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Research paper

Spatial Variation Characteristics of Selected Soils in the Tasik Chini Watershed, Pahang, Malaysia

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Abstract

This study was carried out to assess the properties of soils in Tasik Chini watershed. Approximately 2741.52 ha of the total study area were selected for soil analyses. The physico-chemical properties and nutrient content were analyzed according to standard methods. The analyses showed that the sand dominant soil series were Serdang, Kuala Brang and Kekura series. The lowest sand content soil in both top soil and subsoil was Lating series (2.02% to 3.48%). On the other hand, the highest percentage (46.49%) of silt was measured in the Kedah soil series with the lowest value (17.71%) in the Kuala Brang series. The low pH value and low electrical conductivity was found in all studied soils. The results show that the cation exchange capacity (CEC) value of all top soils were comparatively higher than those of the subsoils. The mean CEC value of all the studied soil series was lower. The concentration of soil available phosphorus (P) and magnesium (Mg) of all the series were measured and categorized as low and very low, while the potassium (K) exchangeability of all series were higher. The obtained data indicated that some selected heavy metals were found in all the studied soils but did not exceed the normal stipulated levels.

Keywords: *Soil properties; available nutrients; heavy metals; soil profile; Tasik Chini*.

1. Introduction

Soil quality is related to soil characteristics such as fertility and contamination. Soil characteristics depend on human land use, as well as land management by humans to produce crops and benefits [1]. The main sources of heavy metals in soil can be divided into two sectors. Firstly they arise from natural processes, such as mineralization and weathering. Secondly they come from anthropogenic sources due to human activities [2]. Soils are altered significantly by anthropogenic activities in urban and agricultural environments [3]. Deforestation due to logging, land use change, construction of road and other interferences by human activities will increase the rate of erosion and the amount of sedimentation into the lakes, rivers, reservoirs and seas. Although erosion is a natural process on the earth surface, it is seriously accelerated by human action. Generally soils contain the higest amount of contaminants. The concentration of pollutants in the soils depend mostly on adsorption and soil properties. The concentration of heavy metals are typicaly influenced by so many factors of the soils such as soil pH, organic matter, electrical conductivity, moisture content etc. [4-5]. Moreover, it is challenging for scientists to research on heavy metals because of their methods of determination, analysis and monitoring, toxicity to living organisms, transformation and mi-gration in the environment [6].

Thirty one soil series were identified within the Tasik Chini watershed (Figure 1). Seven sampling stations were selected based on soil series (of the study area) that could hamper the Chini Lake water quality. The studied soils covered nearly 2349.74 ha or 40.37% of the study area. The seven major series were the Prang, Serdang, Tebok, Kedah, Kekura, Kuala Brang and Lating. The Kekura soil series is weakly weathered and gray in colour. The Kuala Bang soil series is bright reddish brown in colour and moderately weathered soil. The colour of Prang series is yellowish and strongly weathered soil. The Latin, Serdang, Kedah, and Tebok soil series constituted partly eroded soils. These seven soil series are distributed within and around the Tasik Chini (Figure 1). Based on the Malaysian Soil Taxonomy Classification, the Prang soil series belong to Oxisols soil; the Tebok, Serdang, Kedah, Kuala Brang and Lating to Ultisols soil and, the Kekura is Entisols soil. However, soil physico-chemical properties affect the heavy metal availability in diverse ways. A large amounts of metallic elements can become very toxic to both plants and animals. The concentration of soil contaminants basically depends on the surface assimilation properties of soil matter. Some soil factors (pH, conductivity, moisture content etc.) directly influence the availability of soil heavy metal ions. Therefore, the present study focused on soil characteristics and heavy metals concentration in order to quantify their potential physico-chemical impact on the Chini Lake water quality. The aim of the present work was to measure the physical and chemical properties of the seven soil series and the concentration of selected heavy metals in the Tasik Chini watershed to assess the soil quality and soil environment.

