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Evaluation of Heavy Metal Concentration in Total Suspended Solids (TSS) of Engineering and Built Environment Lake Faculty at UKM Campus during 2019

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Abstract

A study of metal concentrations in total suspended solids (TSS) in Engineering and Built Environment Lake Faculty - UKM, Selangor, Peninsular Malaysia was conducted in January, April, July, and October 2019. Water samples were collected using acid washed, distilled water rinsed polyethylene bottles and triplicates water samples were pooled together then immediately filtered using 0.45µm membrane filters (APHA,1992). The dried samples were put in test tubes and digested with 5 ml of a mixture of concentrated tri- acid HNO_3:$HClO_4$:H_2SO_4 (10:4:1) at 100 ºC in a hot plate for 2 hrs. Six metals i.e. cadmium, chromium, lead, nickel, zinc, and copper were determined by Inductively Coupled Plasma Mass Spectrometer (ICP –MS), Perkin Elmer Elan,Model 9000. The results show that copper had the highest concentration (9.55 µg /g), while cadmium had the lowest concentration (0.91 µg /g) in Total Suspended Solids samples. For Cu,Zn,Cr,Ni,Pb and Cd the highest and lowest concentrations were (9.55- 3.68, 3.79-3.78, 3.73-2.31, 2.60-1.59, 3.19-0.29 and 0.91-0.05) respectively. Furthermore, the average for Cu,Zn,Cr,Ni,Pb and Cd in Total suspended solids were (6.60),(3.79),(3.02),(2.08),(1.73) and (0.48) respectively. The accumulation of heavy metals in total suspended solids depends on the factors like metal content in water, absorption properties of the plankton species, and to the metal of sediment (Elmaci et al., 2007). In the present study, the amounts of metals concentrations depends upon the deposition of dead plankton, sedimentation of the suspended particles having trace metals content.

Key word: metals concentration. total suspended solids. Engineering Lake.

INTRODUCTION

Metal contaminants in aquatic ecosystems cause a serious environmental hazard because of their persistence and toxicity. Toxic metals from various sources namely discharge of industrial or sewage influents, domestic wastewater, periodic precipitation contaminated with airborne pollutants, transport, burning of fossil fuels, and fertilizers containing trace metals could affect fish healthy (Handy,1994; Jent et al.,1998;Chaisemartin,1983).Metals have been used in various human activities since thousands of years ago and metal pollution in the aquatic environment

has been an issue. Malaysia as a developing country, finds it inevitable avoiding this problem. The existence of metals concentration in the environment could be of natural causes or anthropogenic. The natural causes could be weathering; climate changes (wind and temperature) inflicted on igneous and metamorphic rocks. However the burning of fossil fuels, mining, melting minerals, industrial wastes, the use of fertilizers and pesticides in the agriculture are the main contribution of anthropogenic sources (Kendrick *et al.*1992). In the context of environmental pollution, the existence of metal pollution and the existence of metal concentration could be categorized into 3 important types; non- critical, undiluted toxic metals which hardly exist and toxic metal concentrations which are widely used (Forstner & Wittman 1992). Unlike organic pollution, toxic metals could be not eliminated through biodegradable process and the impact of toxic metals could remain permanently in the environment. In some heavy metals such as mercury and cadmium, are known to have toxic effect although they have low concentrations (Forstner & Wittman 1992). Heavy metal concentrations in aquatic ecosystems are usually monitored by measuring its concentration in water and biota (Camusso *et al.* 1995), which generally exist in low levels in water and attain considerable concentrations in biota (Namminga & Wilhm1976). Heavy metals including both essential and non- essential elements have a particular significance in ecotoxicology, since they are highly persistent and all have the potential to be toxic to living organisms (Storelli *et al.* 2005). Heavy metals do not exist in soluble forms for a long time in waters; they are present mainly as suspended colloids or are fixed by organic and mineral substances (Kabata – Pendias and Pendias 2001). In aquatic ecosystems, water contamination by heavy metals is one of the main types of pollution that may stress the biotic community (Baldantoni *et al.* 2004).
The objective of this research is to identify the metal concentrations in total suspended solids in Engineering Lake Faculty at UKM Campus in 2019.

MATERIALS AND METHODS

Study area

Engineering and Built Environment Lake Faculty is a man – made freshwater lake. It is geographically located at 02^0 55' 30'' N and at 101 46' 20'' E. The depth is 1.5 meters. The main source of water was Langat River and rain water, the drainage was through one drainage pipe to the surrounding areas. Engineering Lake covers average of 1.8 acres (Personal Communication) (Fig. 1).

Determination of Heavy metals Concentration in Total Suspended Solid (TSS)

Water samples were collected using acid washed, distilled water rinsed polyethylene bottles. The triplicates water samples were pooled together. The water samples were immediately filtered using 0.45µm membrane filters (APHA,1992).The filtered samples were put in Petri dishes and dried at 103-105 ºC for 48 h by oven (Memmert / F503.022 Model). The dried samples were put in test tubes and digested with 5 ml of a mixture of concentrated tri- acid HNO_3:$HClO_4$:H_2SO_4 (10:4:1) at 100 ºC in a hot plate (COD Reactor Sastec / ST-DBMK200-4 Model) for 2 h. The cooled residue was dissolved completely by adding 1 ml HCl (35%) and the volume was completed to 25 ml with distilled water in conical flasks (FAO 1983). The solution was filtered by vacuum (Gast / DOA-P504-BN). The metals concentration were determined by Inductively Coupled Plasma Mass Spectrometer (ICP –MS), Perkin Elmer Elan,Model 9000 (AOAC 1990) . All samples were analyzed in triplicates.

Statistical analysis

One –way analysis of variance (ANOVA) was conducted to see the variation of heavy metal concentration among the different months. All data were analysis using the statistical package SPSS (Version 20).

RESULTS

Metal concentration in total suspended solids.

