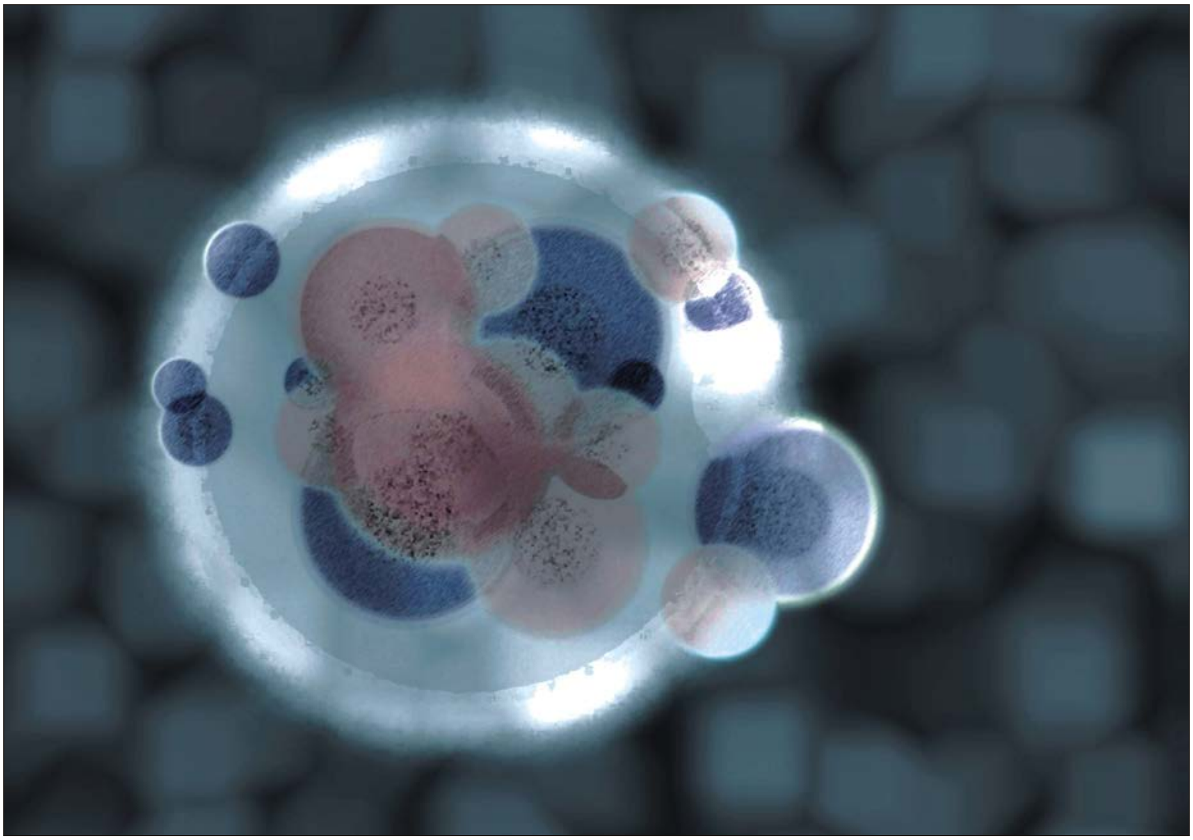

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Heavy Metal Concentrations in Sediments and Fishes from Lake Chini, Pahang, Malaysia

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Abstract: A study was conducted to determine water quality and cadmium, copper, lead and zinc concentrations in sediments and 15 fish species from Lake Chini, Pahang. Physical parameters measured were water temperature, dissolved oxygen concentration, pH and conductivity. Sequential sediment extraction was conducted to extract metals from sediment, which involves three different of non-residual fractions. Fish tissues were extracted using wet digestion method. Metals concentration in sediment and fish were measured using atomic absorption spectrophotometer AAS 4100 Perkin Elmer. According to Malaysian National Interim Water Quality Standards (INWQS), Lake Chini was classified between moderate to good quality. Lake Chini was found to have low metal concentrations in sediments and fish, which indicates no significant anthropogenic metals input to the lake. One-way ANOVA test indicated that all metal concentrations were significantly different ($p<0.05$) between fish species, but not between feeding behavior. Heavy metal concentrations in fish tissues were found lower than the maximum allowable limit suggested by the Malaysian Food Act, which ascertain that the fish is safe to be eaten.