2. Site Description

The study site (5820.52 ha) was situated in the southeastern part of Pahang state in Malaysia, Tasik Chini is the second largest natural fresh-water lake in Peninsula Malaysia, encompassing 202 hectares of open water, as well as 700 ha of Riparian, Peat and lowland Dipterocarp forest [7]. The lake system is located at longitude 102° 52′40″ to 102°58′10″E and latitude 3°22′30″ to 3°28′00″N, and about 100 km far from Kuantan city, the capital of Pahang state. Some communities of indigenous people live around the lake. Tasik Chini is totally surrounded by variously vegetated lower hills and undulating surface of land which constitute the watershed. There are three hilly regions surrounding the lake specially the Ketaya hills (209m) located southeast, the Tebakang hills (210m) at the north and the Chini hills (641m) southwest. The study area has humid tropical climate with two monsoon periods, characterized by the following bimodal pattern. The study watershed received an annual average rainfall of 2,500 mm. During the study period, the annual rainfall varied from 1488 to 3071 mm. The average maximum temperature recorded during summer was 32°C and the minimum was 21°C during monsoon. The Tasik Chini watershed has very hot and humid climate during the summer season with the highest mean temperature of 33°C during the day. The average annual potential evapotranspiration (PE) ranges from 500 to 1000 mm.

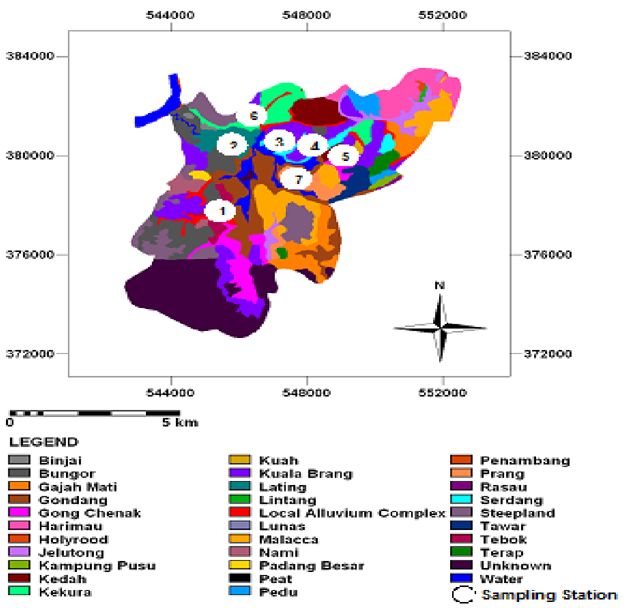

Fig. 1: Location of the study area and sampling stations

3. Materials and Methods

3.1. Sample Collection and Preparation

Top and subsurface soil samples were collected from different locations of the Tasik Chini watershed, as shown in Figure 1. The Global Positioning System (GPS) was used to determine the actual coordinates of the sampling stations. Seven sampling sites were selected throughout the study area based on soil series and land use patterns. Topsoil samples were collected from a depth of 0 - 20 cm using a soil probe. Five samples were collected and labeled from each location site. Topsoil was collected randomly with a Dutch auger. Approximately 500g soil samples were taken from every sampling station. Soil samples from the subsoil at each sampling location were also collected. Subsurface soil samples were also obtained from each identifiable horizon within the soil profile for laboratory analysis. The soil horizons in the profiles were isolated and described. All soil samples were properly labeled in polythene bags and brought to the laboratory. All samples were air dried in a clean area and broken into smaller sized particles with a wooden mortar and pestle in the laboratory. The dried samples were sieved through a 2 mm sieve.

3.2. Analytical Methods

Soil samples from each site were lab tested for size of soil particles, density, soil organic matter content, soil pH, electrical conductivity, exchangeable acidic (Al and H) and basic cations (Ca, Mg, K and Na), cation exchange capacity (CEC) and available nutrients in the soil. Heavy metal content was determined by inductively coupled plasma–mass spectrometry (ICP–MS). The particle size was measured using the pipette method [8]. Soil texture class was obtained by plotting the percentage ratio of sand, silt and clay using the soil textural triangle [9]. The bulk density of soil was measured using the open ended metal cylinder (Ring) method [10] and true density was calculated using the equation derived by [11]. The percent porosity was obtained using the true and bulk densities. The amount of organic matter present was determined from weight loss on ignition [12]. Soil pH was measured using a 1:2.5 soil-to-water ratio [13]. Exchangeable soil acid cations (Al and H) were measured by titration method with 1.0 M KCl extract [14]. The basic exchangeable cations of the studied soils were determined using 1.0 M ammonium acetate extract and the Flame Atomic Absorption Spectrophotometer (FAAS) [15]. The cation exchange capacities of studied soils were quantified by summation of the acidic and basic cations. The electrical conductivity of soil was determined using a saturated gypsum extract [16]. Available potassium (K) and magnesium (Mg) were extracted by the double acid method and determined by the spectrophotometer. The extractable phosphorus (P) was measured by the UV Spectrophotometer.