The metal concentrations in total suspended solids of Engineering Lake are given in Table 1 and figures (from 2 to 7). In the present study, copper had the highest concentration while cadmium had the lowest concentration as shown in table 1. Cadmium values confirmed the lower values on January and April (0.05 µg /g), and the higher values on July and October (0.91 µg /g), and the average was 0.48± 0.50µg /g (fig2). Copper values showed the lower value on April (3.68 µg /g) and the higher value on July (9.55 µg /g), and the average was 6.60± 3.37µg /g (fig3). Lead values demonstrated the lower value on January and April (0.29 µg /g) and the higher value on October (3.19 µg /g), and the average was 1.73 ± 1.67 µg /g(fig4). Zinc values recorded the lower value on October (3.78 µg /g) and the higher value on January, April and July (3.79 µg /g), and the average was 3.79 ± 0.01 µg /g (fig5). Chromium values explained the lower value on April (2.31 µg /g) and the higher value on October (3.73 µg /g), and the average was 3.02± 0.81 µg /g(fig6). Nickel values recorded the lower value on January and April (1.59 µg /g) and the higher values on October (2.60 µg /g), and the average was 2.08 ± 0.57 µg /g (fig7). The results revealed that the order of concentration of elements in total suspended solids was Cu >Zn> Cr>Ni> Pb > Cd.

Metal concentration in sediments

The metal concentrations in sediment of Engineering Lake are given in figures (from 8 to 13). The sediment of Engineering Lake contained detectable amounts of heavy metals. Among the detected heavy metals in sediment, copper had the highest concentration while cadmium had the lowest concentration. Cadmium values confirmed the lower value on July and October (0.91 µg /g) and the higher value on January (0.97 µg /g), and the average was 0.93± 0.03µg /g(fig 8). Copper values proved the lower value on January and October (9.48 µg /g) and the higher value on July (9.55 µg /g), and the average was 9.50± 0.03 µg /g (fig 9). Lead values demonstrated the lower value on July (3.16 µg /g) and the higher value on April, July and October (3.19 µg /g), and the average was 3.18 ± 0.02 µg /g(fig 10). Zinc values recorded the lower value on April (11.41 µg /g) and the higher value on July (11.57 µg /g), and the average was 11.48 ± 0.08 µg /g (fig 11). Chromium values explained the lower value on July (3.71 µg /g) and the higher value on January and October (3.73 µg /g), and the average was 3.72± 0.01 µg /g(fig 12). Nickel values showed the lower value on July (2.55 µg /g) and the higher values on October (2.60 µg /g), and the average was 2.57 ± 0.02 µg /g(fig 13).Sediments samples contained high levels of metals and the accumulation order was Zn >Cu> Cr>Pb> Ni > Cd.

DISCUSSION

Metal concentration in TSS

In the present study, Engineering Lake contained detectable amounts of Cd, Cu, Pb, Zn, Cr and Ni.The study as well revealed that the total suspended solids contained low concentrations of heavy metals compared to their concentrations level in sediments due to its concentrations in the water samples. High concentrations of particulate matter can lead to increased sedimentation and saltation in a stream, which in turn can ruin important habitat areas for fish and other aquatic organisms. Suspended particles also provide attachment places for other pollutants such as metals and bacteria (Kabata –Pendias and Pendias 2001) .High suspended solids or turbidity readings can be used as indicators of other potential pollutants. Furthermore, total suspended solids and turbidity values vary naturally for two main reasons – physical, and biological. Heavy rains and fast-moving water are erosive. They can pick up and carry enough dirt and debris to make any water look dirty. As such, heavy rain fall may cause higher total suspended solid concentrations or turbidity, unless the additional particles are dispersed through large volumes of water (Gray 1999). Total Suspended Solids (TSS) concentration and turbidity both indicate the amounts of solids suspended in water, whether mineral (e.g., soil particles) or organic (e.g., algae). However, the TSS test measures the actual weight of material per volume of water, while turbidity measures the amount of high scattered from a sample (more suspended particles cause greater scattering) (Chapman1998). In natural aquatic ecosystem, metals occur in low concentrations, normally at the nanogram to microgram per liter level. In recent times however, the occurrence of metal contaminants especially the heavy metals in excess of natural loads has become a problem of increasing concern. This situation has arisen as a result of the rapid growth of population, increased urbanization and expansion of industrial activities, exploration and exploitation of natural resources, extension of irrigation and other modern agricultural practices as well as the lack of environmental regulations (FAO 1992). The study revealed that all studied metals were decrease in dry months (January to June) and increase in wet months (July to December) in tropical region as Malaysia.

Sediments and total suspended solids act as the most important reservoir or sink of metals and other pollutants in the aquatic environment (Gupta et al.2009). Heavy metal concentrations in sediment can affect the water quality and bioaccumulation of metals in aquatic organisms, resulting in potential long-term implication on human health and ecosystem (Fernandes et al.2007). For these six metals, therefore, toxic effects would be rarely observed. Variations in levels of metals among TSS may be explained in terms of the chemical forms of the elements, sediment (organic matter, clay content, pH, etc.), microbial activity and the extent of contamination by the local environment. Heavy metal concentrations in the various matrices of the lake also depend on the geochemical structure of the lake basin that may consist of heavy metals rich metamorphic rocks.

The accumulation of heavy metals in total suspended solids depends on the factors like metal content in water, absorption properties of the plankton species, and to the metal of sediment (Elmaci et al., 2007). In the present study, the amounts of metals concentrations depends upon the deposition of dead plankton, sedimentation of the suspended particles having trace metals content.

Metal concentration in Sediments

The study revealed that the sediment from Engineering Lake contained high concentrations of heavy metals when compared with their concentration in water. Sediments act as the most important reservoir or sink of metals and other pollutants in the aquatic environment (Gupta et al.2009). Heavy metal concentrations in sediment can affect the water quality and bioaccumulation of metals in aquatic organisms, resulting in potential long-term implication on human health and ecosystem (Fernandes et al.2007). For these six metals, therefore, toxic effects would be rarely observed. Variations in levels of metals among sediments may be explained in terms of the chemical forms of the elements, physico-chemical characteristics of the sediment (organic matter, clay content, pH, etc.), microbial activity and the extent of contamination by the local environment. Heavy metal concentrations in the various matrices of the lake also depend on the geochemical structure of the lake basin that may consist of heavy metals rich metamorphic rocks.