Key word: Heavy metal, fish, sediment, Lake Chini, bioaccumulation, biological monitoring

INTRODUCTION

Malaysia as a developing country is facing with various types of pollutions risk. Heavy metals are amongst main pollutants that cause serious adverse effects to aquatic pollution. These elements are discharge through numerous anthropogenic sources and collective into receiving systems such as sediment, soil and water. Various studies have concerns on metal dispersion into these receiving systems (Kim *et al*., 2002; Lee *et al*., 2001). Increase of industrialization and agriculture could contribute their elevation level in aquatic system (Whalberg *et al*., 2001). Some metals are essential to biotic but could be very harmful when present at excessive concentration. Heavy metals are non-degradable and very harmful to plants, aquatic organisms and human health at certain levels of exposure (Mustafa and Nilgun, 2006).

Pollutants in the aquatic ecosystems will precipitate on the sediment surface and form as deposited pollutants. Sediments naturally consist of a complex mixture of organic and inorganic components like clays, silicates, carbonate, sulphide, minerals and bacteria. Sediment is well known as an important sink and a source for metal contaminants (Li and Thornton, 2001). Pollutants like heavy metals are spread in sediment components and react through ion exchange, absorption and precipitation (Yuan *et al*., 2004). There are three major mechanisms in heavy metals intake by sediments, which are physico-chemical absorption from water, biological intakes and accumulation of metals that are enriched with particles (Hart, 1982).

Fish occupies the highest tropic level in aquatic system (APHA, 1981). Besides that, it has high economical values, thus fish is suitable for water quality symbol and easy to be interpreted by public. Fish can response to environmental changes that can be used for pollution indicator study. Fish is a good bio-indicator because it is easy to be obtained in large quantity, potential to accumulate metals, long lifespan, optimum size for analysis and easy to be sampled (Batvari *et al*., 2007). Heavy metal intakes by fish in polluted aquatic environment are different depends on ecological requirements, metabolisms and other factors such as salinity, water pollution level, food and sediment. Fish accumulates metals in its tissues through absorption and human can be exposed to metals via food web. This will cause acute and chronic effect to human (Dogan and Yilmaz, 2007; Fidan *et al*., 2007). The use of fish as bioindicator can determine the actual situation of pollution level before and during monitoring.

In Malaysia, there are some studies on heavy metals in lakes and rivers such as Bera Lake, Lake Chini, Kenyir

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Lake and Rompin River were conducted (Shuhaimi-Othman *et al*., 2007; Mushrifah and Ahmad, 2005; Ebrahimpour and Mushrifah, 2008, 2009). Lake Chini is one of the tourism attraction destinations that have wide swamp areas and can be considered as pristine. This wet land can react to control water quality and quantity, maintain ecological system and also as a habitat for various species of flora and fauna. Fish from Lake Chini are widely caught by local aborigine for their daily diet or to be sold. Thus, study on metals concentration in sediment and fishes is very crucial to assess the current threats to human health from heavy metal pollution. This study was conducted to establish the concentrations of copper, cadmium, lead and zinc in sediments and fishes from Lake Chini.

MATERIALS AND METHODS

Study area: Lake Chini is the second largest Malaysia's natural lake after Bera Lake. The lake is located at South East of Pahang Darul Makmur. Lake Chini has 12 open water areas that are known as 'sea' by the aborigines. The areas are Laut Gumum, Laut Pulau Balai, Laut Cenahan, Laut Tanjung Jerangking, Laut Genting Teratai, Laut Mempitih, Laut Kenawar, Laut Serodong, Laut Melai, Laut Batu Busuk, Laut Labuh and Laut Jemberau (Shuhaimi-Othman *et al*., 2007). Chini River is the only river that link Lake Chini with Pahang River (Fig. 1).

In general, the lake is considered as pristine and free from metal pollutions even though it has encountered with water overflow and sedimentation which caused by the construction of small barrage at Chini River. Lake Chini is important in tourism industry and fishing activities and generates good incomes to the state government. A number of twelve random sampling sites were chosen within the lake to collect sediment samples, whereas fish were caught at various sites within the lake. The *in situ* measurement was undertaken for selected water quality parameters namely dissolved oxygen, pH, water temperature and conductivity using YSI meter model 85.

