂၊ ကန်၏ရေထွက်ပေါက်နှင့် စိုက်ပျိုးရေးဧရိယာတို့တွင် အသီးသီးကောက်ယူခဲ့ပါသည်။ မန္တလေးစက်မှုဇုန်အတွင်းရှိ စက်ရုံများမှ သန့် စင်မှုပြုလုပ်ထား ခြင်းမရှိသောရေများကို ကန်အတွင်းသို့စွန့်ထုတ်မှုများ ရှိနေပါသည်။ ကန်အတွင်းရှိ အနည်များတွင် အန္တရာယ်ဖြစ်နိုင်သောသတ္တုများ၏ ပါဝင်နေမှုအပေါ် အခြေခံ၍ပါဝင်မှုအနည်း အများကို စီစဉ်ရာတွင် Pb >Mn> Cu > Cr > Cd > As အတိုင်း တွေ့ရှိရပါသည်။ Pb၊ Cd နှင့် Cu တို့၏ တန်ဖိုးများသည် ကမ္ဘာ့အပေါ်ယံမြေလွှာရှိ ၎င်းတို့၏ သတ်မှတ်တန်ဖိုးများထက် ပိုများနေသော်လည်း Cr နှင့် As တန်ဖိုးများသည် သတ်မှတ်တန်ဖိုးများအောက် လျော့ နည်းပါသည်။ geo-accumulation ညွှန်းကိန်းအရ အနည်အနှစ်များတွင် Pb နှင့် Cd တို့၏ ညစ်ညမ်းမှုမှာ အလွန်မြင့်မားနေပြီး Cu ၏ ညစ်ညမ်းမှုမှာ သာမန်အဆင့်မှ ပြင်းထန်သော ညစ်ညမ်းမှုအဆင့်ရှိ၍ Cr နှင့် As တို့၏ ညစ်ညမ်းမှုမှာ အနည်းငယ် ညစ်ညမ်းသည့် အဆင့်တွင်ရှိပါသည်။ ကန်အနည်များ၏ Pb နှင့် Cd ပါဝင်မှုမှာ (EF>40) ဖြစ်၍ အဆိုပါသတ္တုများသည့် လူသားတို့၏ လုပ်ဆောင်မှု ဖြစ်စဉ်များမှ ဖြစ်တည်လာခြင်းဖြစ်ပါသည်။ Cu၊ Cr နှင့် As တို့ပါဝင်မှုမှာ အလွန်နည်းပါးသဖြင့် သဘာဝအလျောက်ဖြစ်ပေါ်သည့် ဖြစ်စဉ်များမှ ဖြစ်တည်လာခြင်း ဖြစ်ပါသည်။ ကန်၏ရေအဝင်အမှတ်၊ လူနေထိုင်ရာဧရိယာ-၁၊ ကန်၏ ရေထွက်ပေါက်အမှတ် နှင့် စိုက်ပျိုးရေးဧရိယာတို့တွင် pollution load index (PLI) တန်ဖိုးမှာ ၁ ထက်ပိုနေသဖြင့် heavy metals များကြောင့် ညစ်ညမ်းမှုရှိနေပါသည်။ လူနေဧရိယာ-၂တွင်မူ PLI တန်ဖိုးမှာ ၁ အောက် လျော့နည်း နေသဖြင့် heavy metals များကြောင့်ညစ်ညမ်းမှု မရှိပါ။ heavy metal များကြောင့် ကန်ပတ်ဝန်းကျင် ညစ်ညမ်းမှုများကို ထိန်းချုပ်ရေး အစီအမံများတွင် ကန်အနီးရှိ စက်မှုဇုန် အဆောက်အဦးများအား ပိုမိုကောင်းမွန်အောင် ပြုပြင်ခြင်းနှင့် မန္တလေးစက်မှုဇုန်မှ ရေဆိုးများကို သန့်စင်ပြီးမှသာ စွန့်ထုတ်ခြင်းများ ဆောင်ရွက် သင့်ပါသည်။ တောင်သမန် အင်းအတွင်းရှိ အနည်

အနှစ်များ၏ ညစ်ညမ်းမှုကို ပိုမိုကောင်းမွန်စွာ ထိန်းချုပ်နိုင်စေရန် အတွက် စက်မှု လက်မှု လုပ်ငန်းများမှ ရေဆိုးများစွန့်ထုတ်မှုကို ပိုမိုထိရောက်စွာ စောင့်ကြပ် ကြည့်ရှုရန်လိုအပ်ပါသည်။

Assessment of Heavy Metals in Sediment of the Taungthaman Lake, Mandalay Region, Myanmar

1 Introduction

1.1 Background Information of Studied Area

Myanmar is a tropical country with the total land extent of 676,557 square kilometers (261,228 sq miles) and located in continental South East Asia sharing its international boundary with People Republic of China in the North and North East, Lao in the East, Thailand in the south East, Bangladesh and India in the west. It enjoys tropical monsoon climate with three well defined seasons, namely summer, rainy and cold season. Myanmar is a developing country and also rich in natural resources by which it is finding to pave the way to an industrialized nation (ECD, 2020).

Mandalay city is located in the central region of Myanmar at 21° 58' N 96° 05' E. It is also the second largest city and the last royal capital of Myanmar. It is bordered by the Ayeyarwaddy River in the west. The city has an estimated population of 1.46 million in 2016, the area is 163.84 square kilometer (63.62 square miles), annual rainfall is 956 mm/year. Mandalay City is the main commercial, educational, health and economic hub of Upper Myanmar and had been considered as the center of Buddhism in Myanmar (ECD, 2020).

According to Figure 1, Taungthaman Lake is situated at Amarapura Township. Pyi Gyi Tagon Township is to the east and there are many industries at Mandalay Industrial Zone. The most industries such as sugar factory, textile industry, wood processing, plastic goods, battery, detergent, pharmaceutical, fertilizer, metal smelting and metal casting are disposal of waste water to the Lake and become sedimentation (Adereti et al., 2017). At the southern part of the Lake, there are many farmlands to grow peanuts, corn and sunflower. The farmlands are appeared when the water level have been dropped in opening season (ECD, 2020).

1.2 Introduction for Sediments in Lake and Heavy Metals

Lakes were the important role for various ecosystem services like water cycling, climate regulation, and providing habitat for organisms in lake (Hansen, 2012; Thevenon et al., 2013; Uluturhan & Kucuksezgin, 2007). Sediment of the Lake can be defined a mixture of different components of mineral species such as organic debris, present by ultimate sink of several Heavy metals discharged into their environments (Hassan et al., 2010; Salah et al., 2012). Sediments can adsorb heavy metals in water and reduce the level of pollution of the water, but the pollutants can be released from the sediments with the changing processes of environment in water and in the sediments (Xu et al., 2017). The bed sediments of the lakes conduct like sink and carrier for heavy metals in lakes systems(Liang et al., 2019; Singare et al., 2011; Singh et al., 2005; Zhang et al., 2017).

The sediments of the lake including heavy metals were generally sourced from natural processes and anthropogenic inputs, such as sediment erosion, atmospheric deposition, discharge of industrial wastewater and agricultural wastes (Addis & Abebaw, 2017).

Heavy metals were metals and metalloids and they have relatively high density more than 5 g/cm^3. They can be toxic or poisonous even their concentration was very low. Heavy metals can be found naturally in soil or sediment by alteration and erosion of geological processes.

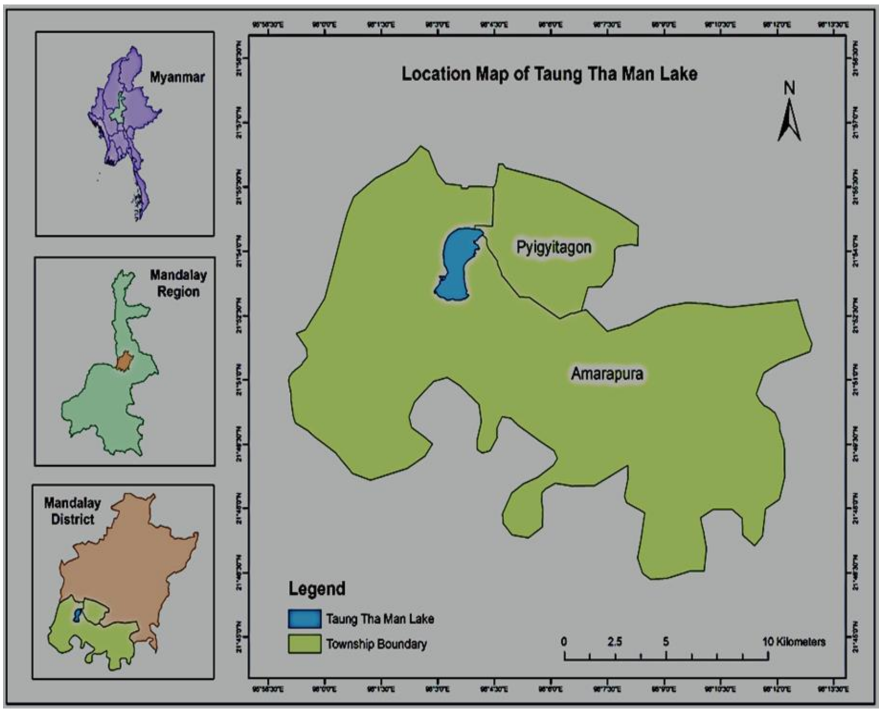

Figure 1 Study Area of Taungthaman Lake at Amarapura Township, Mandalay District, Myanmar

The primary sources of heavy metals were water drainage basins and runoff from banks, chemical leaching of bedrocks (Hassan et al., 2010). Heavy metals were released into the environment by anthropogenic activities through industrial effluents, mining, metal finishing, domestic and commercial activities, pesticides and fungicides used for agricultural farmlands, fertilizers, animal manures and pesticides (Nega, 2020). The most important sources of heavy metals in the environment were the anthropogenic activities such as mining, smelting procedures, steel and iron industry, chemical industry, traffic, agriculture as well as domestic activities (Nega, 2020).

Heavy metals were became accumulation and pollution in sediments and it was very dangerous to human and aquatic ecosystem both direct contact and dermal. Heavy metals were contended in water and sediments due to industrial and domestic discharge as waste water. Sometime acid rain may cause the broken the rocks and releasing of heavy metals into water body and it’s deposited in sediments. Heavy metals in sediments can’t migrate easily because of their long residual time and toxicity (Reymond & Sudalaimuthu, 2021).

Sediment quality was a good indicator of pollution in water body, where it tends to concentrate the heavy metals and other organic pollutants. Sediments can incorporate and accumulate many metals added to a body of natural water (Nega, 2020).

The causes of heavy metal (cadmium (Cd), lead (Pb), copper (Cu), nickel (Ni), Arsenic (As), chromium (Cr), zinc (Zn) and mercury (Hg)) contamination were the airborne absorption of aerosol particles (<30 mm in diameter), raindrops containing heavy metals or gaseous types of elements, direct applications of agricultural fertilizers and various organic materials like sewage sludge’s, animal manures, food waste and compost (Nega, 2020).

Heavy metals were a natural component of rocks. But, as the result of rocks weathering processes they were transferred to soil and bottom sediments, where they were supplemented with metals originating from anthropogenic activities such as urbanization, industrialization, energy production, municipal waste and agricultural fertilizer and pesticide (Kowalska et al., 2018; Wojciechowska et al., 2019).

Assessing the hazard or risk posed by metals in sediments was estimating the amount of metal that was potentially bioavailable. The bioavailability of metals in sediments was a function of their distribution between the dissolved and solid phases, with dissolved metals in pore-water generally considered to be the most bioavailable fraction. Accordingly, several methods have been developed to estimate the distribution of metals (Tóth et al., 2016; Wuana & Okieimen, 2011).

Emissions of heavy metals to the environment occur via a wide range of processes and pathways, including to the air (e.g., during combustion, extraction and processing), to surface waters (via runoff and releases from storage and transport) and to the soil (and hence into ground waters and crops (Nega, 2020).

Heavy metals were seriously pollution to the environment because they had the availability of toxicity, persistence and non-degradation. We can investigate sources of heavy metals, water quality depend upon the levels of polluted sediments (Hassan et al., 2010).

Their toxicity depends on several factors including the dose, route of exposure, and chemical species, as well as the age, gender, genetics, and nutritional status of exposed individuals. Because of their high degree of toxicity, arsenic, cadmium, chromium, lead, and arsenic rank among the priority metals that are of public health significance. With the assumption that heaviness and toxicity are inter-related, heavy metals also include metalloids, such as arsenic, that are able to induce toxicity at low level of exposure. In recent years, there has been an increasing ecological and global public health concern associated with environmental contamination by these metals.