Moreover, the concentrations of metals may probably be affected by the geological mining history of the localities as well as the urban and domestic activities.

The concentrations of heavy metals in sediments were higher than those in the waters of the lakes, hence the sediment could be an influential factor on the levels of metals in the water of the lakes with other enhancing factors such as water current and pH values. Since acidic water is known to influence the solubility and availability of metals (Schwartz et al.1986). Heavy metal concentrations in the various matrices of the lake also depend on the geochemical structure of the lake basin that may consist of heavy metal rich metamorphic rocks (Fernandes et al. 2007). In addition, mineralogical studies of polluted sediments indicate that the heavy metals are found to be associated with fine particles of silt, clay that have large surface areas and the tendency to absorb and accumulate metal ions due to their intermolecular forces (Pande & Sharma 1999).

CONCLUSIONS

The study revealed that the heavy metals concentration in total suspended solids are in order of Cu >Zn> Cr>Ni> Pb > Cd.

REFERENCES

- AOAC,1990.Official methods of Analysis oa AOAC International. 16th ed. Virginia, USA: The Association of Analytical Communities.
- APHA, 1992. *Standard Methods for the Examination of Water and Waste water.* 18th edition. Washington: American Public Health Association (APHA).

- Baldantoni, D., Alfani, A., & Tommasi, P.D, 2004. *Assessment of macro and micrelement accumulation capability of two aquatic plants*. *Environmental Pollution, 130,* 149-156
- Barbosa, A.E.& Hvitved J.T.1999.High way runoff and potential for removal of heavy metals in an infiltration pond in Portugal. *Science of the total Environment* 235(1-3):151-159.
- Camusso, M., Vigano, L.,& Baitstrini, R, 1995. *Bioaccumulation of trace metals in rainbow trout. Ecotoxicology and Environmental Safety*, 31, 133 – 141.
- Chaisemartin,C.,1983.Natural adaptation to fertilizers containing heavy metals of healthy and contaminated populations of Austropatamobius pailpes (LE). Hydrobiology 17,229-240.
- Chapman.D, 1998.Water quality assessment . Second edition. Published on behalf of water.Health. Organization. New York.
- Elmaci,A., Teksoy, A.,Topac, F.O.,Ozengin, N., Kurtoglu, S., Bakaya,H.S.,2007.Assessment of heavy metals in Lake Uluabat, Turkey.Afr.J. Biotechnol.6, 2236-2244.
- FAO (1992). Committee for Inland Fisheries of Africa. Report of the third session of the Working Party on Pollution and Fisheries. Accra, Ghana, 25-29 November 1991. FAO Fisheries Report, 471, Rome, FAO.
- Fathi,A.L. &Hashimi.B.A.2013.Determinatiion of heavy metal concentrations in Arius thalassinus and Johnius belanngri fishes from the coastal waters of Kapar and Mersing, Malaysia. Ph.D thesis. Universiti Kebangsaan Malaysia.
- Fernandes C, Fontainhas- Fernandes A, Peixoto F, Salgado MA, 2007. Bioaccumulation of heavy metals in Liza saliens from the Esomrizparamos coastal lagoon, Portugal. Ecotox.Environ.Saf. 66:426-431.
- Food and Agriculture Organization.1983.Compilation of Legal Limits for Hazardous Substances in Fishers and fishery Products. FAO Fishers Circular No.464:5-100, Rome: Food and Agriculture Organization.
- Forstner, U. & Wittman, G.T.W, 1982. *Metal pollution in the aquatic environment*. New York: Springer – Verlag.
- Gray.N.F,1999. Water technology An introduction for enviromental scientists and engineers. First edition. Arnold Publisher.London.
- Gupta A, Rai DK, Pandey RS, Sharma B ,2009.Analysis of some heavy metals in the riverine water, sediments and fish from river Ganges at Allahabad. Environ.Monit. Assess. 157:449-458.
- Handy,R.D.,1994. International exposure to aquatic pollutants: assessment, toxicity and sublethal responses in fish and invertebrates. Comp. Biochem. Physoil.,107C-84C.
- Jent,S., Heing.J.S.,Tate,C.M.,1998. Concentration, distribution and composition of selected trace elements in bed sediment and fish tissue in the South Platte River Basin,USA, 1992-1993. National Water Quality Assessment (NWQA) program report.
- Kabata –Pendias, A., & Pendias, H,2001. *Trace elements in soil and plants* (3rd ed). Boca Raton, FL: CRC Press.
- Kendrick, M.J., May, M.T., Plishka, M.J. & Robinson, K.D,1992. *Metals in Biological Systems*. Ellis Harwood Limited, pp. 183.
- Khaled S.A. Said, M.Shuhaimi –Othman and A.K.Ahmad.2012. The Determination of Water Quality and Metal Concentrations of Ampang Hilir Lake, Selangor, Peninsular Malaysia. Pakistan Journal of Biological Science. Asian Network for Scientific Information.
- Khaled S.A. Said, M.Shuhaimi –Othman and A.K.Ahmad.2012. The Evaluation of Water Quality and Metal Concentrations of Titiwangsa Lake, Selangor, Peninsular -

Malaysia. Pakistan Journal of Biological Science. Asian Network for Scientific Information.
- Mushrifah.I. 2019. (Personal Communication). School of Environmental Sciences and Natural Resources, Faculty of Science and Technology - Universiti Kebangsaan Malaysia (UKM)
- Namminga, H.N., & Wilham, J,1976. *Effects of high discharge and an oil refinery cleanup operation and heavy metals in water and sediments in Skeleton Creek. Proceedings of the Oklahoma Academy of Science,* 56, 133- 138.
- Pande,K.S.&Sharma,S.D.1999.Distribution of organic matter and toxic metals in the sediment of Ram Ganga River at Moradabad. *Pollution Research* 18:43-47.
- Schwartz,J.,Angle,C.&Pitcher,H.1986.Relationship between childhood blood lead levels and stature. *Pediatric77*:281-288.
- Storelli, M.M., Storelli, A., & D' ddabbo, R., marano, C., Bruno, R., & Marcotrigiano, G.O, 2005. *Trace elements in loggerhead turtles (Caretta caretta) from the eastern Mediterranean Sea: Overview and evaluation. Environmental Pollution, 135, 163 – 170.*

*Department of Geography. Faculty of Human and Social Sciences. Universiti Kebangsaan Malaysia (UKM) (2019).