Fish and sediment sampling: The study was undertaken in December 2007. Fish were randomly caught using gill net and cast net. A total of fifteen fish species were randomly caught, whereas twelve sediment samples were systematically collected using a soil grab. The fish's physical parameters such as weight and total length were measured prior to the preservation. The fish samples were kept frozen prior to analysis. Water quality measurements were carried out at five stations to determine existing water quality of the study area. The Hydrolab YSI model 85 was used to measure Dissolved Oxygen (DO), pH, temperature (°C) and Total Dissolved Solid (TDS) and conductivity (µS cm^{-1}).

Extraction and determination of metals in fish and sediment: Fish samples were washed with distilled water and scale was removed. Only tissues without bone were selected for extraction. In order to get boneless tissues,

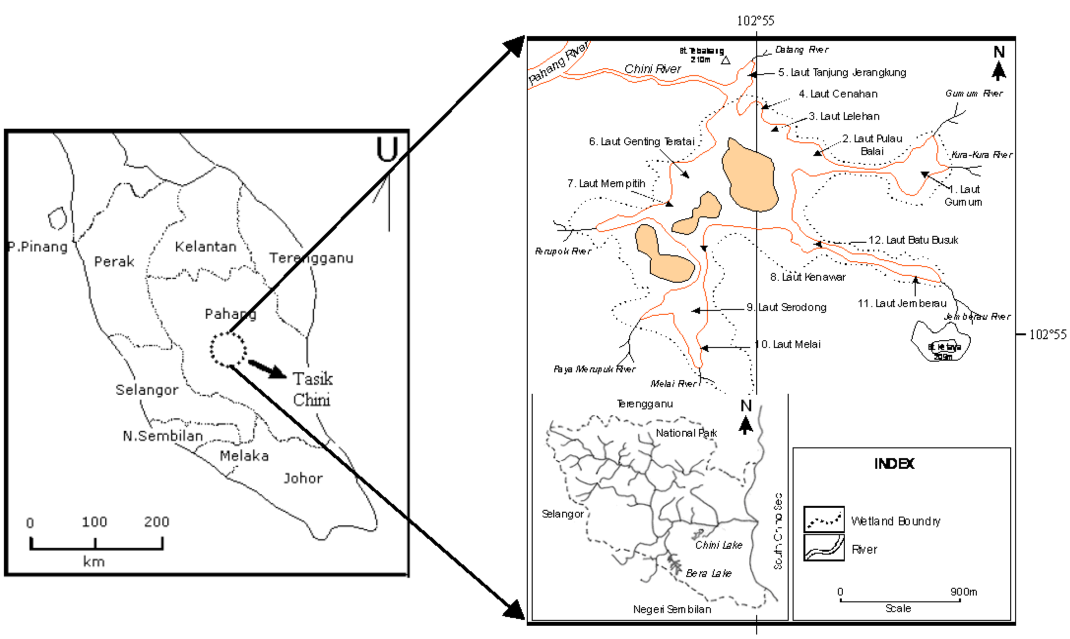

Fig. 1: (a) Malaysian Peninsular and (b) Lake Chini and feeder rivers

only ventro-lateral tissues were taken for further analysis. About 5 g of dry tissues samples were used for extraction. The wet digestion method based on Agemian *et al.* (1980) was used to extract fish tissues. The dry tissue samples were extracted with concentrates nitric acid (HNO_3) followed by perchlorid acid ($HCLO_4$) and digestion was done on the hot sand bath. The sample mixtures (yellowish colour mixture) were then filtered through 0.45 μm pore size and the filtrates were then analyzed using the atomic absorption spectrophotometer AAS model Perkin Elmer 4100B for metal detection.

Sediment samples were dried prior to extraction. Sediment samples (<63 μm) were extracted according to Badri and Aston (1983) and Tessier *et al.* (1979) with some modifications. The sequential extraction was performed by means the three steps in the non-resistant fraction. The three fractions that focus in this study are exchangeable (EFLE), Acid-Reduction (AR) and Organic Oxidation (OO). Ammonium acetate (pH 7) was used to extract metals from EFLE fraction, 0.25 M hydroxylamine (pH 2) was used in AR fraction and ammonium acetate (pH 3.5) and hydrogen peroxide (30%) were used in OO fraction.

Determination of cadmium, copper, lead and zinc in fish and sediment were performed using flame atomic absorption spectrophotometer Perkin Elmer Analyst 800 model. For quality control, procedural blanks and triplicates of the samples were analyzed. Validity of extraction methodology for fish was checked using Standard Reference Material (SRM). TORT-2 (Lobster Hepatopancreas marine) (National Research Council, Canada). All data are measured in μg g^{-1} dry wt.