4. Results and Discussion

4.1. Characteristics of Physical Properties

The characteristics of soil physical properties varied from soil series to series. The results showed that all the soil series contained low amounts of organic matter (OM). The highest values recorded were in the Lating, Kuala Brang and Prang series and they ranged from 3.88% to 8.73%. These soils were rated as clay soil. The amount of OM was found to decline with increasing depth. The highest OM concentrations were measured in the topsoil due to breakdown of massive leaf litter, found on the surface. The lowest soil organic matter content was recorded in the sandy texture soils, such as the Kekura series (1.14%). In [3] reported that the clay soils retained high amounts of organic matter compared to sandy soils. Similar results have also been reported by [17] where OM content ranged from 1.10% to 2.90% in sandy texture soils. According to the classification of [18], OM in the studied soils came under the category of medium to low (OM< 10%).

Bulk density values in the present study ranged from 1.03 to 1.32 g/cm^3 with an average value of 1.13 g/cm^3. The bulk density of the clay loam soil (Serdang) was the highest (1.32 g/cm^3) and the clay textured soil (Prang) had the lowest (1.03g/cm^3) values. The bulk densities of the topsoils were always lower value than those of the subsurface soils, due to the presence of OM. In [19] indicated that the dramatically increase in soil bulk density and decline in percent pore space in the soil were the most possibly caused by the decrease in the soils' organic matter content. The bulk density of Kekura soil series (sandy loam texture) was also high due to low organic matter content. Sandy loam textured soils usually have higher bulk density because of larger but fewer pore spaces. On the other hand, the Prang, Kuala Barng and Lating soil series were under lowland dipterocarp forest and primary forest vegetation. That eventually resulted the content of higher amount of organic matter and huge root penetration. However, the bulk density value was recorded lower than that of the Kekura soil series. Similar results were found in the forest soils of Japan where the average bulk density was affected by the presence of organic matter [20]. In [21] reported that the undisturbed forest soil normally had lower bulk density compared to soil used for agriculture due to the greater pore volume generated by coarse roots and rich soil structures. In [22] noted that the depletion in bulk density could be imputed to higher organic matter content of the soil.

The true density in the present study ranged from 2.52 to 2.74 g/cm^3. The mean value for the true density was 2.65 g/cm^3. The highest true density was found (2.74 g/cm^3) in the Kekura soil series due to the sandy nature of the soils and the lower organic matter content. The Prang series had the lowest value of true density (2.52 g/cm^3) due to the presence of high organic matter in soil. In [23] reported that the content of organic matter in a soil significantly affected the true density in soils. The calculated total porosity values varied from 51.65% to 59.55% with mean value of 57.42%. The highest value (59.55%) was found to be recorded in the clay textured soils (Kuala Brang series) and the lowest value (51.65%) in the clay loam soil (Serdang series). The highest total porosity obtained from the untroubled forest soils such as Prang Tebok, Kedah, Kuala Brang and Lating soils. Due to agricultural activities, the Serdang series was troubled soil and had the lowest porosity value. The Serdang series was influenced by human activities throughout the oil palm plantation area. The porosity of the top soil was slightly higher than that of the sub surface soil. In [24] reported that the soil total porosity was directly influenced by root growth of plant, storage and movement of air and water.