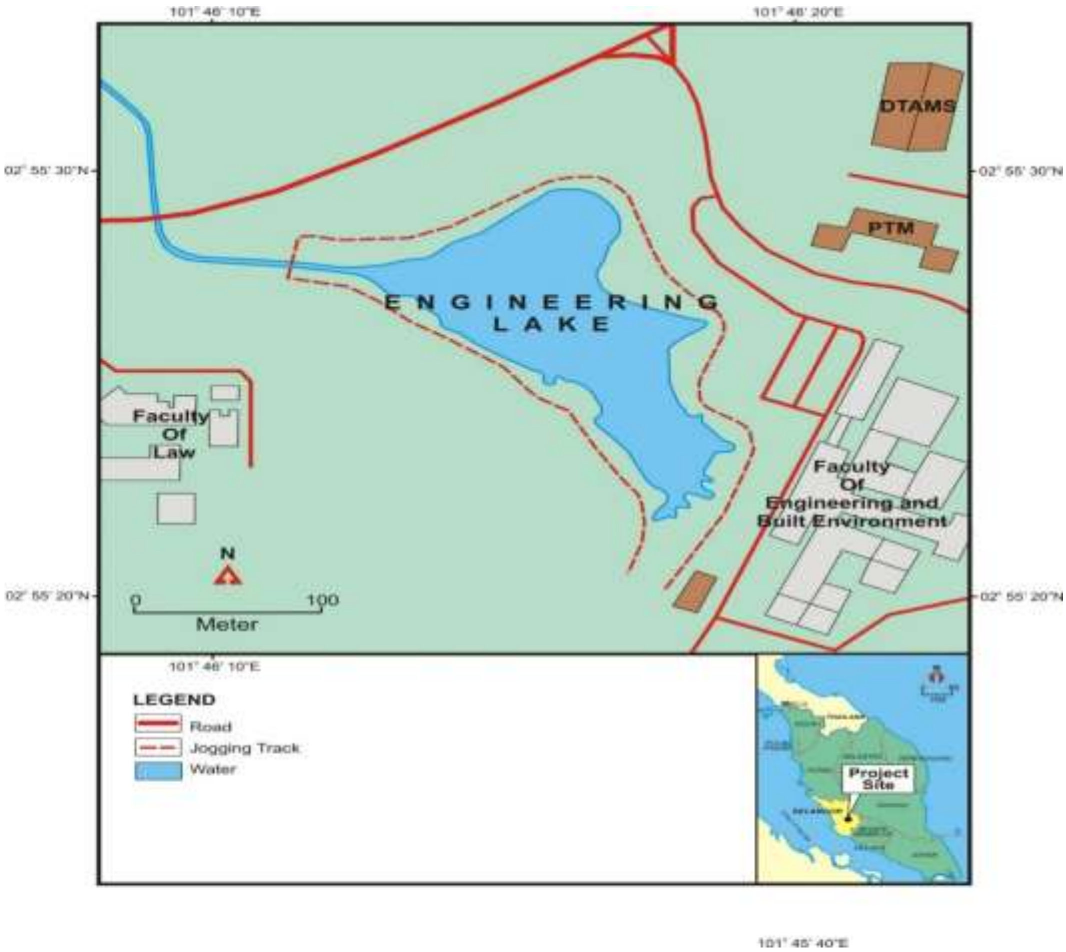


Fig.1. Geographical location of Engineering and Built Environment Faculty Lake - UKM, Selangor, Peninsular Malaysia.

Table 1: Metal concentrations in TSS (µg /g dry weight) of Engineering Lake, Selangor, Peninsular Malaysia (2019).

Metal	Jan	Apr	Jul	Oct	Ave
Cd (µg /g)	0.05	0.05	0.91	0.91	0.48±0.50
Cu (µg /g)	3.69	3.68	9.55	9.48	6.60±3.37
Pb (µg /g)	0.29	0.29	3.16	3.19	1.73±1.67
Zn (µg /g)	3.79	3.79	3.79	3.78	3.79±0.01
Cr (µg /g)	2.32	2.31	3.71	3.73	3.02±0.81
Ni (µg /g)	1.59	1.59	2.55	2.60	2.08±0.57

Table 2: Metal concentrations in TSS (µg /g dry weight) of different studies

Metal	*Portugal Pond	**Urban off in Beijing, China	***Ampang Hilir Lake , Malaysia	****Titiwangsa Lake, Malaysia
Cd	1.0	0.28 – 1.31	0.04	0.40
Cu	54	68.1 - 142	3.58	6.22
Pb	-	73.1 - 222	0.38	1.33
Zn	-	264 - 664	1.58	3.15
Cr	-	57.9 - 154	2.18	3.54
Ni	-	25.8 – 78.0	2.98	2.67

*Barbosa& T Hvited Jackson (1999), ** Fathi& Hashimi (2013), ***&****khaled et al.2012