Cadmium occurs naturally in ores together with zinc, lead and copper. Cadmium compounds were used as stabilizers in PVC products, colored pigment, several alloys and re-chargeable nickel–cadmium batteries. Cadmium was also found as a pollutant in phosphate fertilizers. Toxic cadmium may cause kidney damage in high concentration and skeleton damage in low condition (Li et al., 2019; Tóth et al., 2016). And Cadmium also can be harmful effects such as bone disease, coughing, headache, hypertension, lung and prostate cancer, kidney diseases, and hypochromic anemia (Ololade, 2014).

Lead occurs in mines, smelters and welding of lead painted metal, and in battery plants. High levels of air emissions may cause pollution to the areas near lead mines and smelters. Because airborne lead can be deposited on soil and water and also can reach humans through the food chain, lead in blood was bound to erythrocytes, and organic lead compounds may penetrate body and cell membranes. Tetra-methyl lead and tetra-ethyl lead penetrated the skin easily. These compounds may also cross the blood–brain barrier in adults, and thus adults may suffer from lead encephalopathy related to acute poisoning by organic lead compounds (Li et al., 2019; Tóth et al., 2016).

The symptoms of acute lead poisoning were headache, irritability, abdominal pain and various symptoms related to the nervous system. Lead encephalopathy was characterized by sleeplessness and restlessness. Children may be affected by behavioral disturbances, learning and concentration difficulties.

Arsenic was a widely distributed metalloid, occurring in rock, soil, water and air. Inorganic arsenic is present in groundwater used for drinking in several countries all over the world (e.g., Bangladesh, Chile and China), whereas organic arsenic compounds are primarily found in fish. The processes of smelting of non-ferrous metals and the production of energy from fossil can produce arsenic. Fuel production and usage for industrial processes that lead to arsenic contamination of air, water and soil, being the largest single anthropogenic source of atmospheric pollution (Jaishankar et al., 2014).

Arsenic was acutely toxic and intake of large quantities leads to gastrointestinal symptoms, severe disturbances of the cardiovascular and central nervous systems, and eventually death. In survivors, bone marrow depression, hepatomegaly, polyneuropathy and encephalopathy may be observed (Jaishankar et al., 2014).

Chromium compounds were found in the environment from the erosion of chromium-containing rocks, and could be redistributed by volcanic eruptions. Chromium was also famous for its reflective, metallic luster when polished. It can be used as a protective and decorative coating on car parts, plumbing fixtures, furniture parts and many other items, usually applied by electroplating (Jaishankar et al., 2014; Järup, 2003). Chromium may become bronchopneumonia, chronic bronchitis, diarrhea, emphysema, headache, irritation of skin, liver diseases, lung cancer, nausea, renal failure and reproductive toxicity (Ololade, 2014).

Although Copper doesn’t react with water, but it does slowly react with atmospheric oxygen to form a layer of brown-black copper oxide in moist air, protects the underlying metal from further corrosion. Copper occurs in a variety of minerals, including native copper, copper sulfides such as chalcopyrite, chalcocite, copper carbonates such as azurite and malachite (Järup, 2003; Li et al., 2019).

Gram quantities of various copper salts have caused acute copper toxicity in humans, possibly due to redox cycling and the generation of reactive oxygen species that damage DNA. Corresponding amounts of copper salts 30 mg/kg are toxic in animals. Chronic copper toxicity does not normally occur in humans because of transport systems that regulate absorption and excretion. Human can feel the abdominal pain, anemia, diarrhea, headache, liver and kidney damage, metabolic disorders, nausea and vomiting because of copper toxicity (Ololade, 2014).

The disposal of metal containing compounds such as engine oil, vehicle spare parts and welding activities, were sources of heavy metal pollution to environment. Soil pH was an important role in sorption and desorption of contaminants in soil (Järup, 2003). The human activities such as mining and smelting of metals, burning of fossil fuels, use of fertilizers and pesticides in agriculture and production of batteries may increase the concentration of heavy metals at Osun State, Nigeria, and especially the heavy metal concentration in soil in the dry season is higher than that of wet season (Adereti et al., 2017).

1.3 Problem Statement

Now-a-days, the processes of rapid urbanization and industrialization contribute to the degradation of urban environment and health hazard of urban population. These processes are mainly formation of anthropogenic sources of heavy metals in the lake sediments, often with very high concentration. Because of acute or chronic processes of toxic metals in the lake sediment, there are many health risks towards people and animals next to the lakes. It was urgent to control the pollution of the relevant lakes and surrounding environments.

1.4 Research Questions

(1) What is the concentration of heavy metals in sediment in which it is to compare among the heavy metals concentration at the inlet point of the Lake and the other points (points at residential areas, outlet point and other point near farmland)?

(2) What is the level of heavy metal contamination and pollution in lake sediment based upon the results of geo-accumulation index and enrichment factor?

(3) What is the condition of the sediments quality of lake according to the contamination of heavy metals using the results of contamination factor and pollution load index?

(4) What are the sources of heavy metals deposed in sediments where they are come from?

1.5 Research Hypothesis

(1) The levels of heavy metals concentration in the sediment of Taungthaman Lake are significantly different or not at the Inlet point of the Lake, Residential area-1, Residential area-2, Outlet point of the lake and Agricultural area.

(2) The lake sediment is very high contamination or not with the content of heavy metals in sediment.

1.6 Research Objectives

The main objectives of the research are;

(1) To investigate the concentration and distribution of Arsenic (As), Copper (Cu), Cadmium (Cd), Lead (Pb) and Chromium (Cr) in sediment at the Inlet point of the Lake, Residential area-1, Residential area-2, Outlet point of the lake and Agricultural area.

(2) To access the level of heavy metal contamination and pollution in lake sediment based upon the results of geo-accumulation index and enrichment factor.

(3) To evaluate the sediments quality of lake according to the contamination of heavy metals with the results of contamination factor and pollution load index.

(4) To discuss the sources of Heavy Metals deposed in sediments where they are come from.

2 Literature Review

The level of heavy metals concentration in the sediment may be increase because of long-term wastewater irrigation, the application of various types of pesticides and fertilizer in the vegetable farmlands (Hakanson, 1980). Many measures have been used to assess heavy metal pollution in sediment, e.g., the geo-accumulation index, the potential ecological risk index, the enrichment factor, contamination factor, pollution load index, etc (Kowalska et al., 2018; Salah et al., 2012). The analysis of heavy metal concentrations and distributions in sediment of the lake were important role for the condition of heavy metal contamination in bed sediment, to assist environmental management for water quality, and to understand the behavior of heavy metals in aquatic ecosystems (Deng et al., 2016).

The Inle Lake in Myanmar, there was a study about contamination and pollution of heavy metals in 2017. The lake is kind of Graben lake, formed about 65 million year ago. It was situated Shan Plateau and the basin is near the western margin of the Shan Scrap.

Geology of the lake was mainly composed of lower Paleozoic to Tertiary carbonate and classic sedimentary rock. The sediment samples were collected in July, 2017. According to the results of the paper by using the method of geo-accumulation index $I_{geo}=\log_2[C_n/(1.5\times B_n)]$, the western part of the lake and downstream of the lake (Nan Pilu Chaung) were unpolluted to moderately polluted as their index of geo-accumulation is ($I_{geo}>0$) and very less degree of pollution. Nanlet Chaung and southern part of the lake were moderately polluted because of geo-accumulation index is ($I_{geo}>1$) for As. Nanlet Chaung and the northern part of the lake were moderately to strongly polluted as geo-accumulation index is ($I_{geo}>2$) for Sb, Nan Pilu Chaung and the inlet of Nan Pan Chaung were very less pollution because of geo-accumulation index is ($I_{geo}>0$) while geo-accumulation index was ($I_{geo}>1$) show moderately polluted near the western bank of the lake especially at the downstream of the lake for Sb and Pb [2]. The value of I_{geo} for Pb and Bi show very less degree of pollution level as compare to other studying metals. The I_{geo} values of As are moderately pollute while Sb can be consider as moderately to strongly pollute in the Inle Lake.

In this paper, by using enrichment factor (EF) to investigate the level of heavy metal contamination and the source of those metals. The EF values were Cd(0.19-2.78), Pb(0.1-4.37), Bi(0.0-9.36), As(0.63-6.71) and Sb(0.71-14.19). The sediments of the lake may be deficiency to minimal enrichment with respect to Cd, Pb and Bi where as it may be moderate enrichment with respect to As and Sb. The lake sediments have uncontaminated with heavy metals, such as Cr, Mn, Cu, Zn and Cd. Especially, sediments of Inlay Lake may be significantly contamination with respect to As, Sb and Pb (Chen et al., 2016). The metals Cr, Mn, Co, Ni, Cu and Zn were entirely from crustal materials of natural weathering processes, while As, Cd, Pb, Bi and Sb were impacted by natural and anthropogenic sources.

In China, there were many processes of serious problems dealing with pollution and contamination of heavy metals in lake sediment because of rapid urbanization and industrialization around lakes (Martin & Meybeck, 1979; Ololade, 2014; Singh et al., 2005).

The study area was the Dongjiu Lake, located Yixing City, Jiangsu Province, China. Dongjiu Lake was 8 km^2 with the maximum depth of 5.8 m and the average depth of 1.85 m and was connected with Xijiu Lkae and Taihu Lake. Their water collected from Yili mountain area, southern Maoshan mountain area and the along river valley. Taihu Lake had suffered from serious pollution problems for many years ago because of rapid urbanization and boosting of industries of non-ferrous metalling. The sediment samples collected about 76 samples from 56 cm core. The samples took from Dongjiu Lake near the estuary of Taihu Lake in September, 2004.

According to the experimental results with the method of Enrichment Factor (EF), the concentration of Cd, Cu, Pb, Zn, Cr and Ni obviously increased from the depth of 43 cm in core. The concentration of Cd increased abruptly from 29 cm and then, at the depth of 20 cm, the concentration of Cd came to peak value about 6.9 mg/kg and more than the Chinese Standard of Soil Environmental Quality. And also Cu Cr, Pb, Zn and Mn were enriched in the upper layer of the core. So, Dongjiu Lake had intensively Cd pollution problem. In China, most of the sediments of lakes were contaminated by Cd and Hg due to human activities such as waste water from agricultural farmlands, urbanization and industrialization (Martin & Meybeck, 1979). In the present state, the environments of most Lakes were affected by different anthropogenic activities as well as various hydrodynamic disturbances (Dai et al., 2018). The concentrations of Mn, Sr and Na were relatively high below 43 cm, dropped rapidly around 43 cm and continuously increased to the surface.

If the Enrichment Factors (EF) will be 1, the lake sediments completely originated from the initial soil or mother rock without the anthropogenic influence. When it is larger than 1, there should be another source besides a natural input which can be attributed to an anthropogenic input. In Dongjiu Lake, the EFs of Cd, Cu, Pb, Cr, Fe, Mn and Ni were more than 1. Therefore, those heavy metals in lake sediments were mainly came from anthropogenic sources (Tiwari et al., 2013).

The Zariwar Lake is a freshwater and located in Iran. The lake is a depth of 5 m, its area is 8 km^2 and 1285 m above sea level. The sample core is 50 cm long with the diameter of 4 cm, and collected in December, 2016. A sample was taken from each centimeter of the 50-cm core. The average sedimentation rate was found out to be 5.6 mm/year. This means that the sediment core represents 450 years of history.

Chemical partitioning and sequential extraction methods have been widely applied to determine sediments bonds with trace metals, to detect pollution. The metallic bonds in carbonate, sulfide and organic phases are probably indicators of pollution. In addition, metallic pollution in sediments was assessed using a number of pollution indices, i.e., geochemical accumulation index (Igeo), pollution index (I_{POLL}) developed by Karbassi et al., enrichment factor (EF) and Hakanson index. Finally, sedimentation rate is determined to see how the lake has changed during the past centuries.

High organic matter decay rate tends to be witnessed near the sediment–water interface rather than the deeper sediments. Thus, maximum organic content can be seen at deeper sediments. The color of the core sediments seen during sampling also approved these findings where the shallower sludge was of lighter color than the deeper one.

Mean sedimentation rate of Zariwar Lake is greater than those of Lake Superior in the USA (0.1–2 mm/year), Lake Taihu in China (0.1–1.54 mm/year) and Anzali wetland in north of Iran (1.4–2.45 mm/year). In general, average sedimentation rate in Zariwar Lake is more than that reported in freshwater lakes, which is 1 mm/year (Tang et al., 2008).

According to contamination factors (CF), the sediments are clear from excess amounts of the studied metals. The results dragged from the studied pollution indices are approved by the previous studies in lakes with similar conditions.