4.2. Characteristics of CHEMICAL PROPERTIES

The chemical properties of the soil series varied from station to station. The pH values of the soils varied from 3.22 to 4.82 with the mean value of 4.04. Almost all of the pH values were below 4.50 due to presence of acid forming ions. These values are considered very low (pH < 4.50) in the classification by [25]. These values of soil pH are common for forest soils in Malaysia where chemical process and leaching occur endlessly moreover the breakdown effect of organic matter. The most studied soil profiles showed a little bit increase in the pH values with depth, with the exception of the Prang soil series. In [26] reported that the soil pH values increased a bit with deepness of the profile, indicating the occurrence of moderate leaching and weathering process. In present study area the electrical conductivity (EC) values ranged from 2.02 to 3.32 mS/cm. A lower range of EC was measured in the studied soil series. The lowest value (2.02 mS/cm) was recorded in the Prang soil series and the highest value (3.32 mS/cm) for the Kekura series. The average EC value was 2.67 mS/cm. The estimated values of EC were below 4.00 mS/cm, demonstrating that these soils were not saline. The variation of EC values in study area did not affect the quality of soil and these soils are suitable for crops. In [4] showed that the soils with EC below 4.00 mS/cm are non-saline and EC values above 8.00 mS/cm are considered severely saline.

The average values for the cation exchange capacity (CEC) ranged from 1.08 to 9.70 meq/100g soil, and the mean value of 5.36 meq/100g soil. The calculated CEC values of all the top soils were mostly higher than those subsurface soil profiles. In [27] reported that the surface soil had higher CEC value than that of the subsurface horizons and decreased with soil depth. The variation of CEC values in soils might be influenced by the types of soil texture. The CEC value in the Kedah soil series was the highest (9.70 meq/100g soil), while the lowest (1.08 meq/100g soil) was for the Prang soil series. The exchangeable basic cation values of top and subsurface soils were very low due to the low pH. The results indicated that the base exchange at the surface soil was controlled by the acidic cations such as Al3+ and H+. The Kekura series was dominated sandy loam in texture soil but the CEC value was higher than that obtained from the clay in texture soil series (Prang). Moreover, the Kekura soil had low pH and was influenced by the acidic cations of Al3+ and H+ (3.00 meq/100g soil) as opposed to the Prang (1.90 meq/100g soil) soil series. Similar characteristics of acidic soils were found by [28] in their study in Malaysia. In the present study the range of the CEC values were considered low class according to the classification by [18]. On the other hand, about two-thirds of the total land area in West Malaysia is acid dominated soils which are Ultisols and Oxisols. Ultisols and Oxisols are highly weathered soils with low pH value, lower cation exchange capacity and low basic cation content soils [29].

4.3. Soil Fertility Status

The value of available phosphorus in the different soil series ranged from 3.08 to 9.94 µg/g, with an average value of 6.54 µg/g. The P values are lower compared to the data (< 15 µg/g) reported by [29] for a study conducted in the secondary forests of Malaysia. In [30] stated that the concentration of nutrients especially available phosphorus was influenced by the presence of higher clay and exchangeable Al in the soils. All the studied soil series contained a bit higher level of available P at the surface layer and these values declined with soil depth (Table 1). In [31] found that available P was higher at the surface and decreased rapidly with depth in the forest soils of Malaysia. Higher concentration of P near the soil surface could probably be due to long-term fertilizer application. Usually, large amounts of phosphorus are essential for Malaysian soils because of the presence of large quantities of clay particles and amorphous materials in soils.

Table 1: Concentration of selected available nutrients in the studied soil series

Station	Soil Series	Horizon	Depth	Available Nutrient (µg/g)		
			(cm)	PO_4^{-3}	K^+	Mg^{2+}
1	Tebok	A	0 – 10	7.54	56.91	16.25
		B	> 10	6.23	37.96	15.45
	Top Soil (Mean of 5 replications)		0 – 20	7.81±1.75	60.53±6.81	21.31±7.61
2	Lating	A	0 – 8	7.92	42.28	25.48
		AB	8 – 20	6.62	38.13	9.46
		BA	20 – 30	5.85	26.25	8.13
		B	> 30	5.08	19.73	6.63
	Top Soil (Mean of 5 replications)		0 – 20	8.84±1.96	43.67±7.19	26.15±4.52
3	Serdang	A	0 – 20	4.39	28.58	3.58
		B	> 20	3.85	25.08	1.66
	Top Soil (Mean of 5 replications)		0 – 20	5.26±1.67	44.01±5.54	10.52±2.47
4	Kuala Brang	A	0 – 12	6.77	39.61	11.78
		B	> 12	5.05	32.56	7.85
	Top Soil (Mean of 5 replications)		0 – 20	7.73±2.27	53.27±9.99	18.55±10.19
5	Kedah	A	0 – 8	7.77	31.16	4.69
		E	8 – 18	6.69	26.78	3.04
		B	18 – 30	6.31	24.83	2.01