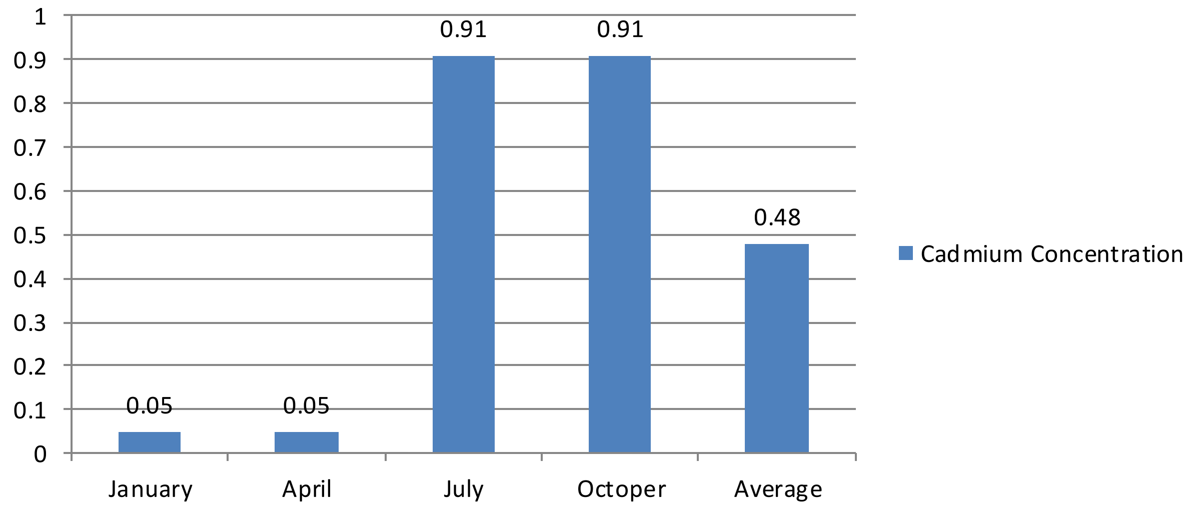


Fig.2. Cadmium Concentration (µg /g dry weight) in Total Suspended Solids of Engineering Lake during 2019

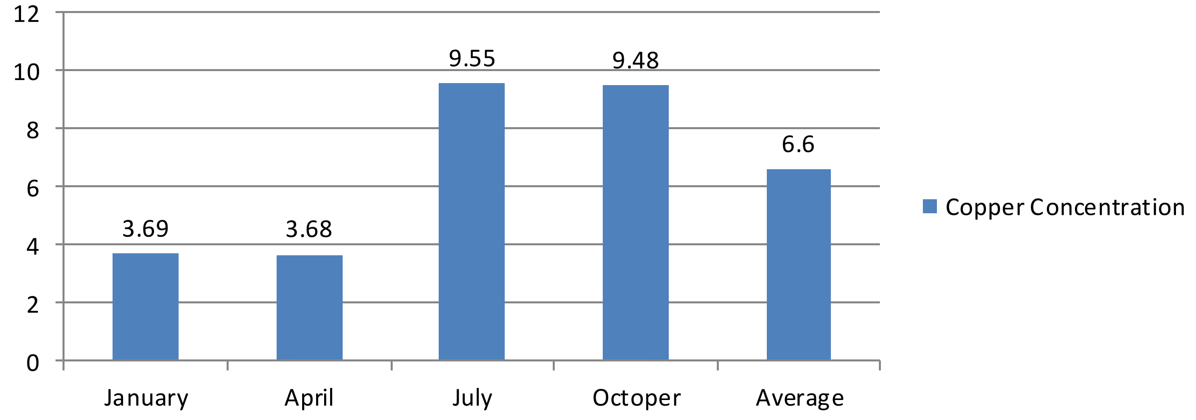


Fig.3. Copper Concentration (µg /g dry weight) in Total Suspended Solids of Engineering Lake during 2019

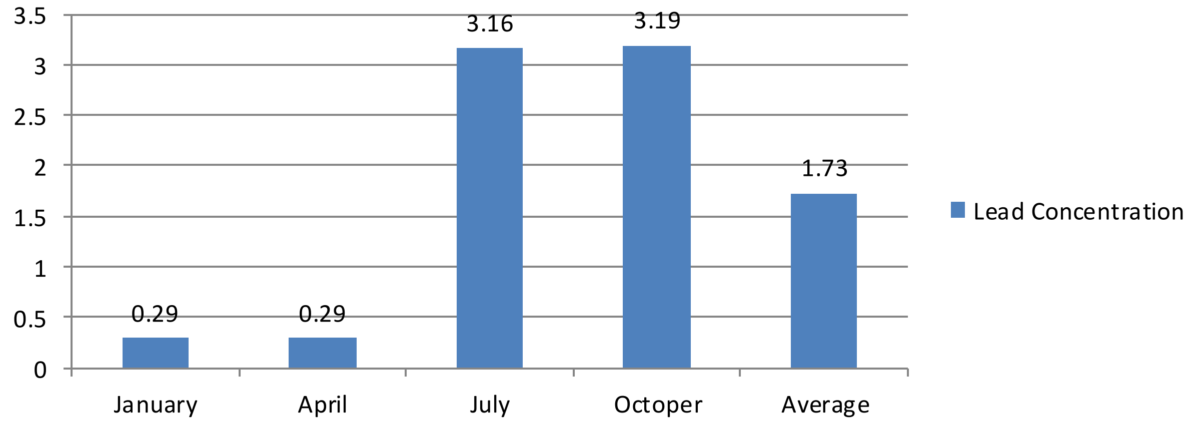


Fig.4. Lead Concentration (µg /g dry weight) in Total Suspended Solids of Engineering Lake during 2019

Fig.5. Zinc Concentration (µg /g dry weight) in Total Suspended Solids of Engineering Lake during 2019

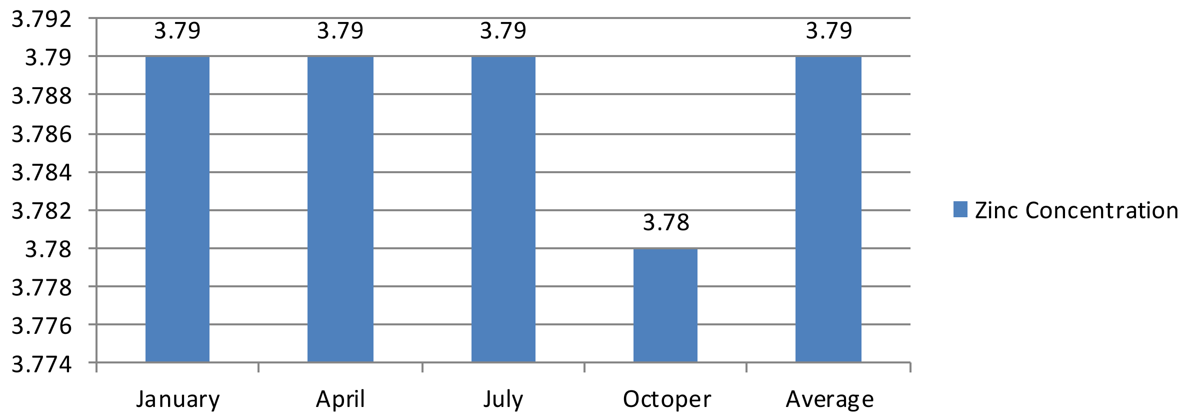


Fig.6. Chromium Concentration (µg/gµg /g dry weight) in Total Suspended Solids of Engineering Lake during 2019