According to EF, the upper level of sediments in Zariwar Lake is almost clean in terms of all the studied metals except for Mn. According to the studied pollution factors, the concentration of almost all the metals was in a range which showed minimal to no pollution in the lake sediments. However, there is average pollution in terms of Mn according to EF as a pollution index, which can be concluded to be negligible according to chemical partitioning analysis and interpretation. Regarding the sedimentation rate, an increasing trend was observed which could result in short phases of lake sedimentation and degrade the aesthetic quality of the aquatic environment. In general, results of the present study provide a thorough perspective of the past and present conditions of the lake. This allows decision makers to come up with proper solutions to alleviate risks in the Zariwar Lake in future (Tang et al., 2008).

Greenwood Lake was a man-made lake and located at the convergence of the Reedy and Saluda Rivers in South Carolina on the border of Greenwood. The sediment samples were collected a top 8 cm of sediments. By using the student’s t test, the Cr concentration in all sediments of the lake was 0.57 ppm and it was lower than the previous studied result 10.2 ppm, whereas the concentration of Cd, Cu, Fe and Pb were

0.09 ppm, 0.27 ppm, 1.4 ppm and 1.003 ppm respectively and those were also lower than the previous studied results. The results of Cr, Cd, Cu, Fe and Pb were lower than the background level established by Canova, 1999 (17 ppm, 0.8 ppm, 9 ppm, 12311 ppm and 11 ppm). Therefore, heavy metals contamination did not appear to be a significant concern in this Lake. In this research, it showed that the sediments had buried by the unpolluted sediments even the effects of flooding in Greenwood Lake at 2015 (Reymond & Sudalaimuthu, 2021).

The Ramgarh Lake was located in the region of Uttar Pradesh, India and it was a shallow, perennial eutrophic lake. Five samples of the sediment were collected in December, 2009. In this study, the order of concentration of heavy metals in sediments in the lake were Zn (188.3)> Cu (32.47)> Pb (22.07)> As (13.17)> Cd (0.77) mg/kg. Zn concentration 188.83 mg/kg was very much concentration whereas the other elements Pb, Cd, As, and Cu were little. The concentration of Cd was more than the background value 0.2 mg/kg and others were lower than the background value according to EPA guideline.

According to the results of potential ecological risk coefficient, Cd (45.99) was moderately ecological risk for the lake while others are very low risk. It shows that Cadmium was the main contributor to the sediment pollution at Ramgarh Lake (Singh & Upadhyay, 2012). Therefore, the lake was classified between moderate to good quality sediments. It was happened by anthropogenic sources such as pesticides and fertilizers are the main source of heavy metal pollution in lake near agricultural area, and urban sewage.

3 Materials and Methods

3.1 Study Area

Taungthaman Lake was situated in Amarapura Township of the Mandalay within the Doke Hta Waddy River Basin. Although the water storage area was 2500 acres many years ago, nowadays it became about 800 to 1000 acres in normal rainfall. Sometimes it was around 1800 acre if it got the heavy rainfall, and the water level was raised from 9 feet to 15 feet depth. The water level of the lake dropped at the hot season from November to May and sometime, the flooding may become in the rainy season, started from June to the beginning of October. Almost five million species of flora and fauna occur in the lake. The water of the lake flew pass through the Shwe Sar Yan Creek and then enters into the Ayeyarwaddy River (ECD, 2020).

Taungthaman Lake was situated at latitude 21° 53' north and longitude 96° 03' east. The elevation is 210 feet (64 metres). The water inlets of the Taungthaman Lake were Pa Yan Taw Creek and Lat Khote Pin Stream. The Pa Yan Taw Creek passed the agricultural land, Mandalay Industrial Zone and residential area of Pyi Gyi Tagon Township. There was a branch of Pa Yan Taw Creek, Kolumbo Channel which crosses the domestic quarter. The Lat Khote Pin Stream passed the agricultural and residential areas. Pa Yan Taw Creek was concerned to the variety of pollution sources including Mandalay Industrial Zone and it was combined with the Lat Khote Pin Stream near the lake as shown in Figure 2. Pyi Gyi Tagon Township had 28.5 km^2 in area, 8343/km^2 in density and its population was about 234,698. Pyi Gyi Tagon combines both the industrial and urban nature. Amarapura Township had 237,618 in population, 205 km^2 in area and 1160/km^2 in density (ECD, 2020).

Mandalay Industrial Zone has been established since 1990, located in Pyi Gyi Tagon township of Mandalay, and has 3530 plots on the 1820 acre. This Industrial Zone has involved 1292 industries which are 392 in large, 304 in medium and 596 in small including distillery, sugar factory, textile industry, wood processing, plastic goods, battery, detergent, pharmaceutical, fertilizer, metal smelting, metal casting, tannery, paper mill and so on. Central Wastewater Treatment System for Mandalay Industrial Zone is under construction stage. Therefore, most of the industries directly discharge the wastewater into the water resources nearby and 10 inches pipeline. The amount of discharged wastewater from point source of Mandalay Industrial Zone is 1956.37m^3/day and 714,075m^3 within one year. There are 27 industries along the Pa Yan Taw Creek; the industrial type and number of these 27 industries are classified as six distilleries, one candy factory, ten sugar factory, one textile industry, five tanneries, one paper mill and three cardboard factories. There are 18 wastewater discharging industries in the industrial zone into Pan Yan Taw creek.

Most of the area of Amarapura Township was the rural communities and they depended on the Taungthaman Lake for their living. Some villagers were fishing, duck farms, agriculture, livestock, recreation and livelihood within the lake (ECD, 2020).

Yadanarbon University was situated at the eastern part of the lake in Amarapura. Therefore, there had a lot of hostels and restaurants to support the university students. Furthermore, area occupied by squatters or illegal tenants has been situated between northern east of the lake and the Mandalay Industrial Zone which has no sanitary latrine system. The heavy rain causes floods around the Taungthaman Lake every year and the water has remained in the squatting area and it was dried in summer season (ECD, 2020).

During the dry season starting from November to May of the year, the water level of the lake was dropped. Meanwhile, the bed of the lake appears and the cultivation on the lake starts. Seasonal crops including peanut, corn, paddy, and onion were planted on and around the lake.

3.2 Sediment and Water Samples Collection

I would like to observe the concentration of heavy metals such as Arsenic (As), Copper (Cu), Cadmium (Cd), Lead (Pb), and Chromium (Cr) concentration in the sediment of the Taungthaman Lake. Sediment samples were collected at May and June, 2021 by using a hand-driven Steel coring pipe of 7.5 cm inner diameter wide. The collected samples areas were divided into five parts as Inlet area, Residential area-1, Residential area-2, Outlet area and Agricultural area.

There were 5 sediment sample points and they were taken two points in from Residential area, another three points from Inlet area, Outlet area and Agricultural area. The first point was at the Inlet point of the lake (21°54'2.86"N, 96°4'17.53"E) of Pa Yan Taw Creek which passes the agricultural land, Mandalay Industrial Zone and residential area, the second was the point (21°53'27.47"N, 96° 3'41.53"E) at the eastern part of the Lake which is Residential Area-1 near Yadanarbon University, hostels and some restaurants, the third sample place was the point (21°53'46.33"N, 96°3'11.85"E) of Residential Area-2 near the western shore of the lake under the U Bein Bridge in which there are many restaurants and shops. The fourth point was near the Outlet point (21°53'34.88"N, 96°2'49.49"E) of the Lake, the water pass through Shwe Sar Yan creek to Ayeyarwaddy River, and there are many farmlands. The fifth point was the point of Agricultural Area (21°53'10.75"N, 96°2'58.10"E) at the southern part of the Lake which is near the farmlands when the water level had dropped at the opening season. It can be seen in Figure 2.

In the lake, there were three types of sediments such as clay, silt and sandy deposit. The distribution of heavy metals at sandy sediment was faster than those of clay and silt sediments. But, the content of heavy metals was very high in clay and silt sediments because the sediment has fine grain size particles and can absorb heavy metals from the water.

The sediments of the lake are comprised mainly of material (sediment of clay, silt, and sand sizes), organic debris, chemical precipitates, or combinations of these. The relative abundance of each depends upon the nature of the local drainage basin, the climate, and the relative age of a lake. According to the study about the sedimentation of the lake, annual sedimentation rate was 1-1.5 cm in the depth of clay, silt and sandy sediment because of the process of fluvial deposit from Doktawaddy River. Mandalay Industrial Zone was locating near the lake and it was started in 1990. So, the lower layer was became before building Mandalay Industrial Zone, whereas the upper layer and median layer may be formed and their sediments can be connected by the wastewater discharged from the Industrial Zone.

The sediment samples were collected 50 cm long core at each sample point and then got 5 sample cores. The sample of 50 cm core were divided into 3 segments like the (bottom) lower part of 15 cm, the middle part of 15 cm and the upper part was 20 cm long. So, there have 15 total sediment samples to do the experiment. The water sample was collected at the point (21°53'36.31"N, 96° 3'23.44"E) in the middle of the lake with water sample bottle.

The sediment samples were taken with clean polyethylene bags and coded the labels with date and sample point locations. Then, the sediment samples transported to the laboratory and took out the experimental results.

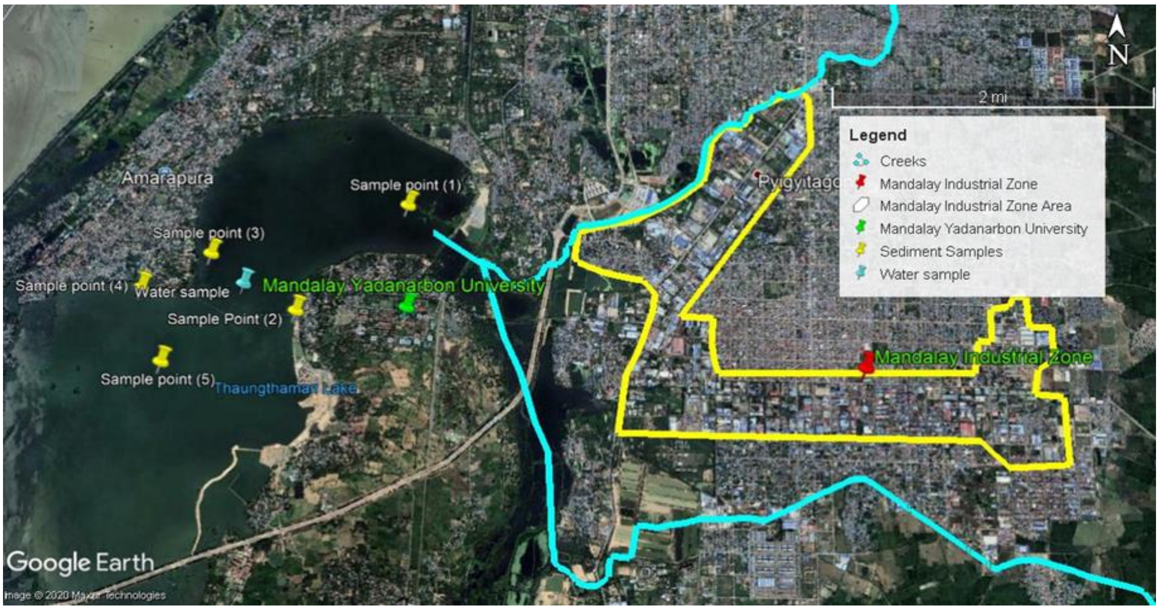

Figure 2 Water Sample and 5 Sediment Sample points at Taungthaman Lake and Mandalay Industrial Zone

3.3 Sediment Samples Analysis

The analysis of heavy metals in the collected lake sediment and water were performed at the Department of Research and Innovation, the Government of the Republic of the Union of Myanmar, and determined by using atomic absorption spectrophotometer (Perkin Elmer Titan MPS System). The sediment samples were drying at room temperature, ground, homogenized and sieved. The weight of 0.1 g of prepared sample was digested with the mixture of acid 6 ml HCL (35-37%), 2 ml HNO_3 (70%) and 1 ml HF (49%) in the digestion vessel 75 ml. The water sample was also determined by AAS and sample solution filtrate by filter into beaker with 4% of HNO_3. The sediment pH was measured the ratio of sediment: water (1:2.5 dry weight/volume) with a pH Meter. Detection limits heavy metals are 0.005 mg/kg for sediments samples and 0.015 mg/l for water samples.

3.4 Contamination Assessment Methods

3.4.1 Geo-accumulation index (I_{geo})

When I got the experimental results of heavy metals at 15 sediment samples, and I would like to investigate the pollution and contamination of Heavy Metals at Taungthaman Lake, by using Geo-accumulation Index (I_{geo}), Enrichment Factor (EF), Contamination Factor (CF) and Pollution Load Index (PLI).

Geo-accumulation Index (I_{geo}) can be applied to access the quality of sediment in lake, which may be contaminated or not because of concentration of heavy metals (Tiwari et al., 2013). Heavy metal pollution of the lake can be calculated with geo-accumulation index (Muller, 1969) by the following equation;

$$I_{geo} = \log_2[C_n/(1.5\times B_n)] \qquad \textbf{(}\text{Equation 1)}$$

Where, C_n is the concentration of heavy metals included in sediment and B_n is the geochemical background value of the element in the earth's crust (Rudnick et al., 2003). The constant 1.5 is to minimize the effect of possible variations in the background values which may be attributed to lithological variations in the sediments.