		C	> 30	5.15	19.08	1.85
	Top Soil (Mean of 5 replications)		0 – 20	8.87±2.33	46.45±10.23	7.23±2.16
6	Kekura	A	0 – 8	6.15	32.75	8.96
		AB	8 – 18	5.39	25.69	6.40
		BA	18 – 29	4.62	24.76	4.49
		B	> 29	3.08	23.23	3.29
	Top Soil (Mean of 5 replications)		0 – 20	7.69±0.55	37.63±15.29	14.99±3.80
7	Prang	A	0 – 15	8.04	20.72	24.00
		B	> 15	7.82	18.63	3.45
	Top Soil (Mean of 5 replications)		0 – 20	9.94±1.20	42.65±8.20	26.1±6.90

The amount of available K in the studied soil series ranged from 18.63 to 60.53 µg/g, with an average value of 34.18 µg/g. The available K in surface soils were higher than that in the subsurface soils throughout the study area. Based on the soil quality index [30] the mean available K in the soils was satisfactory (>12.8 µg/g) than the range of K. According to [25], the classification of exchangeable K content in soil series was high (>16.80µg/g) and the K content in the studied soils was considered satisfactory. The K values decreased with depth in the studied soil series (Table 1). The changes of K in the soil might be due to the soil properties (such as OM, pH etc.), supply of nutrients, moisture availability and plant population. In [30] reported that the available K was higher in the topsoil than in the subsoil and occasionally was stable in the tropical soils in Malaysia. He also noted that the decomposition of dead plants and heavy rainfall might dissolve exchangeable K easily into the soils. These results were similar to those of other studies done in Malaysia by [28].

The available Mg values in the different soil series varied from 1.66 to 26.15 µg/g with an average value of 10.86 µg/g. The low amounts of exchangeable Mg were due to the presence of acid metals (low pH). In the present study, all the soil series were deficient in Mg. Earlier studies indicated that the soils in Malaysia showed Mg deficiency at many locations and Mg content was below the critical level of deficiency (0.40 meq/100g) [32]. The range of available Mg was considered very low compared to the normal range (<18.00 µg/g) of Mg as classified by [25]. All the studied soil series also showed a little bit higher content in the topsoil and this decreased with depth (Table 1). In [30] reported that higher Mg content in the surface soil were due to the association of biological accumulation with biological activity and accumulation from the plants. In a previous investigation, in [32] reported that available Mg increased significantly with increasing soil pH in Malaysia. Correlation analysis indicated that the relationship between Mg absorption by the plant and soil pH was positive and significant (r=0.948), while there was no significant relationship between Mg absorption and either organic matter content (r=0.-0.255) or cation exchange capacity (r=0.012) for Malaysian soils [31,33].

4.4. Concentration of Heavy Metals in the Studied Soil Series

The concentration of heavy metals in the soil profile and topsoil of the seven soil series and their mean values are given in Table 2. The heavy metals were present in the study area such as Pb, Zn, Cu, Co, Ni, Cr and Cd. High levels of these elements were observed in the subsoil and topsoil of the Prang, Lating, Serdang and Kuala Brang series and higher in other soil series. The content of Zn, Co, Ni and Cr in the surface and subsurface of Kuala Brang soil series was found to be high level than that found in the other soil types. Pb content in the Kuala Brang, Lating, Serdang and Prang soil series was relatively high, ranging from 20.31 to 160.87 µg/g in both the topsoil and horizon; the highest value (160.87 µg/g) was recorded for the Kuala Brang series. Higher content of Cu and Ni was found in the Serdang (7.47 to 23.42 µg/g) and Lating (13.64 to 18.32 µg/g) series. The seven types of soil series contained low values of Cd, ranging from 0.09 to 3.28 µg/g for both the top soils and horizons. The concentrations of Zn in the seven soil series ranged from 2.53 to 59.43 µg/g with an average of 20.39 µg/g. The concentration was high in the Prang series and low value in the Kedah soil series.