RESULTS

Water quality: Table 1 shows mean results of the water quality parameters that been determined *in situ* at the study sites. Data shown are an average of three measurements that taken at each of twelve sampling sites. Average Lake Chini water temperature was 29.3±0.87°C with the range of 27.6 to 30.9°C. The pH level of this lake was slightly acidic (5.1 to 6.4). The dissolved oxygen concentration was varied and differed significantly between stations (3.5 to 6.0 mg L^{-1}). Mean water electric conductivity was 31.6±9.44 μS cm^{-1}. Data obtained indicates that dissolved oxygen and pH value were varied between sites. One-way ANOVA test (post-hoc test) demonstrates that both parameters were significantly different between each sampling sites. However, an opposite result was obtained for water temperature and conductivity ($p>0.05$). As regards to Malaysian Interime Water Quality Standards (INWQS), the lake can be classified between classes I to III which is still suitable for water contact recreational activities.

Table 1: Mean value of selected water quality parameters in Lake Chini

Parameters	Average value±SD
Temperature (°C)	29.3±0.87
pH	5.8±0.30
Dissolved oxygen (DO) (mg L^{-1})	4.7±0.77
Conductivity (μS cm^{-1})	31.6±9.44

Table 2: Validation of extraction and analysis with standard reference materials (TORT-2)

Heavy metal	Measured value	Certified value	Accuracy (%)
	---------------(μg g^{-1})	---------------	
Cu	86.30±0.42	106.00±10.00	81
Zn	183.80±1.70	180.00±6.00	98
Pb	0.44±0.01	0.35±0.13	74
Cd	22.21±0.86	26.70±0.60	83

Table 3: Concentrations of anthropogenic metals in sediment from twelve sampling stations (mg kg^{-1} dry wt.)

Station	Lead (Pb)	Copper (Cu)	Zinc (Zn)	Cadmium (Cd)
1	14.30±2.13	4.42±0.56	44.67±2.23	1.57±0.06
2	9.55±1.66	4.08±0.05	32.16±1.79	1.38±0.05
3	4.46±1.23	3.69±1.09	25.66±0.59	1.37±0.01
4	5.05±0.15	2.88±0.06	17.92±1.44	1.25±0.08
5	5.31±1.36	3.52±0.25	30.47±1.81	1.38±0.10
6	5.63±0.58	5.60±0.13	61.69±0.52	1.65±0.09
7	10.70±3.92	7.73±0.52	70.07±2.39	1.73±0.10
8	7.59±0.58	9.41±0.10	78.11±2.04	1.95±0.05
9	4.99±0.19	9.65±0.52	96.85±1.91	2.13±0.07
10	17.95±0.89	6.50±0.40	61.81±0.54	1.78±0.06
11	30.64±3.94	8.84±2.02	59.84±1.94	2.22±0.25
12	17.74±1.10	8.31±0.42	56.86±0.88	1.80±0.11

Standard reference materials: Table 2 shows the measured values for TORT-2 standards reference materials. The result from the analysis shows a strong agreement with the certified reference values provided by the NRC of Canada. Only lead exhibits low recovery which is below 80% of total metal concentrations.

Anthropogenic metals in sediment: The total metal concentrations in non-resistant fraction frequently used to indicates the level of pollution in aquatic systems. Although, various name and chemical were used to extract metals from non-resistant fraction, the aim is similar that is to estimate metals load in aquatic systems. Concentration of anthropogenic metals in sediment is the total concentration of heavy metals in three non-resistant fractions, which includes easily and free leachable and exchangeable fraction, acid reduction and organic oxidation fraction (Table 3). Zinc was detected at highest concentrations in every sample as compared to other metals. Cadmium was the most mobile metals which found highest in EFLE fraction followed by Zn and Cu, respectively. Similar rank of metals concentrations was recorded in acid reduction fraction (Fig. 2). The organic oxidation fraction contains highest Pb (almost 100%) followed by Cu, Zn and Cd. This fraction bound metals harder than other fractions and reduces metal mobility in aquatic systems. Therefore, Pb was found to be the least mobile and in contrast Cd was the most mobile metal.