According to the results of the geo-accumulation index, there are seven classes of geo-accumulation index and they are < 0=practically unpolluted, 0-1=unpolluted to moderately polluted, 1-2=moderately polluted, 2-3=moderately to strongly polluted, 3-4=strongly polluted, 4-5=strongly to extremely polluted, and >5=extremely polluted (Taylor, 1964).

3.4.2 Enrichment Factor (EF)

To know about the level of heavy metal contamination in lake sediment and the possible sources of heavy metals in sediment of the lake by using Enrichment Factors and it was calculated by with the following equation (Buat-Menard & Chesselet, 1979);

$$F = \frac{\frac{M}{x}\ (\text{sample})}{\frac{M}{x}\ (\text{earth crust})} \qquad \text{(Equation 2)}$$

Where, CM is the content of metal studied in sediment of the lake and Cx is the content of immobile elements by Mn. The manganese (Mn) is selected to determine the reference of the earth crust (Zhang & Liu, 2002).

There are five levels of Enrichment Factor, i.e., EF<2 refers to deficiency to minimal enrichment; EF=2–5 refers to moderate enrichment; EF=5–20 refers to significant enrichment; EF=20–40 refers to very high enrichment; and EF > 40 refers to extremely high enrichment (Sutherland, 2000).

3.4.3 Contamination Factor (CF)

The contamination factor (CF) is the levels of contamination of bed sediments of the Lake caused by heavy metals contents and to investigate CF, the following equation can be applied;

$$CF = C_m \text{ Sample}/ C_m \text{ Background} \qquad \text{(Equation 3)}$$

Where, C_m Sample is the concentration of a heavy metal in studying sediment, and C_m Background is the value of the metal in the world surficial rock (Martin & Meybeck, 1979). Four levels of contamination factor (CF) can be seen in Table 1.

Table 1 Levels of Contamination Factor (CF)

Contamination Factor (CF)	Contamination Level
$CF < 1$	Low contamination
$1 \leq CF < 3$	Moderate contamination
$3 \leq CF < 6$	Considerable contamination
$CF > 6$	Very high contamination

3.4.4 Pollution Load Index (PLI)

The PLI is based on the concentration factors of all metals at each site of the sediment sample. The concentration factor is the ratio obtained by dividing the concentration of each metal in the sediment by the base line or background values. And PLI for a set of n polluting metals was defined as the geometric mean of the concentration factor values for the n metals. We have decided to focus on the comparison between the concentrations obtained in this study and the concentrations with the background values in the study to reveal the metal contamination trends.

The Pollution Load Index (PLI) is defined as the n^{th} root of the multiplied contents of contamination factor (CF). For each sample site, pollution load index (Ololade, 2014) can be calculated by the following method;

$$PLI = (CF_1 \text{ x } CF_2 \text{ x} \dots CF_n)^{1/n} \qquad \text{(Equation 4)}$$

The Pollution Load Index (PLI) is an assessment of the contamination of heavy metals in a sediment sample of the lake and the value of PLI < 1 indicates no contamination, PLI = 1 presents only baseline levels of pollutants and the value of PLI >1 shows heavy metal contamination is already happen in the sediment (Tomlinson et al., 1980; Varol, 2011).

4 Results and Discussion

4.1 Concentration of Heavy Metals in sediments of the Lake

4.1.1 Concentration and Distribution of Heavy Metals at all Sample points according to the Lab Results

In the Taungthaman Lake, the sediment concentrations of six heavy metals were investigated including; Pb, Cu, Cr, Cd, As and Mn as shown in Table 2. The table lists the heavy metal concentrations and the pH level of sediments at each sampling sites. And also shown in Table 2 are the standard deviation of measured concentrations, the average, minimum and maximum values, geochemical background reference values of Earth Crust by (Taylor, 1964), Upper Continental Crust Composition (Rudnick et al., 2003) and threshold effect concentration (TEL) and probable effect concentration (PEL) of Interim Freshwater Sediment Quality Guidelines (ISQGs) values proposed by (CCME, 1999; Puig et al., 1999). According to the Lab's results, all study sites in the Lake, the rank of heavy metals concentration in the lake sediments follow as Pb>Mn>Cu>Cr>Cd>As (Figure 3).

The heavy metals concentrations of lake sediments and their distribution are shown in Table 2. According to Table 2 and Figure 3, the highest concentration of Pb is 10700 mg/kg at the middle part of the Iutlet point (SP-1M) and the second is 9200 mg/kg at the middle part of the Residential Area-1 (SP-2M). On the other hand, the lowest concentration of Pb is 5.21 mg/kg at the middle part of the Residential Area-2 (SP-3M), 8.48 mg/kg at the lower part of the Residential Area-1 (SP-2L) and their concentrations are lower than the critical value 17 mg/kg in the upper continental crust. The concentration of Pb at the other 13 sites are higher than the critical value 17 mg/kg of the earth crust.

The concentration of Pb at SP-1M and SP-2M are higher than those of the upper layer and lower layer at Iutlet point and Residential Area-1. It assumes that the upper layers are sandy-rich deposits and the middle layers are clay-rich deposits (muddy sediment).This was happened because muddy sediments contained more clay size particles which were high in heavy metals (Wu et al., 2007). It was almost a rule that the concentration of clay size particles, the sediments will be higher content of heavy metals (Wan et al., 2016; Xu et al., 2017). There were correlations between organic matter and heavy metals because organic matter can absorb heavy metals (Zhang et al., 2017).The level of organic matter in muddy (clay and silt) sediment was higher than sandy sediment. So, the level of heavy metals in muddy sediment was higher than those in the sandy sediment. The variations of metal concentration were controlled by the grain size and source of the surface sediment. The concentrations of heavy metals in clayey silt were higher than that in fine sand, indicating that the distributions of heavy metal in surface sediment were well correspond to the sediment types (Wu et al., 2007). Heavy Metals can depose in muddy layer (SP-1M and SP-2M) when sedimentation process become at the Iutlet point and Residential Area-1 of the lake. So, the concentration of Pb is very high in those middle layers.

The highest concentration of Mn is 2200 mg/kg at the middle part of the Agricultural Area (SP-5M) and the lowest is 400 mg/kg at the middle part of the Residential Area-2 (SP-3M).

The concentration of Cu at the lower part of the Outlet point (SP-4L) (14.55 mg/kg), the upper part of the Residential Area-2 (SP-3U) (18.19 mg/kg), the lower part of Residential Area-1 (SP-2L) (24.66 mg/kg) are lower than the critical value 28 mg/kg of the earth crust and the lowest concentration of Cu is from the lower part of the Outlet point (SP-4L). At the other sites, the concentration of Cu are grater than the critical value 28 mg/kg of the earth crust. The highest concentration of Cu is the middle part of Residential Area-1 (SP-2M) (271.45 mg/kg).

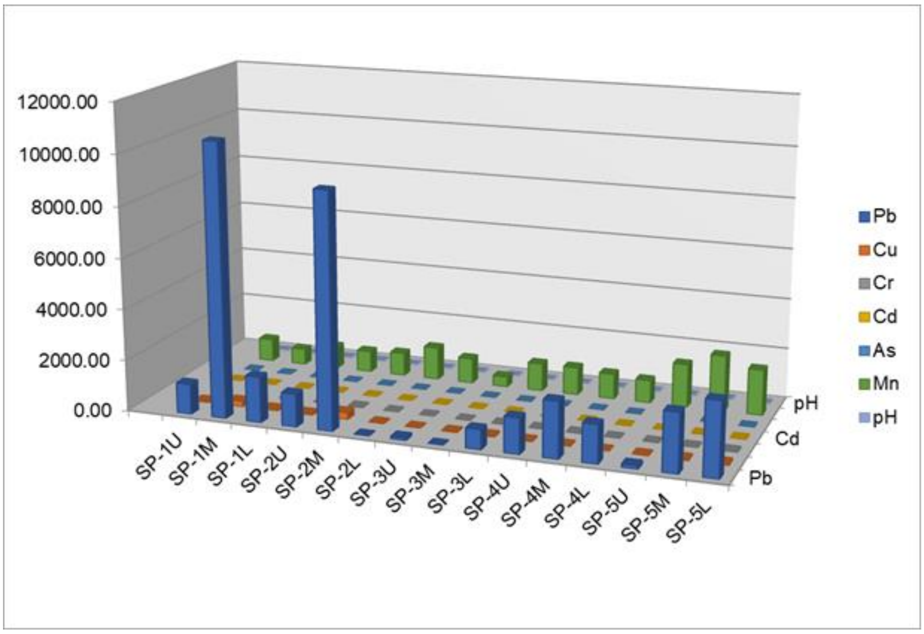

Figure 3 Concentration and Distribution of heavy metals in sediments of Taungthaman Lake

The highest concentration of Cr appears in the middle part of Residential Area-1 (SP-2M) (29.52 mg/kg) and the lowest from the middle part of Residential Area-2 (SP-3M) (10.95 mg/kg). The concentration level of Cr at all points. However, are lower than the critical value (92 mg/kg) of the earth crust.

Table 2 Metals Concentration (mg/kg) in sediments and Comparison with ISQGs and average abundance of chemical element in the earth's crust

Samples	**Pb**	**Cu**	**Cr**	**Cd**	**As**	**Mn**	**pH**
SP-1U	1200.00	57.69	18.73	2.95	0.03	900.00	7.90
SP-1M	10700.00	221.18	18.74	1.87	0.08	632.61	7.63
SP-1L	1800.00	73.89	20.63	2.37	0.08	900.00	7.59
SP-2U	1300.00	57.32	19.14	6.82	0.004	841.67	7.97
SP-2M	9200.00	271.45	29.52	2.33	0.02	921.17	7.69
SP-2L	8.48	24.66	13.28	2.37	0.03	1300.00	7.42
SP-3U	108.16	18.19	11.81	2.45	0.004	1000.00	6.45
SP-3M	5.21	31.42	10.95	2.34	0.004	400.00	6.17
SP-3L	781.99	51.65	22.74	3.24	0.004	1100.00	6.83
SP-4U	1400.00	38.05	20.14	4.92	0.03	1100.00	7.01
SP-4M	2200.00	39.84	19.70	3.50	0.03	1000.00	7.08
SP-4L	1500.00	14.55	15.45	3.18	0.03	900.00	7.06
SP-5U	141.37	25.29	16.26	2.25	0.07	1700.00	8.04
SP-5M	2300.00	64.56	19.14	11.13	0.02	2200.00	7.72
SP-5L	2900.00	83.33	28.07	13.58	0.004	1800.00	7.60
Mean	2369.68	71.54	18.95	4.35	0.03	1113.03	7.34
Standard Deviation	3214.50	74.41	5.22	3.52	0.03	466.34	-
Minimum	5.21	14.55	10.95	1.87	0.004	400.00	-
Maximum	10700.00	271.45	29.52	13.58	0.08	2200.00	-
Water sample	0.015	0.028	0.020	0.003	0.01	0.272	6.78
Taylor (1964)	12.50	55.00	100.00	0.20	1.80	950.00	-
Rudrnck & Gao (2003)	17	28	92	0.09	4.8	-	-
ISQG(TEL)	35	35.7	37.3	0.6	5.9	-	-
ISQG (PEL)	91.3	197	90	3.5	17	-	-

Sediment samples used the unit of (mg/kg), Water samples used (mg/l)

The highest concentration of Cd is from the lower part of Agricultural Area (SP-5L) (13.58 mg/kg) and the lowest is from the middle part of Inlet (SP-1M) (1.87 mg/kg). All the results of Cd concentration at all samples are higher than the critical value (0.09 mg/kg) in the upper continental crust.

The concentration of As at all sample sites are lower than the critical value 4.8 mg/kg in the upper continental crust, the highest concentration result is 0.08 mg/kg at both layers of the middle and lower parts of the Inlet point (SP-1M, SP-1L).

The pH values of sediments at all sites are in the range from 6.17 to 8.04 with a mean value of 7.34 and most sediment samples are neutral. The highest level of pH is 8.04 at the upper part of Agricultural Area (SP-5U) and the lowest level is 6.17 at the middle part of Residential Area-2 (SP-3M).

The result of heavy metals in water sample of the lake is 0.015 mg/l for Pb, 0.028 mg/l for Cu, 0.02 mg/l for Cr, 0.003 mg/l for Cd, 0.01 mg/l for As, 0.272 mg/l for Mn and the pH is 6.78. The pH level is normal and contents of heavy metals are very low in water sample which is compared with sediment samples of the lake. This means that the heavy metals may accumulate immediately when they reached into the lake water. Thus, the heavy metals which came from anthropogenic source such as industrial effluents, municipal waste water and waste water from farmlands (Dai et al., 2018; Muller, 1969), and they don't cause pollution in water of the lake according to the Lab result.