Table 2: Concentration of heavy metals (µg/g) in the studied soil samples

Station	Soil Series	Horizon	Pb	Zn	Cu	Co	Ni	Cr	Cd
			µg/g						
1	Tebok	A	6.00	12.87	2.41	15.80	9.86	18.57	1.78
		B	5.17	12.90	3.03	16.57	12.00	20.14	1.47
	Top Soil (Mean of 5 replications)		1.62	13.17	2.75	10.32	8.06	20.88	2.60
		SD	0.54	2.43	0.73	2.62	0.83	3.37	0.10
2	Lating	A	32.05	21.55	6.72	27.25	16.98	45.16	1.77
		AB	33.48	25.65	6.54	28.67	18.32	44.21	1.83
		BA	31.78	25.25	6.55	29.20	15.47	47.82	2.06
		B	26.49	18.53	6.52	33.70	13.64	48.12	2.39
	Topsoil (Mean of 5 replications)		20.31	25.12	4.63	22.51	17.91	43.37	2.16
		SD	1.23	1.09	0.91	3.87	3.04	2.92	0.21
3	Serdang	A	36.57	12.93	13.18	22.37	9.44	26.69	2.03
		B	46.47	16.30	23.42	23.83	10.37	29.59	2.60
	Topsoil (Mean of 5 replications)		23.19	12.95	7.47	18.27	6.88	25.04	1.25
		SD	2.65	1.02	0.98	3.27	1.29	3.66	0.25
4	Kuala Brang	A	160.87	41.40	11.65	29.73	12.47	44.96	3.28
		B	158.45	40.73	11.22	31.22	12.27	48.11	3.16
	Topsoil (Mean of 5 replications)		114.06	39.23	7.12	26.99	7.89	41.76	1.77
		SD	2.29	4.04	0.63	4.41	0.69	1.91	0.23
5	Kedah	A	9.81	8.68	1.42	12.23	10.43	26.47	2.58
		E	9.76	2.53	1.06	12.88	14.09	27.61	2.19
		B	15.26	3.06	1.13	13.82	13.01	29.91	1.88
		C	15.37	3.28	1.12	15.08	15.38	34.72	1.64

Topsoil (Mean of 5 replications)			9.77	6.82	1.40	11.55	6.25	24.88	2.17
		SD	2.29	3.76	0.41	5.29	0.79	5.44	0.14
6	Kekura	A	12.23	7.78	3.30	11.38	12.94	18.84	1.90
		AB	12.43	8.12	2.66	13.93	10.81	17.77	2.23
		BA	13.18	8.48	2.09	15.25	9.24	19.42	2.44
		B	14.35	5.72	2.03	19.52	9.88	20.14	2.50
Topsoil (Mean of 5 replications)			5.27	6.28	2.59	8.30	6.59	16.68	2.01
		SD	1.61	3.31	0.20	1.30	0.51	2.66	0.36
7	Prang	A	46.86	59.43	7.99	12.38	9.59	10.83	1.25
		B	49.72	55.45	6.83	14.42	15.64	9.66	0.90
Topsoil (Mean of 5 replications)			50.94	56.29	7.08	31.87	16.08	8.85	1.12
		SD	7.70	4.55	0.80	2.53	2.99	1.16	0.23
Critical threshold			100-400	70-400	60-125	25-50	70-100	75-100	3-15

The value of the Co content ranged from 8.30 to 33.70 µg/g with an average of 19.59 µg/g. The highest and lowest values were obtained from the Lating and Kekura soil series respectively. Cr content in all the series ranged from 8.85 to 48.12 µg/g with an average of 28.53 µg/g. The Lating series contained the highest value and the Prang series the lowest. The content of Pb, Zn, Cu, Co, Ni, Cr and Cd were found in high concentration in subsurface soils for the Kuala Brang, and Serdang soil series. On the other hand, the Kekura soil series had a small amount of heavy metals. The Kekura soil series is sandy loam in texture. The current study indicated that the concentration of different metals depend on spatial variation. The concentration of heavy metals disclosed high standard deviation due to great heterogeneity in the heavy metal contamination. Spatial distribution of heavy metals showed the reflection of both natural and anthropogenic source material inputs in the study area. However, the transport of heavy metals in the soil samples depended on an anthropogenic source inputs, type of metals present, soil organic matter content and type of geological formations in the study area. In [4] reported that the deposition and transport of toxic metals in soil depended on the types of metals present and characteristics of the environment. The distribution of heavy metals within the soil matrix was reported to be governed by the type and content of clay minerals and organic matter present [34, 35]. There was no clear pattern of the decreasing or increasing levels of heavy metals in the topsoils compared to that in other horizons. The content of heavy metals in the topsoils and soil pro-files were below the threshold limit. The concentrations of heavy metals recorded are considered as potentially non-toxic [32].