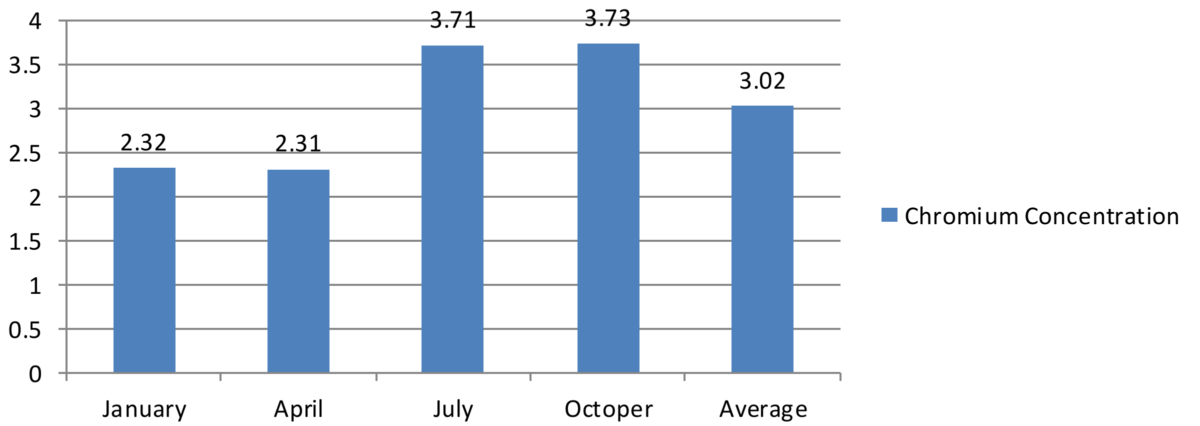


Fig.7. Nickel Concentration (µg/gµg /g dry weight) in Total Suspended Solids of Engineering Lake during 2019

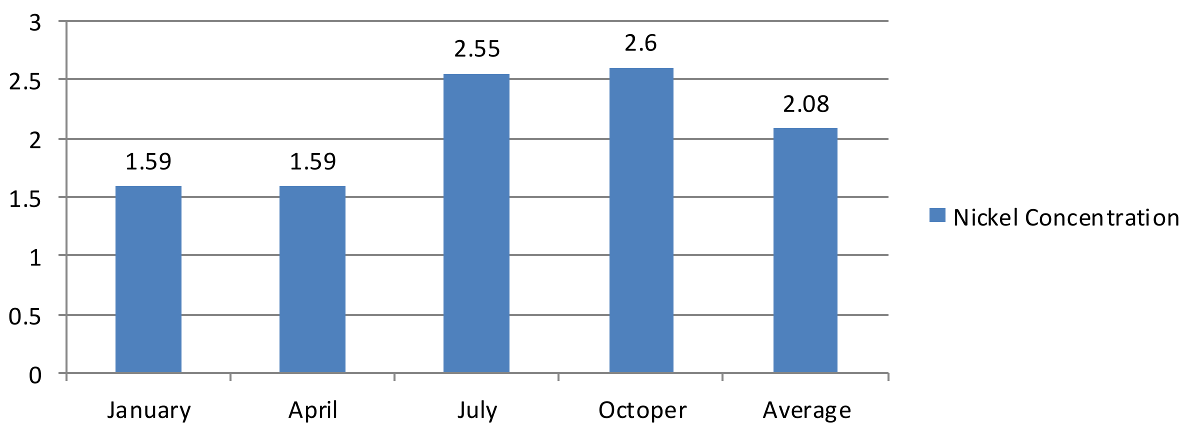


Fig.8. Cadmium Concentration (µg /g dry weight) in Total Suspended Solids and Sediment of Engineering Lake during 2019

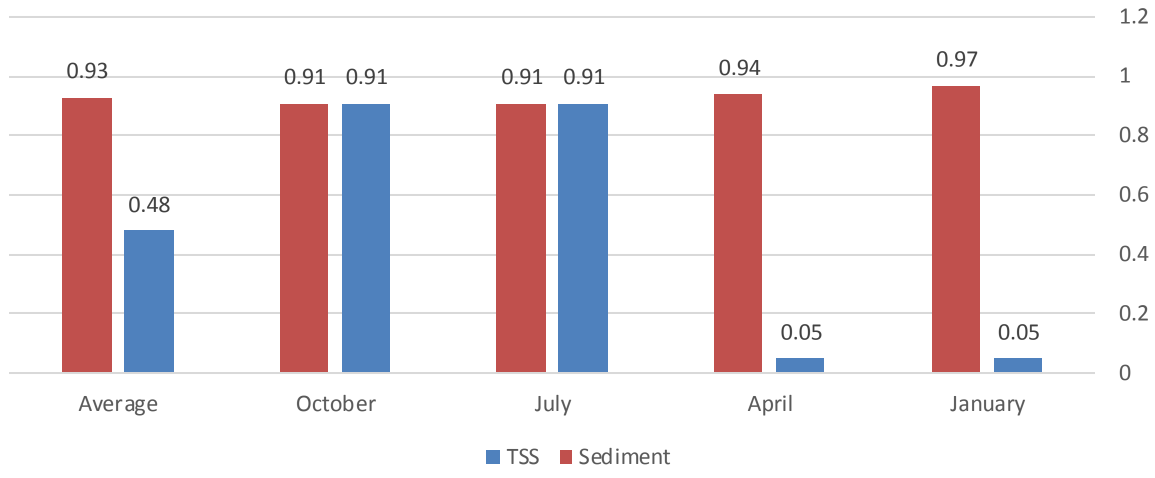


Fig.9. Copper Concentration (µg/gµg /g dry weight) in Total Suspended Solids and Sediment of Engineering Lake during 2019