4.1.2 Concentration of Heavy Metals at Inlet point of the Lake

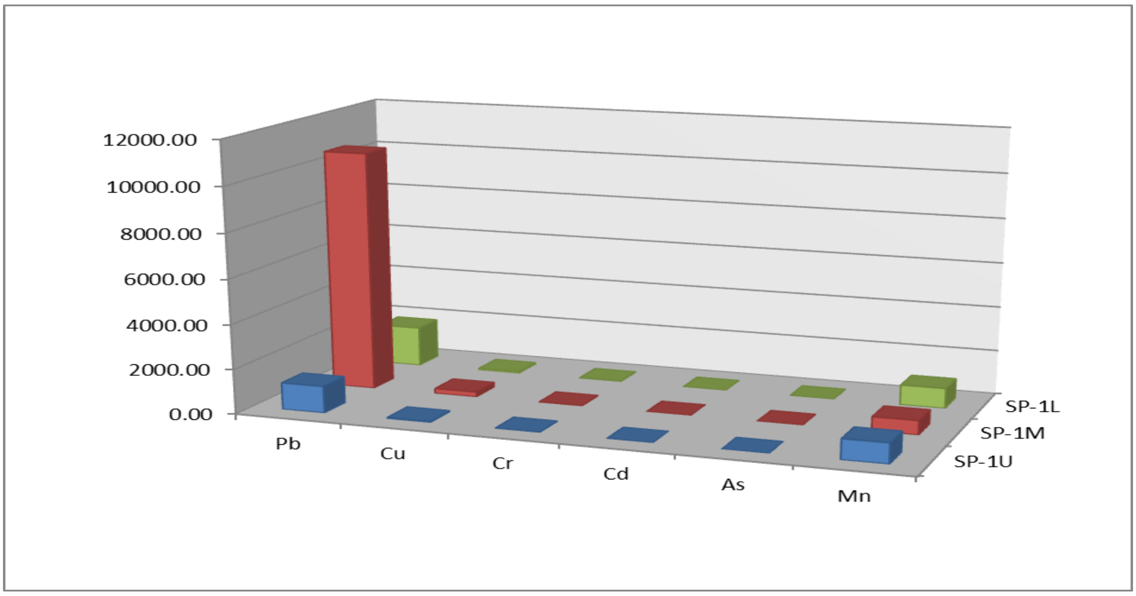

Figure 4 Concentration of Heavy Metals at Inlet Area of the Lake

At the inlet point of the lake, the concentration of heavy metals varies in different samples such as the upper layer (SP-1U), middle layer (SP-1M) and lower layer (SP-1L). The concentration of lead 10700 mg/kg and copper 221.18 mg/kg at middle layer (SP-1M) are higher than the upper layer (SP-1U) and lower layer (SP-1L). Concentration of Mn at the layer of the SP-1U and SP1-L are higher than SP-1M. Within those three layers, concentration of Cr, Cd and As are nearly the same level in each element, as show in Figure 4.

4.1.3 Concentration of Heavy Metals at Residential Area-1

According to the Figure 5, concentration of Pb and Mn are very high while those from others (Cu, Cr, Cd and As) are very low at three layers of Residential Area-1. The Pb concentration is 9200 mg/kg at SP-2M which is higher than SP-2U and SP-2L, but concentration of Mn (1300 mg/kg) at SP-2L is higher than other layers.

4.1.4 Concentration of Heavy Metals at Residential Area-2

At Residential Area-2, the Mn concentration is the highest within the studying heavy metals especially at SP-3U (1000.00 mg/kg) and SP-3L (1100.00 mg/kg), which are higher than the layer of SP-3M. The As concentration is the lowest at three layers of Residential Area-2 instead.

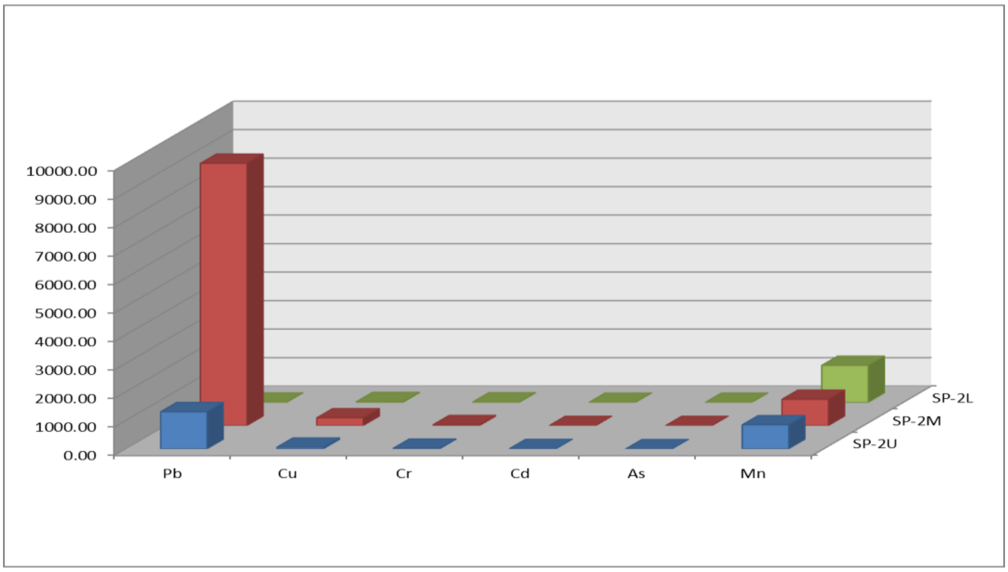

Figure 5 Concentration of Heavy Metals at Residential Area-1

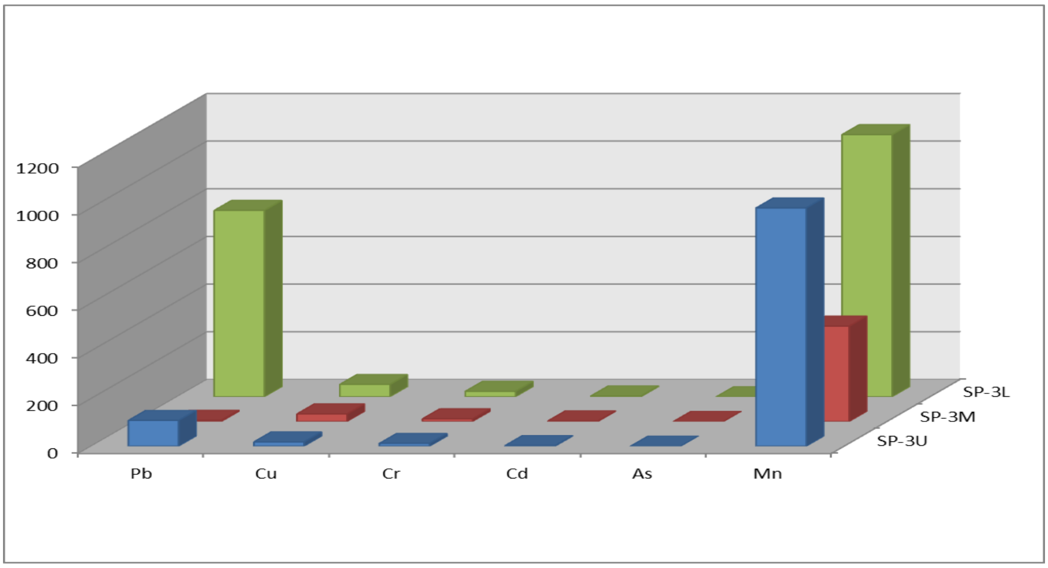

Figure 6 Concentration of Heavy Metals at Residential Area-2

4.1.5 Concentration of Heavy Metals at Outlet point of the Lake

Based on Figure 7, the concentration of Pb and Mn are very high and that of Cu, Cr, Cd and As are low at the Outlet point of the lake. The Pb concentration at the SP-4M (220.00 mg/kg) is higher than that from the SP-4U and SP-4L layers. The concentration of Mn is in the decreasing order of: SP-4U (1100.00 mg/kg)> SP-4M (1000.00 mg/kg) > SP-4L (900.00 mg/kg). The content of As at the three layers are at the same level of 0.03 mg/kg which are the lowest concentrations identified among all heavy metals.

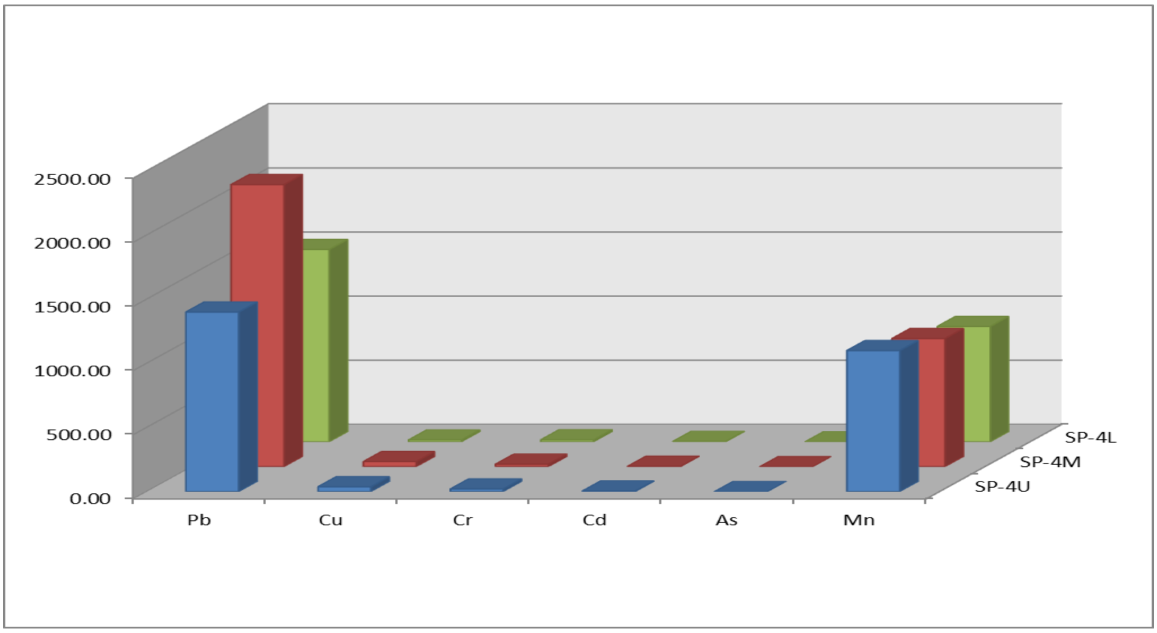

Figure 7 Concentration of Heavy Metals at Outlet point

4.1.6 Concentration of Heavy Metals at Agricultural Area

At this Agricultural Area, the highest concentration is assigned to Pb in SP-5M at 2300.00 mg/kg, and, both Pb and Mn concent at these three layers are very high. The content of Cu, Cr, Cd and As are very low in the layers of the same point. The As concentration at SP-5L is 0.004 mg/kg as the lowest concentration as shown in Figure 8.

In the lake sediment, the Pb content from Inlet point and the Residential Area-2 are very high because of the waste effluent from the Industrial zone with the channel of Pa Yan Taw creek and also the water from Lat Khote Pin stream pass through agricultural farmlands and Industrial zone. The Pb content of Outlet point is lower than the Inlet point. So, we speculate that the overall sedimentation rate of heavy metal is very high. But, the content of Pb at Agricultural Area is higher than the Outlet point possibly because of animal manures and fertilizers, pesticides using for the farms as Pb sources.