The results showed that the anthropogenic activities affected the soils (oil palm estates, rubber plantations and cultivated areas) in the Tasik Chini watershed contained high level of metallic elements than the uncultivated and forested areas (Table 3). The Kuala Brang and Serdang soil series were located in the unstable areas. Anthropogenic sources influence the high concentrations of heavy metals in the surface and subsurface soil compared to that in the other soil series. The use of agricultural fertilizers, organic compounds (e.g. composts and manures), pesticides, soil amendments materials (e.g. lime and gypsum) and solid waste recycled into the soil might be the causes of contamination. In [35] stated that the main sources of heavy metals in the agricultural soils in Kenya were from the use of liquid manure, composted materials and agrochemicals such as fertilizers, and pesticides that could develop into being a risk to the environment and/or human health. In [1] noted that some anthropogenic soils have a very acidic pH with high content of heavy metals, which could pose potential risk to human health.

Table 3: Comparison of the concentration of heavy metals for areas with different land use patterns

Metal	Anthropogenic Areas			Forested Areas		
(µg/g)	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Pb	23.19	160.87	71.36	1.62	50.94	19.78
Zn	12.93	56.98	36.23	1.54	59.43	15.77
Cu	6.12	23.42	10.50	0.11	9.68	3.48
Co	18.27	31.22	24.39	7.24	35.24	18.36
Ni	6.88	20.35	12.59	6.25	13.94	10.82
Cr	19.10	48.11	30.78	0.42	38.12	20.78
Cd	0.48	3.28	1.73	0.06	3.49	1.57

5. Conclusion

A detailed study on the physical and chemical characteristics and concentration of heavy metals in the soils is important in order to better assess the behaviour and pollution status of any particular soil. The results of the study indicated that the soils in current study area were more weathered and leached. The soils of the watershed were predominated by clay loam to clay with the exception of the Kekura series (sandy loam). In most of the locations the content of clay for all the soil series increased with depth. The measured total porosity values of undisturbed forest soils were the highest (Tebok, Lating, Kuala Brang, Prang and Kedah series). The lowest values were recorded for the logged soils of the Serdang and Kekura series. From the study it was apparent that the different land use resulted decrease in OM quality. The distribution of soil organic matters also decreased with soil depth. The lowest content of OM was measured in the Kekura series and the highest in the Prang series. The studied soils were acidic in nature and had low electrical conductivity and exchangeable base cations. Due to chemical and textural characteristics and the dominance of acidic cations (Al3+ and H+), the cation exchange capacity of the Kekura series was higher than that of the clay texture (Prang) soil series. The CEC in the study area was at a very low level due to presence of low soil OM. The availability of P and Mg in the study area were small and very small amount. The low value of pH might reduce the availability of Mg and P. Data collected from soil analyses showed that all the studied soils had low fertility.

Based on the results obtained, it was proved that high concentration of toxic metals in the soils of the study area come mainly from the concentration of the elements and anthropogenic activities (addition of the metals from fertilizers and pesticides, dumping of wastes, uncontrolled effluents and/or atmospheric sources). In addition, agricultural activities contributed to the accumulation of heavy metals in the soils. The concentrations of heavy metals in the Tasik Chini watershed were below the threshold values of heavy metal concentrations in agricultural soils of Peninsular Malaysia. The study also indicated that due to anthropogenic influences, the Kuala Brang and Serdang soil series contained high toxic elements in the lower horizons and top soils. The study also highlighted the necessity of immediate control measures to be taken to ensure the quality of soil is maintained and heavy metal pollution is minimized to prevent future pollution problems. Therefore, the results indicate that continuous monitoring and proper soil management practices are essential for the preservation of the soil systems. A long term strategy for the maintenance of the study area or green lung should be adopted for the Tasik Chini watershed.

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