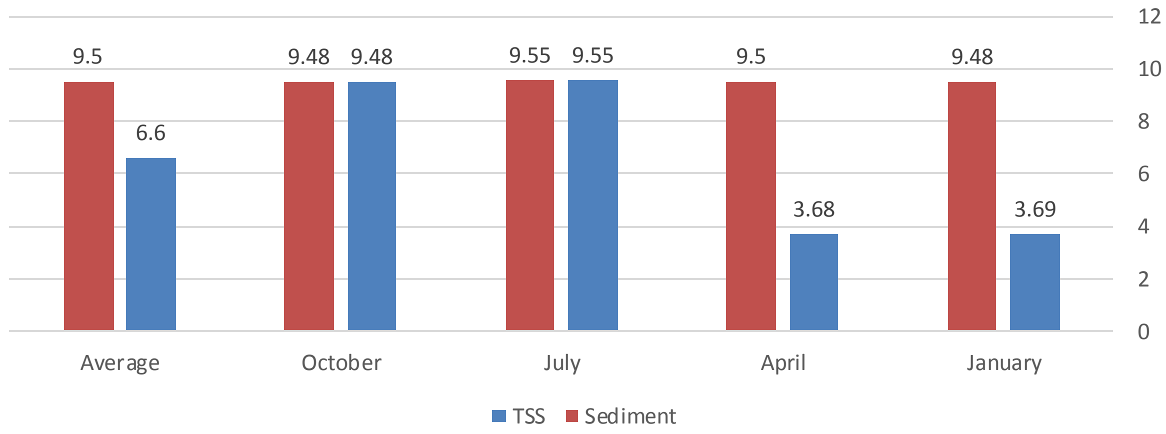


Fig.10. Lead Concentration (µg/gµg /g dry weight) in Total Suspended Solids and Sediment of Engineering Lake during 2019

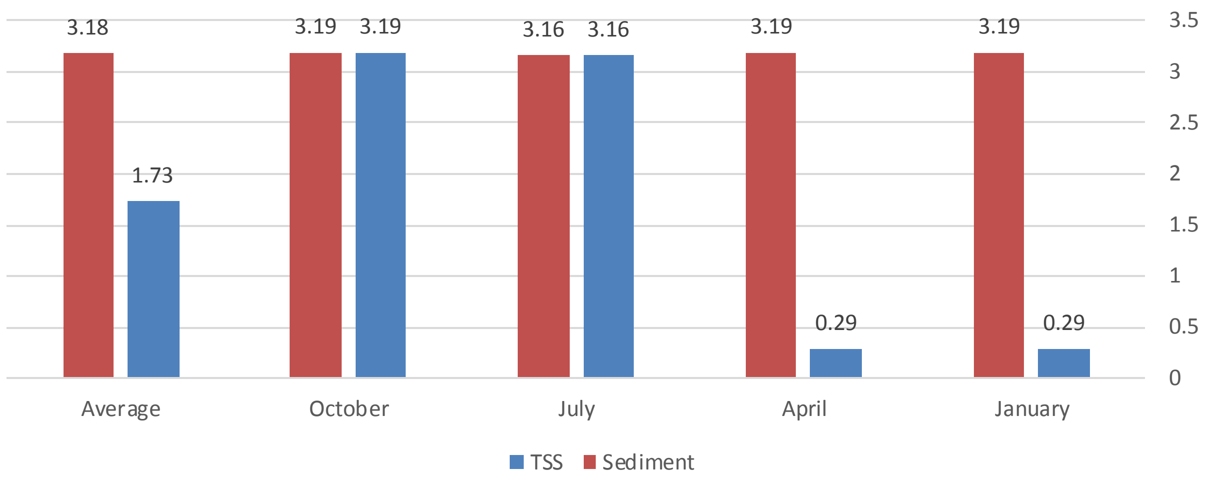


Fig.11. Zinc Concentration (µg /g dry weight) in Total Suspended Solids and Sediment of Engineering Lake during 2019

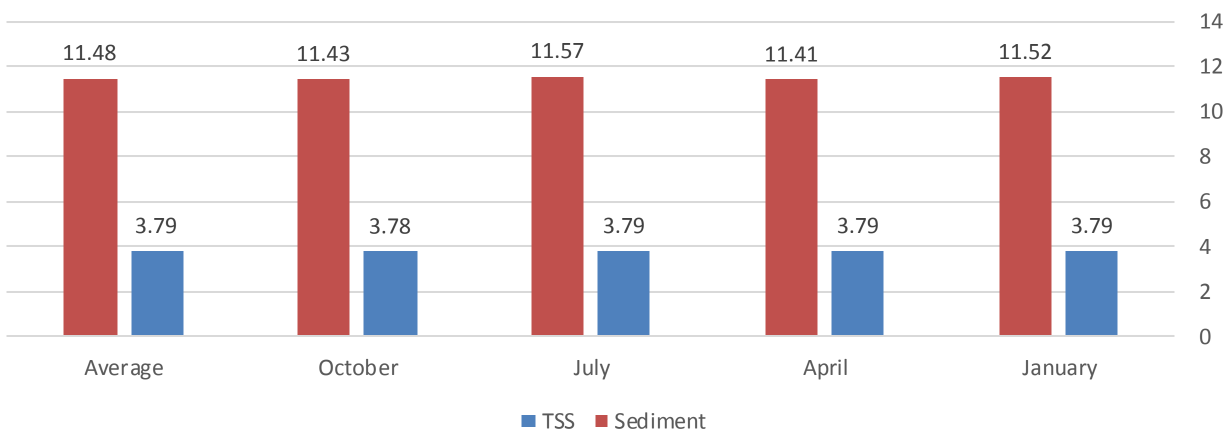


Fig.12. Chromium Concentration (µg /g dry weight) in Total Suspended Solids and Sediment of Engineering Lake during 2019