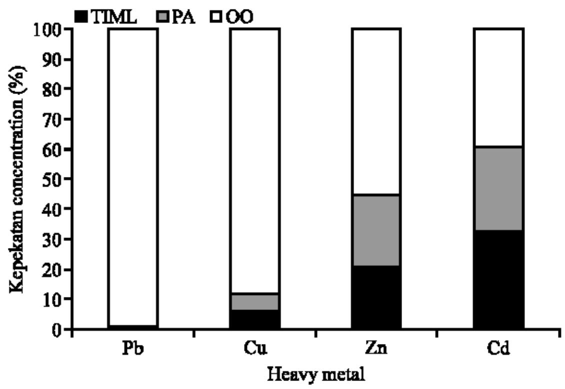

Fig. 2: Proportion of heavy metals in sediments non-residual fraction (anthropogenic)

Table 4: Mean concentrations of heavy metals in sediment from 12 stations ($\mu g\ g^{-1}$ dry wt.)

Heavy metals	Non-residual fraction (Mean concentration±standard deviation)
Pb	11.16±7.86
Cu	6.22±2.50
Zn	53.01±23.45
Cd	1.68±0.31

Table 5: Sediment criteria according to EPA region V[a]

Heavy metals	Unpolluted	Slightly polluted	Seriously polluted	Average concentration in Earth's crust
Pb	< 40	40-60	> 60	16
Zn	< 90	90-200	> 200	80
Cu	< 25	25-50	> 50	70
Cd			> 6	0.2
Fe	< 17000	17000-25000	> 25000	50000
Mn	< 300		> 500	1000

[a]Concentration in $mg\ kg^{-1}$ dry wt.

Metal concentrations in sediment exhibit significant variation between sampling stations. Station 9 contained the highest levels of Zn and Cu (96.85±1.91 $mg\ kg^{-1}$ and 9.65±0.52 $mg\ kg^{-1}$, respectively). Pb and Cd were detected highest in sediments from station 11 (30.64±3.94 and 2.22±0.25 $mg\ kg^{-1}$, respectively).

Although, metals on sediments vary between sampling stations, the mean concentrations of anthropogenic metals (combination of three fractions) obtained from 12 stations (Table 4) were found to be low even lower than EPA guideline concentrations in unpolluted area (Table 5). None of studied metals found exceed the maximum recommended concentration in sediment from unpolluted sediments. This indicates that Lake Chini is considered as unpolluted from those metals.

Metal concentrations in fish muscles: Study on metals concentration in fish muscles of the means to estimate amount of metals transported into human body through feeding. Table 6 shows the physical characteristics of collected fish. The physical parameters were used to estimate fish age. The fish age provides an ideas on how long the fish are exposed to studied metals. As regards to (Mohsin and Ambak, 1991) classification, this study found that most of the fish samples were considered as an adult. The mean metal concentrations ($\mu g\ g^{-1}$ wet wt.) in 15 fish species are shown in Table 7. The average concentrations of Cu, Zn, Pb and Cd are 0.46±0.023, 4.46±0.051 and 0.45±0.024 and 0.28±0.020 $\mu g\ g^{-1}$, respectively. Zinc mean concentrations was the highest as compared to other metals and ranged from 1.69-6.76 $\mu g\ g^{-1}$. Copper was detected highest in *Channa micropeltes* (snake head) followed by Zn. Most of fishes have Zn concentrations above 2 $\mu g\ g^{-1}$ except *Helostoma temmincki* (gouramy). *Cylocheiiichtys apogon* and *Hampala macrolepidota* accumulated the highest level of Zn concentrations (6.76±0.055 and 6.75±0.163 $\mu g\ g^{-1}$, respectively). Metals accumulation in fish was found in the order of Zn>Cu>Pb>Cd. Not like in sediments, metals concentration in fish tissues were detected at small variations.