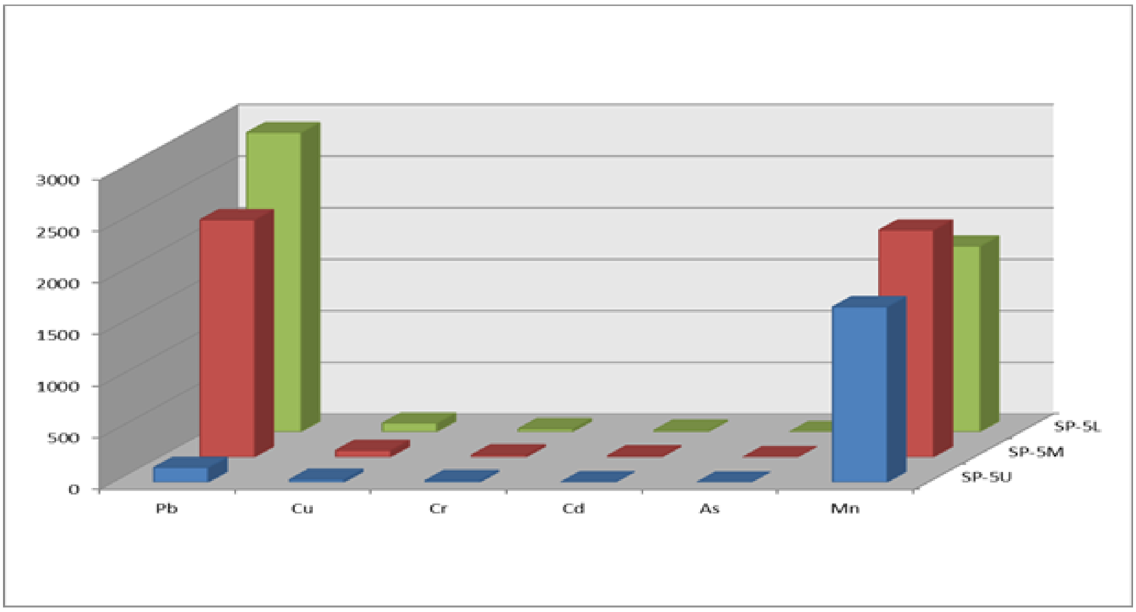

Figure 8 Concentration of Heavy Metals at Agricultural Area

The concentration of Mn at Inlet point is less than that at Outlet point, but the Mn content at Agricultural Area is the highest. The Cr content of Inlet point is lower than Outlet point. Sedimentation rate of Mn and Cr are very low. The content of Cu, Cd and As of Inlet point are greater than those at the Outlet point because of the significant sedimentation process.

4.2 Comparison of Heavy Metals Pollution with Interim Freshwater Sediment Quality Guidelines (ISQGs)

To explore the sediment quality behind the concentration of heavy metals in lake sediments, we used Interim Freshwater Sediment Quality Guidelines (ISQGs), which consist of comparable the threshold effect level of metal concentration (TEL) and the probable effect level (PEL) represented by (CCME, 1999). The values of TEL PEL can be applied to determine a specific metal which are detected in sediment that poses threat to aquatic ecosystem (CCME, 1999). When the concentration of heavy metals in lake sediments is less than the threshold value of TEL, this lake sediment is considered to be clean to marginally pollute. By contrast, if metals concentration is more than PEL values, this sediment is assumed heavily polluted.

In this studying, the contents of Pb at all sites in sediment are greater than the value of ISQGs (PEL) except in site of SP-2L, SP-3M and SP-5U. So, in overall the lake sediment is heavy polluted by Pb.

The values of Cd in sediments are more than the value of ISQGs (PEL) at SP-2U, SP-4U, SP-4M, SP-5M and SP-5L while 10 other sampling sites for the Cd concentration are above the value of ISQGs (TEL). So, this sediment is considered heavily pollute by Cd.

The Cu concentration in SP-2L, SP-3U, SP-3M, SP-4L and SP-5U samples are less than the value of ISQGs (TEL), Cu concentration at SP-2M is more than the value of ISQGs (PEL) and, for the rest 9 samples, Cu concentration are more than the value of ISQGs (TEL). All samples of Pb content are less than value of ISQGs (PEL) except SP-2M. Therefore, this sediment is needed to be cleaned for marginally polluted with Cu.

For all sample sites, the concentration of Cr (37.3 mg/kg) and As (5.9 mg/kg) are less than the value of ISQGs (TEL). Thus, the sediment is considered to be clean to be marginally polluted with Cr and As.

In the studied area of Taungthaman Lake, the sediment quality is mainly polluted by the significant pollution of Pb and Cd metals. However, the concentration of other heavy metals i.e., Cu, Cr and As, are relatively low posing limited pollution threat to the lake sediment.

4.3 Assessments of Heavy Metals Pollution

4.3.1 Geo-accumulation Index (I_{geo})

In the studied area (Taungthaman Lake), there is no record for the geochemical background of heavy metals. So, in the calculation of The geo-accumulation indexes (I_{geo}), the upper continental crust composition by Rudrnick and Gao (2003) are applied as the background values.

The geo-accumulation indexes (I_{geo}) of the investigated heavy metals in the lake sediment are shown in Figure 9 and Table 3. The values of I_{geo} for Pb are in the range of -1.12 to 9.88. The I_{geo} values of Pb at SP-1U, SP-1M, SP-1L, SP-2U, SP-2M, SP-3L, SP-4U, SP-4M, SP-4L, SP-5M and SP-5L are greater than 5. So, The I_{geo} values of Pb indicate that the sediments of the Lake are extremely polluted with Pb at those sample sites. The I_{geo} values of Pb for SP-3U and SP-5U are more than 3 and less than 4 ($3< I_{geo} <4$), and the sediments are suggested to be strongly polluted with Pb in those two sites. The I_{geo} values of Pb for SP-2L and SP-3M are less than 0 ($I_{geo} <0$) which indicates the sediments are practically unpolluted of Pb. The sediments of the lake are very high degree of pollution of Pb (ECD, 2020), especially at Outlet point of the lake and Residential Area-1.

Table 3 Results of Geo-accumulation Index (I_{geo})

Samples	**Pb**	**Cu**	**Cr**	**Cd**	**As**
SP-1U	6.73	1.63	-1.71	5.62	-6.74
SP-1M	9.88	3.57	-1.71	4.96	-5.32
SP-1L	7.31	1.98	-1.57	5.30	-5.32
SP-2U	6.84	1.62	-1.68	6.83	-9.64
SP-2M	9.66	3.86	-1.05	5.28	-7.32
SP-2L	-0.42	0.40	-2.21	5.30	-6.74
SP-3U	3.25	-0.04	-2.38	5.35	-9.64
SP-3M	-1.12	0.75	-2.49	5.29	-9.64
SP-3L	6.11	1.47	-1.43	5.75	-9.64
SP-4U	6.95	1.03	-1.61	6.36	-6.74
SP-4M	7.60	1.09	-1.64	5.87	-6.74
SP-4L	7.05	-0.36	-1.99	5.73	-6.74
SP-5U	3.64	0.44	-1.92	5.23	-5.51
SP-5M	7.66	1.79	-1.68	7.54	-7.32
SP-5L	8.00	2.16	-1.13	7.82	-9.64

According to table 3, the I_{geo} values of Cd in the lake sediments ranged from 4.96 to 7.82, and Cd values of all sampling sites are greater than 5 ($I_{geo} >5$) except SP-1M ($4< I_{geo} <5$). The sediment at SP-1M is considered to be strongly to extremely pollution for Cd while the sediments from other sites are extremely polluted with Cd.

The range of I_{geo} values of Cu is from -0.36 to 3.86. At the sample sites of SP-1M and SP-2M. The I_{geo} values of Cu are more than 3 and less than 4 ((3< I_{geo} <4), and the sediments of the two sites are strongly polluted. The I_{geo} values of Cu for SP-5L is between 2 and 3 (2< I_{geo} <3), so it is moderately to strongly polluted in the sediment. The I_{geo} values of Cu are more than 1 and less than 2 (1< I_{geo} <2) at the SP-1U, SP-1L, SP-2U, SP-3L, SP-4U, SP-4M and SP-5M, so the sediments are moderately polluted at these sites. The I_{geo} values of Cu for SP-2L, SP-3U, SP-3M, SP-4L and SP-5U are less than 0 (I_{geo} <0) and the sediments are practically unpolluted of Cu. The I_{geo} values of Cr and As are less than 0 (I_{geo} <0) for all sampling sites and it indicates that the sediments of all sites are practically unpolluted.

According to Figure 9, this condition shows that the sediments of the lake are strongly to extremely pollute by Pb and Cd, moderately to strongly pollute by Cu and practically unpolluted by Cr and As.

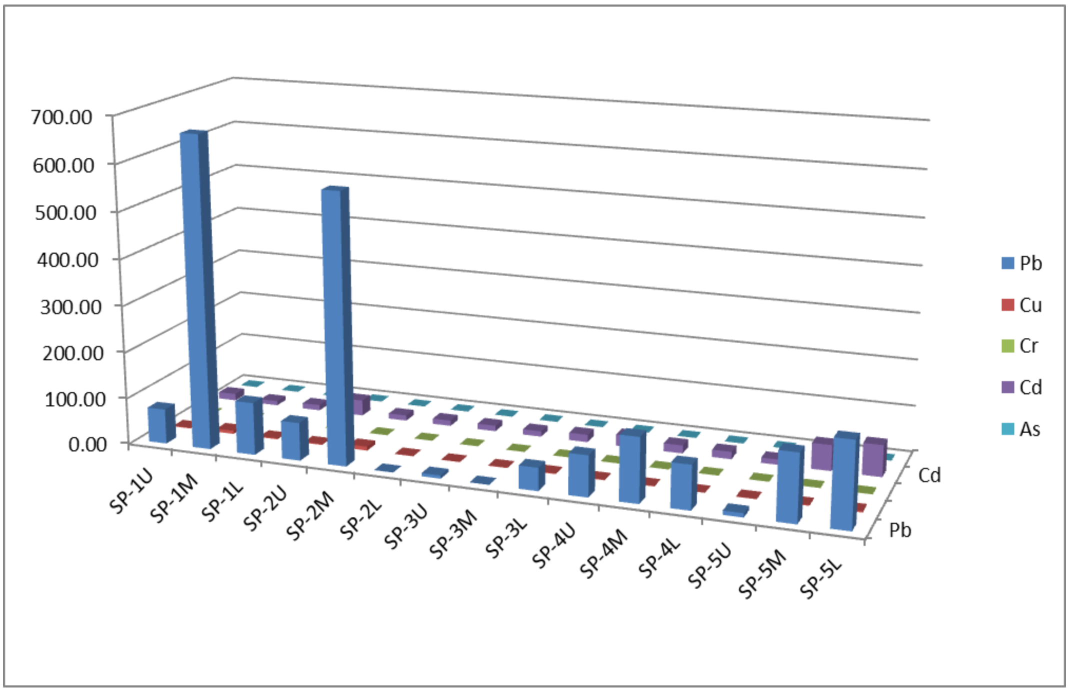

Figure 9 Geo-accumulation Index of Heavy Metals in sediments

4.3.2 Enrichment Factors

4.3.2.1 Condition of Heavy Metals in sediments Represented by Enrichment Factors

Enrichment factor (EFs) are applied to characterize heavy metals contamination rates and to assess anthropogenic inputs of single heavy metals (Wan et al., 2016).

The enrichment factor values of the heavy metals in the sediment samples of the lake can be seen in Figure 10. According to Sutherland, (2000), there are five categories from "deficiency enrichment to extremely high enrichment"(Nega, 2020). The ranges of mean heavy metal enrichment in the bed sediments of the lake are Pb > Cd > Cu > Cr > As, as shown in Table 4.

Table 4 Results of Enrichment Factor

Samples	Pb	Cu	Cr	Cd	As
SP-1U	101.33	1.11	0.20	15.57	0.02
SP-1M	1285.47	6.04	0.28	14.04	0.07
SP-1L	152.00	8.40	0.22	12.51	0.05
SP-2U	117.39	8.43	0.22	38.49	0.00
SP-2M	759.03	6.18	0.30	12.01	0.01
SP-2L	0.50	0.33	0.10	8.66	0.01
SP-3U	8.22	0.31	0.11	11.64	0.00
SP-3M	0.99	1.36	0.26	27.79	0.01
SP-3L	54.03	0.81	0.20	13.99	0.00
SP-4U	96.73	0.60	0.17	21.25	0.01
SP-4M	167.20	0.69	0.19	16.63	0.02
SP-4L	126.67	0.28	0.16	16.78	0.02
SP-5U	6.32	0.26	0.09	6.29	0.02
SP-5M	79.45	0.51	0.08	24.03	0.00
SP-5L	122.44	0.80	0.15	35.84	0.00
MEAN	205.18	2.41	0.18	18.37	0.02

The values of Pb enrichment in the bed sediments of the lake are the range from 0.50 to 1285.47), and it is extremely widely distributed. The maximum EF value of Pb is 1285.47 at SP-1M (a depth of 20-35 cm of sediment sample at Outlet point of the lake) while the minimum EF value of Pb is 0.05 at SP-2L (a depth of 35-50 cm of sediment sample at Residential Area-1). The values of Pb enrichment at SP-2L and SP-3M are less than 2 (EF <2), and they are minimally enriched. In the samples of SP-3U and SP-5U, the EF values of Pb are between 5 and 20 (5< EF< 20) suggesting significantly enriched while the EF values of Pb in the other 11 samples are greater than 40 (EF > 40) and deemed to be extremely highly enriched. Thus, the lake sediments are confirmed of very high degree of contamination for Pb as shown in Figure 10.