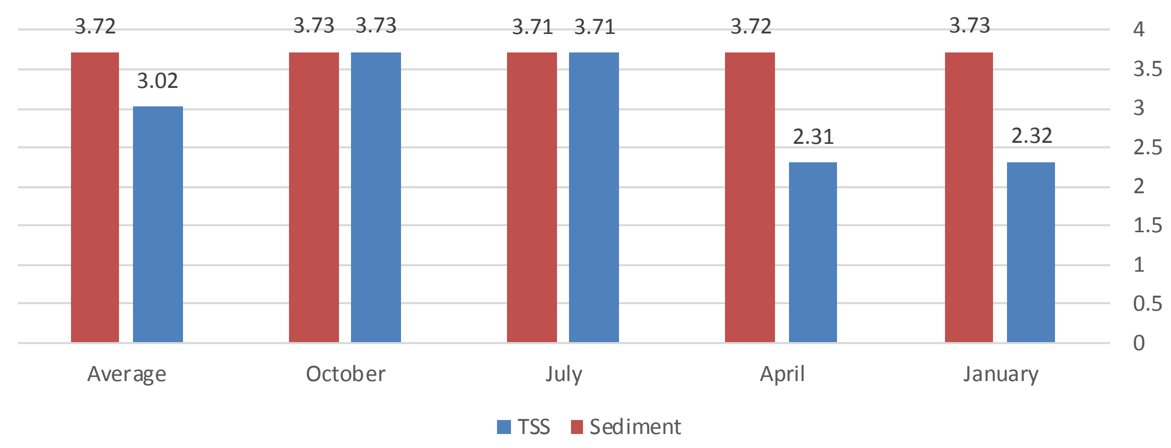
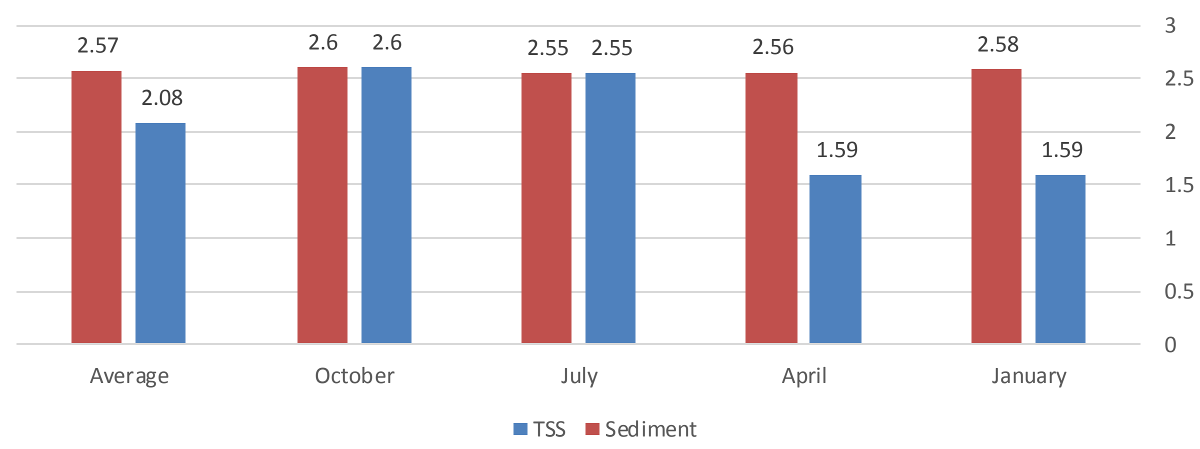


Fig.13. Nickel Concentration (µg /g dry weight) in Total Suspended Solids and Sediment of Engineering Lake during 2019



تقدير تركيز بعض المعادن الثقيلة في المواد الصلبة العالقة الكلية في بحيرة كلية الهندسة و البيئة بالجامعة الوطنية الماليزية خلال عام 2019م

د. خالد صابر عبدالرحمن الشلماني،[1] د. يونس علي طيب،[2] د. أ. د. مشرفة إدريس[3]

الملخص العربي

دراسة تركيز بعض المعادن الثقيلة في المواد الصلبة العالقة الكلية في بحيرة كلية الهندسة و البيئة بالجامعة الوطنية الماليزية خلال الشهور يناير و أبريل و يوليو و أكتوبر خلال عام 2019 م . العينات المائية تم جمعها بواسطة قنينات البولي إيثيلين و بتكرارت ثلاثية ثم رشحت بواسطة أوراق ترشيح قطرها 0.45 ميكرون . تم هضم العينات المائية عن طريق 5 مل من خليط ثلاثة أحماض مركزة عند درجة حرارة 100 درجة مئوية لمدة ساعتين على الفرن الساخن . تم قياس ست معادن ثقيلة (الكادميوم – الكروميوم – الرصاص – النيكل – الزنك – النحاس) بواسطة جهاز المطياف الضوئي . أظهرت الدراسة أن تركيز النحاس كانت الأعلى تركيزاً (9.55) بينما كان الكادميوم الأقل تركيزاً (0.91) . هذا بالإضافة إلى أن أعلى و أقل تركيزات لمعادن النحاس ، الزنك ، الكروم ، النيكل ، الرصاص و الكادميوم كان (-3.73 ,3.79-3.78 ,3.68 -9.55 2.31, 2.60-1.59, 3.19-0.29 and 0.91-0.05) على التوالي كما بينت الدراسة أن متوسط تركيز المعادن الثقيلة في المواد الصلبة العالقة الكلية كان بترتيب تنازلي كالتالي (النحاس – الزنك – الكروميوم – النيكل – الرصاص – الكادميوم) و بالقيم التالية (6.60 ، 3.79 ، 3.02 ، 2.08 ، 1.73 ، 0.48) على التوالي . تراكم المعادن الثقيلة في المواد الصلبة العالقة يعتمد على عدة عوامل مثل محتوي العنصر في المياه، خصائص إمتصاص أنواع العوالق و محتوي المعادن في الرسوبيات . بينت الدراسة أن تركيز المعادن الثقيلة يعتمد على ترسيب العوالق الميتة بالإضافة إلى ترسيب الجزيئات العالقة المحتوية على المعادن الثقيلة .

الكلمات المفتاحية : تركيز المعادن الثقيلة – المواد الصلبة العالقة الكلية – بحيرة كلية الهندسة و البيئة