Table 6: Physical data and age estimation for collected fishes

Species	Length (cm)	*Maturity size/Adult (cm)	Status
Puntius schwanenfeldii	14.5-17.0	6-20	Mature
Ompok bimaculatus	8.5-19.0	50.0	Premature
Cylocheinichtys apogon	11.0-15.0	7.0-20.0	Mature
Osteochilus hasseltii	11.0-13.0	10.0-20.0	Mature
Notopterus notopterus	14.0-16.5	20.0	Mature
Chana micropeltes	12.0-12.5	20.0-100.0	Premature
Puntius bulu	14.0-21.0	50.0	Premature
Labiobarbus festiva	13.5-15.8	12.0-18.0	Mature
Osteochilus melanopleura	11.3-15.7	30.0	Premature
Hampala macrolepidota	25-26	20.0-35.0	Mature
Chela oxygastroides	9.5-11.5	10.0-12.0	Mature
Mystus nigriceps	4.0-15.5	-	-
Thynnichthys thynnoides	11.5-16.0	12.0-19.0	Mature
Barbichthys laevis	12.0-16.0	12.0-20.0	Mature
Helostoma temmincki	17.5-21.0	8.0-30.0	Mature

*Source: Mohsin and Ambak (1991)

Table 7: Mean metal concentrations in various fish species ($mg\ kg^{-1}$)

Species	Cu	Zn	Pb	Cd
Puntius schwanenfeldii	0.30±0.013	4.09±0.071	0.49±0.015	0.23±0.025
Ompok bimaculatus	0.26±0.012	3.18±0.051	0.20±0.025	0.17±0.015
Cylocheinichtys apogon	0.51±0.004	6.74±0.055	<0.01	0.22±0.020
Osteochilus hasseltii	0.13±0.006	4.67±0.020	0.62±0.025	0.47±0.015
Notopterus notopterus	0.23±0.010	4.70±0.020	1.14±0.040	0.32±0.015
Chana micropeltes	2.13±0.153	5.03±0.064	<0.01	0.33±0.025
Puntius bulu	0.32±0.031	2.77±0.036	0.99±0.011	0.15±0.020
Labiobarbus festiva	0.41±0.006	4.97±0.040	0.10±0.001	0.47±0.020
Osteochilus melanopleura	0.14±0.020	4.55±0.036	0.62±0.020	0.18±0.015
Hampala macrolepidota	0.32±0.005	6.75±0.163	0.44±0.035	0.31±0.021
Chela oxygastroides	0.55±0.015	5.14±0.025	0.35±0.031	0.38±0.020
Mystus nigriceps	0.31±0.020	3.16±0.035	0.25±0.035	0.19±0.015
Thynnichthys thynnoides	0.77±0.012	5.86±0.075	0.29±0.010	0.19±0.021
Barbichthys laevis	0.21±0.020	3.66±0.035	0.31±0.021	0.32±0.025
Helostoma temmincki	0.27±0.012	1.69±0.035	0.95±0.094	0.27±0.025
Mean±SD	0.46±0.023	4.46±0.051	0.45±0.024	0.28±0.020

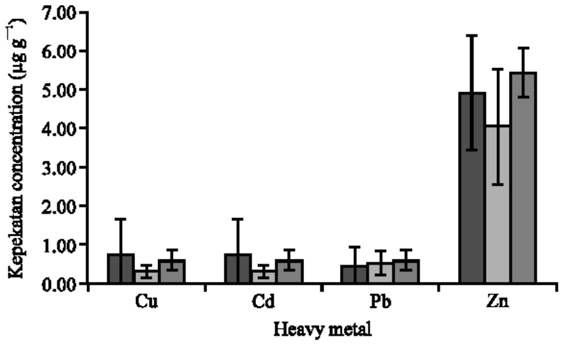

Fig. 3: Heavy metals in fishes of different feeding behavior

Data for metals in fish were tested for normality using Kolmogorov-Smirnov test and result indicates that Cu and Zn concentrations were following normal distribution. One-way ANOVA test indicated significant variation of Cu and Zn across various fish species ($p<0.05$). Post hoc Turkey (One-way ANOVA) test pointed that the concentration of Cu in *Chana micropeltes* was significantly different compared to other fishes, whereas Zn in *Hampala macrolepidota*, *Cylocheinichtys apogon* and *Helostoma temmincki* were dissimilar from the others. Average concentrations of Cd in fish tissues ranged from 0.15-0.47 $\mu g\ g^{-1}$. Various fishes such as *Ompok bimaculatus*, *Puntius bulu*, *Osteochilus melanopleura*, *Mystus nigriceps* and *Barbichthys laevis* have Cd less than 0.2 $\mu g\ g^{-1}$. Concentrations of Pb in all species were also low and not more than 0.70 $\mu g\ g^{-1}$ even below the detection limit in *Cylocheinichtys apogon* and *Chana micropeltes*. However, multiple comparison test using Post hoc Turkey test indicates that *Osteochilus hasseltii*, *Notopterus notopterus*, *Puntius bulu* and *Helostoma temmincki* accumulated significantly higher.