The EF values of Cd in sediment ranged from 6.29 to 38.49. The maximum EF value of Cd is 38.49 in SP-2U sample (a depth of 0-20 cm of sediment sample at Residential Area-1) while the minimum EF value of Cd is 6.29 in SP-5U sample (a depth of 0-20 cm of sediment sample at Agricultural Area). The EF values of Cd in the sediment for samples of SP-2U, SP-3M, SP-4U, SP-5M and SP-5L are more than 20 and less than 40, so these sampling sites are very high enriched with Cd. The other samples sediments are significantly enriched because of their EF values are between 5 and 20. The samples sediments are confirmed to be of high degree of contamination of Cd.

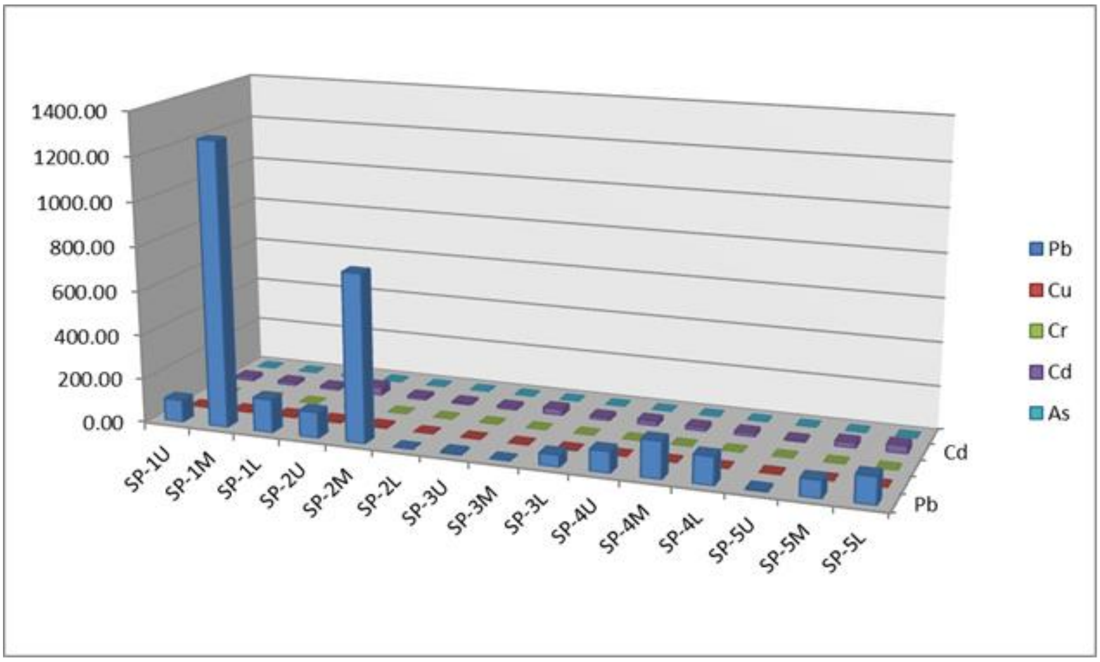

Figure 10 Enrichment Factors of Heavy Metals in sediments

The range of the EF values of Cu is from 0.26 to 8.43. The maximum EF value is 8.43 in SP-2U sample (a depth of 0-20 cm of sediment sample at Residential Area-1) and the minimum is 0.26 in SP-5U sample (a depth of 0-20 cm of sediment sample at Agricultural Area). The EF values for Cu are more than 5 and less than 20 (5<EF<20) for samples SP-1M, SP-1L, SP-2U and SP-2M, they are significantly enriched while the other 11 samples are deficiently to minimally enriched with Cu because their EF values are less than 2 (EF<2). Therefore, the lake sediments are absence of contamination pertaining to Cu except of some samples at the Inlet point and Residential Area-1.

The range of the EF values is from 0.08 to 0.30 for Cr and from 0 to 0.07 for As. At all sample sites, the EF values of Cr and As are less than 2 (EF<2) and the samples sediments are deficient to minimal of enrichment in Cr. So, the results of EF indicate that the whole sediments of the lake are absence of contamination by Cr and As and the concentration of Cr and As in sediments of the lake could be originated from the bed sediment.

4.3.2.2 Sources of Heavy Metals

Heavy metals in the bed sediments of the lake come from not only natural resources but also anthropogenic sources (Wu et al., 2007; Wu et al., 2008). Depending upon the results of enrichment factor (EF) of the lake sediments, if the values of EF are within $0.5 \leq EF \leq 1.5$, it means that the metals come from natural sources of crust materials or weathering processes, the metals come from anthropogenic sources when the EF values are greater than 1.5, and the values of EF is more than 5 (EF>5), it can be considered significantly accumulated from anthropogenic sources of trace metals (Kahn et al., 1992).

The values of EF for Cr and As are less than 1.5, thus the Cr and As metals at all sampling sites in sediments of the lake may come from the natural source crust materials or weathering processes.

At the Inlet point of the lake and Residential Area-1, the metal Cu come from anthropogenic source given that their EF values are greater than 5. At Residential Area-2, Outlet point of the lake and Agricultural Area, the EF values for Cu are less than 1.5, so Cu is originated from natural source.

The EF values of Cd at all sites are more than 5 indicating that metal may come from anthropogenic source. The EF values of Pb at all sites are more than 5 except SP-2L and SP-3M. Pb metal can be contributed to an anthropogenic input. The EF values of Pb and Cd are very high. Therefore, these metals can be interpreted as an anthropogenic input.

The anthropogenic source of heavy metals in the lake sediment is originated mainly from (1) municipal waste water, (2) industrialization such as distillery, sugar factory, textile industry, wood processing, plastic goods, battery, detergent, pharmaceutical, fertilizer production, metal smelting, metal casting, tannery, paper mill, and (3) fertilizers, pesticides and fungicides used for agricultural farmlands (Aung et al., 2019; De Paula Filho et al., 2019; ECD, 2020; Huang et al., 2020). The disturbance of geochemical cycle of heavy metals by anthropogenic processes can be from the accumulation of one or more heavy metals in the sediment of the lake (Dixit et al., 2015). At the Thaungthaman Lake, the above anthropogenic activities may be the main source of Heavy metals in the bed sediment of the lake.

4.3.3 Contamination Factor (CF)

The contamination factor (CF) is used to evaluate the levels of contamination of toxic heavy metals in sediments of the lake (Shirani et al., 2020). In this calculation, the background values of the metals are used from the world surface rock average represented by J. Martin and M. Meybeck (Martin & Meybeck, 1979). The results of CF for Pb, Cu, Cr, Cd and As in sediments are showed in Figure 11 and Table 5.

Table 5 The Values of Contamination Factor

Sample Sites	Pb	Cu	Cr	Cd	As
SP-1U	75.00	1.80	0.26	14.75	0.004
SP-1M	668.75	6.91	0.26	9.35	0.010
SP-1L	112.50	2.31	0.29	11.85	0.010
SP-2U	81.25	1.79	0.27	34.10	0.001
SP-2M	575.00	8.48	0.42	11.65	0.003
SP-2L	0.53	0.77	0.19	11.85	0.004
SP-3U	6.76	0.57	0.17	12.25	0.001
SP-3M	0.33	0.98	0.15	11.70	0.001
SP-3L	48.87	1.61	0.32	16.20	0.001
SP-4U	87.50	1.19	0.28	24.60	0.004
SP-4M	137.50	1.25	0.28	17.50	0.004
SP-4L	93.75	0.45	0.22	15.90	0.004
SP-5U	8.84	0.79	0.23	11.25	0.009
SP-5M	143.75	2.02	0.27	55.65	0.003
SP-5L	181.25	2.60	0.40	67.90	0.001
Mean	148.11	2.24	0.27	21.77	0.004

The maximum value of contamination factor (CF) for Pb is 668.75 at SP-1M (depth of 20-35 cm in the Inlet point of the lake) and the minimum value is 0.33 at SP-3M (depth of 20-35 cm in the Residential Area-2). Thus, the values of CF for Pb in sediments are very widely ranged. According to the classification by (Deng et al., 2016; Hakanson, 1980; Shirani et al., 2020), the CF values of Pb at SP-2L and SP-3M are less than 1 (CF<1), so those two sampling sites have low contamination by Pb. The other 13 samples sites have very high contamination for Pb as their CF values for Pb are more than 6 (CF>6).

The maximum value of contamination factor (CF) for Cd is 67.90 in SP-5L sample (depth of 35-50 cm in the Agricultural Area of the lake and the minimum value is 9.35 in SP-1M sample (depth of 20-35 cm in the Inlet point of the lake). The CF values of Cd at all sample sites are more than 6 (CF>6), so all sampling sites have very high contamination for Cd.

The maximum value of CF is 8.4 for Cu in SP-2M sample (depth of 20-35 cm in the Residential Area-1 of the lake) and minimum value is 0.45 in SP-4L sample (depth of 35-50 cm in the Outlet point of the lake). For SP-1M and SP-2M, the CF values are greater than 6 (CF>6) and they have very high contamination for Cu. The samples of SP-2L, SP-3U, SP-3M, SP-4L and SP-5U have low contamination as the CF values for Cu are less than 1 (CF<1). The other 8 samples have moderate contamination of Cu because their CF values are between 1 and 3 (1<CF< 3). For heavy metals (Cr and As), they are low contamination because their values of contamination factor (CF) are less than 1 (CF<1) at all sampling sites.

According to Figure 11, the sediments of the lake have very high contamination dealing with Pb and Cd, and there have low contamination by Cu, Cr and As. At SP-1M and SP-2M, the contaminations of Pb are very high because those layers are composed by muddy sediment including high level of organic matter.

4.3.4 Pollution Load Index (PLI)

The pollution load index (PLI) is applied to evaluate whether or not the sampling sites are suffered from contamination of heavy metals. When the values of PLI increased, the extent of contaminations of heavy metals also increased (Deng et al., 2016; Shirani et al., 2020).

The range of PLI values is from 0.33 to 6.61 as shown in Figure 12. The highest value of PLI is 6.61 in SP-1M (depth of 20-35 cm in the Inlet point of the lake) whereas the lowest PLI value is 0.33 in SP-2L (depth of 35-50 cm in the Residential Area-1). According to D. Tomlinson (1980), the PLI values of SP-2L, SP-3U, SP-3M, SP-3L, SP-4L and SP-5U are less than 1 and these sampling sites are of no contamination with heavy metals while for samples of SP-1U, SP-1M, SP-1L, SP-2U, SP-2M, SP-4U, SP-4M, SP-5M and SP-5L, there are heavy metals contamination because their PLI values are more than 1.