Fishes collected were grouped according to their feeding behavior and average metal concentration in the muscle are presented in Fig. 3. Each metal found approximately at similar concentration and not significantly differ between feeding groups ($p>0.05$, $\alpha = 0.05$).

DISCUSSION

Water quality: The average Lake Chini's water temperature recorded in this study was slightly higher compared to other researches (Shuhaimi-Othman *et al*., 2007). This could due to long sampling duration that was conducted continuously from 10 am to 4 pm. Lake Chini is a shallow natural lake and receives high sunlight exposure. However, water temperature recorded was still normal for lake water body in tropical countries. Shuhaimi-othman *et al*. (2007) from their study reported that the mean temperature of Lake Chini was ranged between 27.3 to 31.4°C.

This study found that Lake Chini water body was slightly acidic with the mean value was 5.8±0.30 and ranges from 4 to 6. Shuhaimi-Othman *et al*. (2007) found that the average pH level was 6.49±0.15. The presence of water gate (barrage) at Sungai Chini has increase Lake Chini water level and inundated various riparian plants and other aquatic plants such as water lily and lotus. Thus, dead plants were decayed and created eutrophic condition and drop water alkalinity. However, the value is still suitable for freshwater ecosystem (Kutty *et al*., 2005). Fish will die if the pH value is lower than 4 or more than 10. According to Malaysian Interims Water Quality Standards (INWQS), the measured pH value classify Lake Chini in class III, which is moderate condition.

Lake Chini has low mean dissolved oxygen concentrations (4.7±0.77 mg L^{-1}). In recent years, various major developments such as oil palm plantation and illegal logging activities are happening nearby the lake. Soil erosions and forest clearance expected to cause sedimentation and reduce oxygen concentration in water. High decomposition of organic matters in the lake could enhance dissolved oxygen depletion in water. The water gate at Chini River reduces dissolved oxygen concentrations in the lake by reducing water flow. As regards to Malaysian National Water Quality Standard (NWQS), the dissolved oxygen concentrations classify Lake Chini in class III. Water conductivity value recorded was within the natural range of concentration. According to Chapman (1996), conductivity level for most of the freshwater areas are ranged between 10 to 1000 $\mu S\ cm^{-1}$. The conductivity recorded classified Lake Chini in class I. Result from few water quality analysis demonstrates that Lake Chini is characterized by good to moderate quality. A temporal water quality monitoring conducted by Shuhaimi-Othman *et al*. (2007) demonstrates that Lake Chini water quality was varied between seasons and locations.

Heavy metals in sediment: The anthropogenic metal concentrations obtained in this study were compared with other previous studies such as Juru River and Klang River which are declared by Malaysian Department of Environment (DOE) as polluted rivers. Direct comparison is not very suitable since some researches may differ in their methods. However, rough comparison is appropriate in order to estimate metal concentrations in sediments. Result of the study demonstrates that Lake Chini has lower Pb and Cu concentrations compared to the Juru River and Klang River, however higher Zn and Cd concentrations than Juru River. Although, Lake Chini has higher Zn and Cd concentrations, but the values still within the range of other unpolluted river such as Sg. Kelantan (Ahmad *et al*., 2009). Shuhaimi-Othman *et al*. (2007) reported that Lake Chini is potentially to receive some effluents from the nearby mining project through the seepage process.

Although Lake Chini has higher elevation for some metals, the concentrations still below the pollution benchmark as published by EPA (Table 5). This study reveals that although Lake Chini is located far from developed area and free from anthropogenic sources, some metals namely Zn and Cd were found high and potential to contaminate the lake in the future. Improper agriculture and illegal mining activities and land clearance could lead to contamination in future.

Factors that affect the concentrations of heavy metals in fish tissues: The accumulation of metals by the fish depends on the location, feeding behaviour, trophic level, age, size, duration of exposure to metals and homeostatic regulation activities of fish (Sankar *et al*., 2006). Kargin (1996) has listed multiple factors that influence metals accumulation in fish such as season, physical and chemical properties of water. Knowledge of metals concentration in fish is important to management for various purposes such as risk of taking fish as part of diet and metals pollution control strategies. Most of fish are at top in aquatic food chain and have potential to accumulate high metals content even in mild polluted conditions. Therefore, metals concentration in fish could be used as an index to estimate level of pollution especially in aquatic bodies (Karadede-Akin and Unlu, 2007) even in the lake system. Although, fish muscle was reported have lowest metal concentrations compare to bone, gill and liver, this study focus metals in fish muscle since, people eat fish muscle and not others.

Fishes collected from Lake Chini are comprises of three different types of feeding behaviors; herbivor, omnivor and carnivor. *Chana micropeltes*, Hampala *macrolepidota*, *Notopterus notopterus* and *Ompok bimaculatus* are carnivores (consume small fishes); *Osteochilus melanopleura* and *Thynnichthys thynnoides* are herbivores (consume plants) while the *Puntius schwanenfeldii*, *Cylocheinichtys apogon*, *Osteochilus hasseltii*, *Puntius bulu*, *Labiobarbus festiva*, *Chela oxygastroides*, *Mystus nigriceps*, *Barbichthys laevis* and *Helostoma temmincki* are omnivores (Mohsin and Ambak, 1991). Feeding behaviour is one of the decisive factors of heavy metals accumulation in fish. Although, many studies showed carnivores accumulate higher metal concentrations (Mohsin and Ambak, 1991; Amundsen *et al*., 1997) result of this study demonstrates that metal concentrations in three different feeding behavior are not significantly differ (Fig. 3). Low metal concentrations in lake ecosystem could limits the absorption these metals in the organisms.

Age factor or maturity of fish may influence the accumulation of heavy metals (Mohsin and Ambak, 1991). Growth rate is important to stabilize the accumulation of metals. Fish can accumulates high level of pollutants if it has a constant growth and live in polluted ecosystem. This study indicates that mature fish accumulated higher metals compared to juvenile and premature fish. *Labiobarbus festiva*, *Chela oxygastroides* and *Osteochilus hasseltii* (mature omnivour fish) accumulated higher concentrations of Cd rather than *Osteochilus melanopleura* and *Ompok bimaculatus* (premature). Although, comparison between same species is more appropriate, however, the comparison made was based on similar feeding behaviour. This study was unable to obtain sufficient number of fish to make comparison between age for the same species.

Comparison of various studies on metal concentrations in fish muscle is shown in Table 8. This study found Cu and Zn concentrations were almost as low as from unpolluted lake likes Eber (Findan *et al*., 2007). However, Cd and Pb concentrations were higher than fishes from Eber Lake and Taihu Lake (Chi *et al*., 2007). Both metals were probably contributed to the lake through various sources, such as agriculture activities likes oil palm and rubber plantations nearby lake. A large scale of oil palm plantation was developed nearby the lake and the use of chemical

Table 8: Comparison of metals in fish from other sampling locations

	Heavy metals ($\mu g\ g^{-1}$)			
Reference areas	Cu	Zn	Pb	Cd
Eber Lake, Afyonkarahisar[1]	0.33-0.60	6.73-10.74	0.00-0.02	≈0.01
Taihu Lake, China[2]	0.228-1.890	16-130	0.177-0.289	0.004-0.021
This study	0.13-0.77	1.69-6.76	0.00-1.14	0.15-0.47
*Max. permissible limit (Malaysian Food Act, 1983)	30	100	2	1

[1]Fidan *et al*. (2007), [2]Chi *et al*. (2007), *Malaysian Food Act (1983)

fertilization could introduce Cd to the lake. Excessive fertilizer may be transported to the lake through surface run off. Lake Chini has several main feeder streams that could transport these metals into the lake. The inflow water from Pahang River to Lake Chini during rainy season or monsoon season also could bring pollutants including metals into the lake. Nonetheless, the concentrations of these metals were still below the permissible limit suggested by the Malaysian Food Act (1983).

This study indicates that although still below hazardous level, non-essential metals namely, Pb and Cd and essential metal namely Zn were quite high and continues input could risk the lake ecosystem. Continual accumulation in fish muscle could transports metals to human through diet. Local aborigines surround the lake catch fish for their daily diet.

CONCLUSION

According to Malaysian Interim Water Quality Standards, Lake Chini can be classified between classes I to III which is suitable for aquatic organisms growth. Heavy metals concentrations in sediment's non-residual fraction ascertain that Lake Chini is free from metal contaminants, although Pb, Cd and Zn were exhibits slightly high concentration. Fishes are safe to be taken for daily diet since all metals detected in fishes were below the permissible limit suggested by the Malaysian Food Act (1983).

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