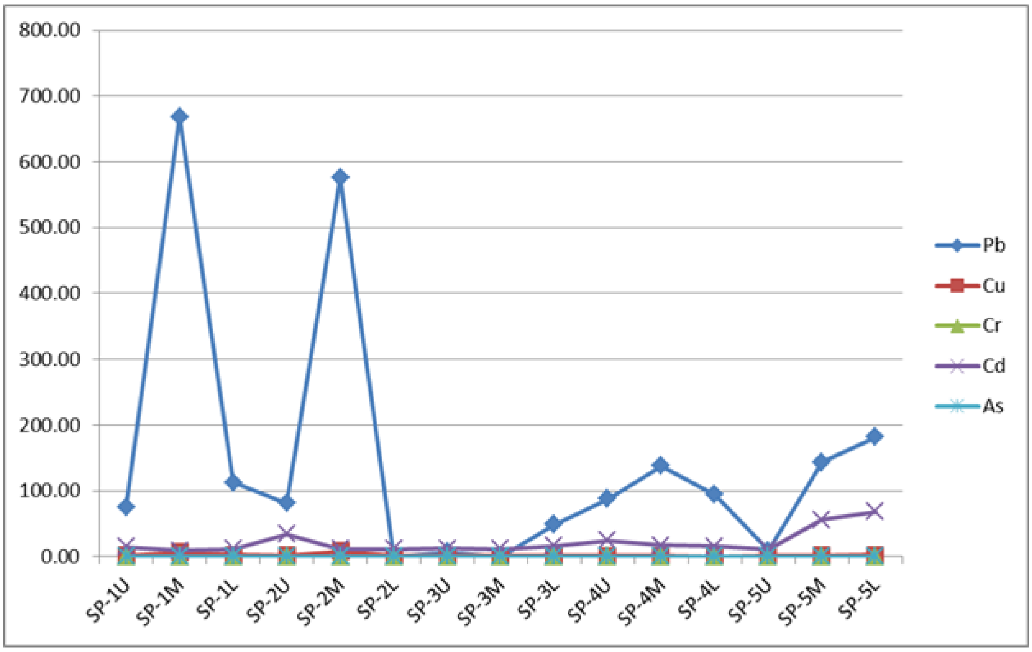

Figure 11 Contamination Factors of Heavy Metals in sediments

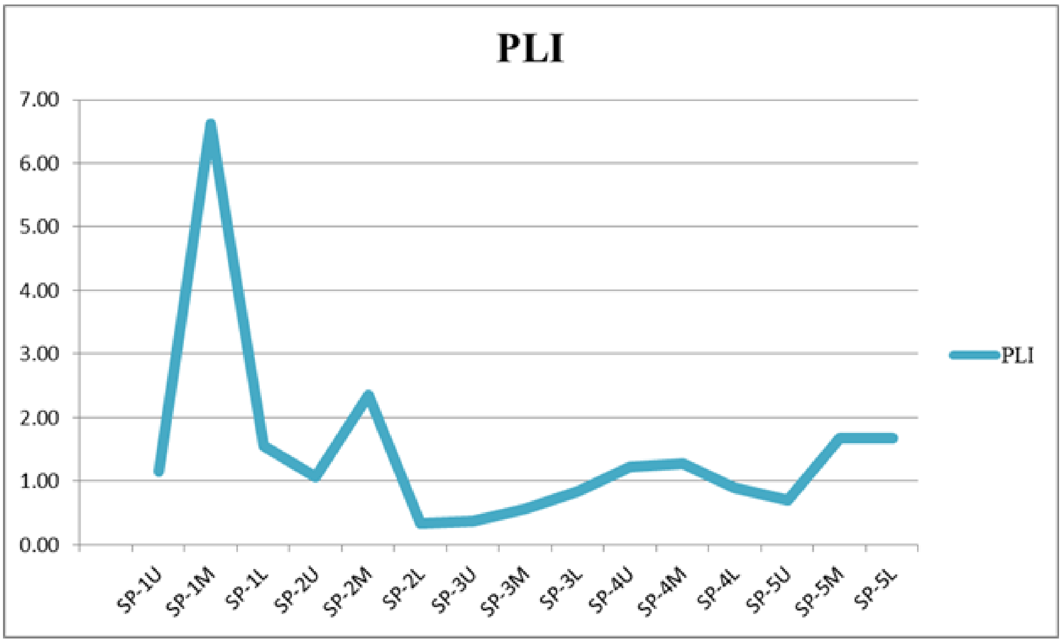

Figure 12 Pollution Load Index of Heavy Metals in sediments

In the studied area, the sampling site (SP-1M) at the Inlet point of the lake has the highest contamination of heavy metals. It suggests that heavy metals come from the anthropogenic sources because this point has water input from the Pa Yan Taw Creek which passes the agricultural land, Mandalay Industrial Zone and residential area of Pyi Gyi Tagon Township.

According to the results of I_{geo}, EF, CF and PLI, it is clear that heavy metal concentrations varied spatially with the highest mean Pb, Cd, Cu, Cr, and As. Concentrations of Pb and Cu are very high at Inlet point of the lake and Residential area-1 whereas Cd is the highest concentration at Agricultural farmland area. The pollution of Pb and Cu were caused by no treatment wastewater discharged from Mandalay Industrial Zone, and deposit at Inlet area. Cd pollution was caused by phosphate fertilizers and pesticides used in agricultural areas, and intense industrial activity at the Agricultural farmlands area.

In terms of Pb and Cd, the values of EF and CF for Inlet point of the lake and Residential area-1 were found to be very highly contaminated, while other sampling points were only moderately contaminated. The PLI values indicated that sediments at Inlet point of the lake, Residential area-1, Residential area-2 and Agricultural area were high contamination and the Outlet area was low contamination.

Table 6 Values of Pollution Load Index (PLI)

Sample Sites	PLI
SP-1U	1.16
SP-1M	6.61
SP-1L	1.55
SP-2U	1.06
SP-2M	2.35
SP-2L	0.33
SP-3U	0.38
SP-3M	0.56
SP-3L	0.84
SP-4U	1.23
SP-4M	1.27
SP-4L	0.90
SP-5U	0.70
SP-5M	1.67
SP-5L	1.67

There is a complex relationship between metals present in lake sediments dealing with heavy metal substances of rocks and parent materials, cycles of soil formation, pollution by human behaviors, and other anthropogenic activities. They threated to the health of human and aquatic ecosystem because of the accumulation of toxic heavy metals in sediments. Therefore, contaminated sediment is necessary to be clean and meanwhile the source of metals pollution in the bed sediment of the lake shall be reduced (Brady et al., 2014).

In this studied area, the sediment of the lake is strongly contaminated by the pollution of Lead and Cadmium. In the opening season, when the water level is dropped and there are many farmlands for growing paddy, bean, sunflower and sesame. And also the dark farms are near the farmlands. The people worked in the farmlands and fishermen in lake (Wojciechowska et al., 2019), who are exposed to the health risks by dermal contacting or ingestion with water and sediment including heavy metals. The pathway of toxic metals ingestion significantly contributed to human health risks of heavy metals in bed sediment (Wan et al., 2016).

The metal (Cd) may cause kidney damage and skeleton damage in chronic poisoning when people have long-term exposure to Cd.

The symptoms of acute Pb poisoning are headache, abdominal pain, sleeplessness and restlessness. Children may cause behavioral disturbances, learning and concentration difficulties. The people who have been exposed to Pb for a long lime, may suffer from memory deterioration, reduction of ability to understand, lung cancer and stomach cancer (Adereti et al., 2017).

5 Conclusions and Control Measures

This studying is intended to investigate the condition of heavy metals contamination and pollution in the sediment of Taungthaman Lake. The concentration of Pb, Cu, Cr, Cd and As were tested from 15 sediment samples and 1 water sample in the lake. The systematic assessments of contamination in lake sediment are performed by calculating Geo-accumulation Index (I_{geo}), Enrichment Factor (EF), Contamination Factor (CF) and Pollution Load Index (PLI). According to concentration of heavy metals, the order of mean values of heavy metals are Pb> Cu>Cr >Cd>As which can be seen in Table 2.

(1) The concentration of Pb presents the highest value not only at the middle layer of Inlet Point, Residential Area-1 and Outlet Point but also at the lower layer of Residential Area-2 and Agricultural Area.

(2) The concentration of Cd and Cu are moderate and the concentration of Cr and As are at the lowest levels at all sampling sites.

(3) The sediment of the lake is polluted by Pb and Cd with comparison of sediment quality guidelines (ISQGs).

(4) With the calculated results of Geo-accumulation Index (I_{geo}), the sediment quality is extremely polluted by Pb and Cd, moderately polluted by Cu and practically unpolluted by Cr and As.

(5) The Enrichment Factor (EF) values indicate that the lake sediment is extremely highly enriched for Pb at the Inlet point and Residential Area-1, moderately enriched at Outlet point.

(6) It is very highly enriched for Cd at Residential Area-1 and Outlet point and significantly enriched at Residential Area-2 and Agricultural Area.

(7) Cu was found with significant enrichment at the Inlet point and Residential Area-1, while Cr and As with very low enrichment at all samples.

(8) Therefore, the lake sediment is of extremely high contamination of Pb and Cd, which come from anthropogenic sources. On the other hand, the less contamination of Cu, Cr and As are come from natural resources.

(9) The results of Contamination Factor (CF), the CF values of Pb and Cd are very high contaminated, moderately contaminated for Cu and very low contaminated by Cr and As at all sites.

(10) According to the results of Pollution Load Index (PLI), the Inlet point, Residential Area-1, Outlet point of the lake and Agricultural Area have severe heavy metals contamination because the values of PLI are greater than 1, but Residential Area-2 has no contamination because PLI value is less than 1.

(11) Industrial effluents, municipal wastewater and fertilizers used in agriculture are key sources of Cd and Pb concentration to the sediment of Taungthaman Lake.

(12) The metals Pb and Cd are coming from anthropogenic source such as lubricant oil, diesel oil, metal smelting, fertilizers and insecticides for farmlands, painting manufacturing and battery production.

The acute and chronic health effects for people and animals may induce skeleton damage, kidney damage, headache, abdominal pain, sleeplessness, restlessness, lung cancer and stomach cancer by direct contact (ingestion and/ or dermal pathway) with heavy metals in the lake. To reduce the health effects of human and aquatic ecosystem, it is necessary to deal with heavy metals in terms of knowledge, attitudes and perception of the people in and around the lake.

The present condition of the Lake environment is affected by many anthropogenic activities, which come from mainly Mandalay Industrial Zone and agricultural farmlands in and around the lake. To improve this sediment quality, it will be conductive to decrease the industrial effluents, agricultural and domestic sewage discharge. The control measures and management of heavy metal contamination can be conducted by the optimization of industrial structures near the lake and by treatment of wastewater from Mandalay Industrial Zone, which pass through wastewater treatment factory.

In the aquatic ecosystem, to control the concentration and pollution of heavy metals, it need to remove the heavy metals from the water column by interacting with organic matter or particulate matters eventually deposited as sediments (Tiwari et al., 2013; Torabi Kachoosangi et al., 2020). From the heavy metal pollution prevention and control measure, it is necessary to prevent heavy metals in the streams sediments from transport into Taungthaman Lake because of human activities. To control heavy metal pollution in sediment, dredging is one of several feasible techniques for the remediation of polluted sediments in lake. We should evaluate the efficiency of sediment dredging for controlling heavy metal pollution (Uluturhan & Kucuksezgin, 2007).

Considering environmental monitoring activities, it is the most essential case to determine the heavy metal levels in the sediment and also it should be within the national standards. Incomplete management and insufficient funds often lead to a portion of untreated domestic and industrial wastewater being discharged into urban streams and lakes (Varol, 2011). The most effective way to reduce heavy metals pollution in lake sediment is efficient control of the pollution sources and strict enforcement of environmental regulations, especially in terms of wastewater discharge (Wojciechowska et al., 2019).

These highly toxic heavy metals have adverse effects on aquatic organisms and human settled down in and around the Lake. Restoration of Lake requires the local government to implement measures to prevent heavy metal pollution as a matter of urgency, particularly in relation to Pb, Cd, Cr, and Cu. These restoration studies should start with training carried out with the aim of providing awareness of the harms of toxic chemicals to fishermen, aquaculture workers, and farmers in the region. In order to reveal the full ecological risk caused by these heavy metals, extensive eco-toxicological studies were needed on the responses of the biota of Taungthaman Lake to these toxic metals.

For better way to control the pollution of heavy metals, wastewater discharges from industrial sources also need to be monitored more effectively than the present status. The results of this paper can provide comprehensive and quantitative reference data for further research of heavy metal pollution in Taungthaman Lake. The findings of the present study lack in toxic heavy metal results which could contribute to future researchers' better understanding of toxic metals' behavior in sediments and need to investigate the degree of biological risk and degree of toxic metal pollution in deep clay core sediments. There were many limitations for this studying as the pandemic of Covid-19 and political issues were happened in the whole country, Myanmar. And also financial resource was limited for this research. Data collecting and lab experiments could be made for once because of time and financial limitations. So, the research could not cover the analysis of heavy metal contamination in lake sediment throughout of the year.

6. Acknowledgment

First of all, the one I would like to express my deepest thanks to my supervisor, Professor Dr. Ke Yin, College of Biology and Environment at Nanjing Forestry University (NFU) for giving me this opportunity to study this interesting topic and for his close supervision, appreciation the great support, tremendous encouragement, and guidance throughout my study. I also thank to my dissertation committee members for their encouragement, suggestions, and comments on the thesis.

Especially the Asia-Pacific Network for Sustainable Forest Management and Rehabilitation (APFNet), which granted me the scholarship program to pursue my master's degree at Nanjing Forestry University (NFU). I also extend my heartiest thanks to all the teaching staff and supporting staff of Nanjing Forestry University for helping me broaden my knowledge and skills, and for their kind support throughout the time at stayed in China. I also acknowledge and appreciate the support of the College of International Education staff to study enjoyable and unforgettable memory in China.

I especially thank to Environmental Conservation Department, Mandalay Division for their help not only support in the field but also the arrangement for travelling and staying at their office to collect the sediment and water data.

I am also grateful to Environmental Conservation Department (Head Quarter) for supporting and permitting to study about assessment of heavy metals and their impacts and health effects to human and aquatic ecosystem in Taungthaman Lake. Furthermore, I am thankful to the Ministry of Natural Resources and Environmental Conservation (MONREC) for giving me that chance to pursue a master's degree in China.

I extended my heartfelt gratitude to Depart of Research and Innovation, Myanmar for their assist in laboratory sample collection processes and in carrying out the laboratory results without which data would have been difficult to obtain.

Lastly, I sincerely thank to my parents for their encouragement and especially my wife who has been a source of constant encouragement, support and patient from the start to the end of this work.

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8. Appendix

1. Photos of Taungthaman Lake


2.Photos of Samples Collection




3.Farmlands Photos

4.Photos of Ducks Farms

5.Photos of Fishing