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ORIGINAL ARTICLE

The Assessment of Water Quality and Metals Concentration in Surface Water of Kenyir Lake

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Abstract

Surface water quality is an important environmental factor affecting both humans and other living things. This present study is purposely to provide a baseline information on physicochemical parameters and metals concentration from surface water of Kenyir Lake and their water quality status. Determination of metals concentration was carried out using ICP-MS. The mean physicochemical parameters were 31.14°C (Temp), 16.29mg/L (TDS), 27.79µS/cm (COND), 4.75mg/L (DO), 7.03 (pH), 1.33NTU (TUR), 0.96mg/L (BOD), 6.48mg/L (COD), 0.11mg/L (AN), 2.17mg/L (TSS) and 227.10mV (ORP) while the mean concentration of metals (µg/L) Al 23.0845, As 0.2983, B 4.1711, Ba 5.0655, Ca 2033.4024, Cu 1.7407, Fe 43.7747, K 916.9054, Mg 456.7255, Mn 4.7387, Ni 0.3346, Se 0.5032, V 0.1428 and Zn 1.6796 respectively. The results revealed that physicochemical parameters and metals concentration at all sampling stations near Kenyir Lake are within Class I and Class II of Malaysia National Water Quality Standard (NWQS) except for dissolved oxygen (DO) that was classified into Class III and Class IV due to high activities of microorganisms that uses up a great amount of oxygen to carry out their metabolizing activities as well as degradation of organic matters. Furthermore, most metals are significantly correlated to each other ($p<0.05$) which may derive from a common source of metals except for Al and Cu, As and Fe, Ba and Ca, Ca and Cu, Ca and Se, Ca and Zn, Cu and Fe, Cu and Mn, Cu and Ni, Cu and Se, Cu and Zn, Fe and Ni, Fe and Se, Fe and Zn, Mn and Zn and V and Zn respectively. Therefore, data from the present study will be useful as baseline data for future reference.

Keywords: surface water; physicochemical parameters; metals; ICP-MS; INWQS; Kenyir Lake

Introduction

Metals are of a particular concern especially among the environmental contaminants because of their capability to bioaccumulate through the food chain and non-degradable (Shamrukh and Abdel-Wahab, 2011; El Shakour and Mostafa, 2012; Goher et al., 2014). A very low of heavy metals concentration exists in the natural environment and usually, they originate from the weathering (Karbassi et al., 2008; Varol and Sen, 2012). Light metal (LM) and heavy metal (HM) are usually associated with water pollution either by natural processes such as weathering, bedrocks erosion process and deposition of ores or anthropogenic processes such as industrial activities, mining, smelting and agricultural and wastewater irrigation (Ettler et al., 2012; García-Lorenzo et al., 2012; Sracek et al., 2012). Consequently, accelerated heavy metals pollution deteriorates invertebrates, fish, and human's health conditions respectively (Yi et al., 2011; Islam et al., 2014; Martin et al., 2015; Islam et al., 2015a, b). Therefore, it leads to a variety of diseases such as cancer, diarrheal disease, respiratory disease, cardiovascular diseases and neurological disorder (Ullah et al., 2014) and neural disorder (Chowdury et al., 2015).

Lakes are essential to water resources and ecosystems that function as one of the main region's water supply, flood control, climate management and biodiversity maintenance (Ra et al., 2011; Hansen, 2012). It can easily accumulate pollutants because they are incapable to do self-clearing have a complicated and fragile ecosystem (Lokeshwari and Chandrappa, 2006). Recent research studies in Malaysia has focused on the assessment of lakes water quality (Shuhaimi-Othman et al., 2007; Ashraf et al., 2010; Sharip et al., 2014) since earlier studies in Bera Lake found that a high level of phosphorus, ammonia and nitrogen were deteriorating the water quality (Chong, 2007) while another study by Mohkeri (2002) revealed that Kelana Jaya Lake which is situated near a recreational park neighbouring near the housing area and commercial centres were severely polluted as many fishes were found dead, floating and rotten resulted from the receiving sewage waste. Despite of its widespread use and benefits, waters are continuously being polluted by anthropogenic activities that directly or indirectly contaminate aquatic ecosystems such as landcover removal in the environs of the water bodies, dumping of waste from domestic, industrial and agricultural industry into the water bodies and extreme waste disposal (O'Donoghue et. al., 2010).

Kenyir Lake is the largest man-made lake in Southeast Asia which located in Hulu Terengganu on the east coast of Peninsula Malaysia between coordinate 4°43'N to 5°15'N and 102°30'E to 102°55'E (Rouf et al., 2008). It was created in 1986 by the damming of the Kenyir River to build the Sultan Mahmud Hydro-electric Power Plant which covered an area of 36,900 ha with a maximum depth of 145m and an average depth of 37m including having more than 340 islands scattered around the lake. According to past studies, the lake is famous among the tourist for its sport-fishing and has cage aquaculture (Kamaruddin et al., 2011; Suratman et al., 2015). However, the making of Kenyir Lake into a duty-free area earlier August 2017 has abruptly increased the number of visitors, develop areas and land uses activities that may bring potential threats to the surrounding area and its biodiversity. Furthermore, the operating boathouses are not well equipped with a septic tank and thereby, the sewage and other domestic wastes were directly flushed out into the water bodies. The condition of the natural environment could deteriorate with the discharge of human waste, fuels spills, use of fertilizers, overfishing and pose a disastrous effect on the aquatic ecosystem. Thus, an assessment on water quality and metals concentration in surface water of Kenyir Lake has been carried out. The objectives of this study were to determine the current level of physicochemical parameters and metals concentration (Al, As, Ba, B, Ca, Cu, Fe, K, Mg, Mn, Ni, Se, V, Zn) in Kenyir Lake surface water, and to define the status of Kenyir Lake water quality based on NWQS (DOE, 2010).

Materials and Methods

Study Area

Kenyir Lake is located in Hulu Terengganu on the east coast of Peninsular Malaysia in between coordinate 4°43′N to 5°15′N and 102°32′E to 102°55′E. It covers an area of 36,900 ha with a maximum depth of 145m, an average depth of 37m and surrounded by more than 340 islands. In this study, 16 sampling stations located near the developed area were selected. Figure 1 demonstrated the location of the 16 sampling stations.

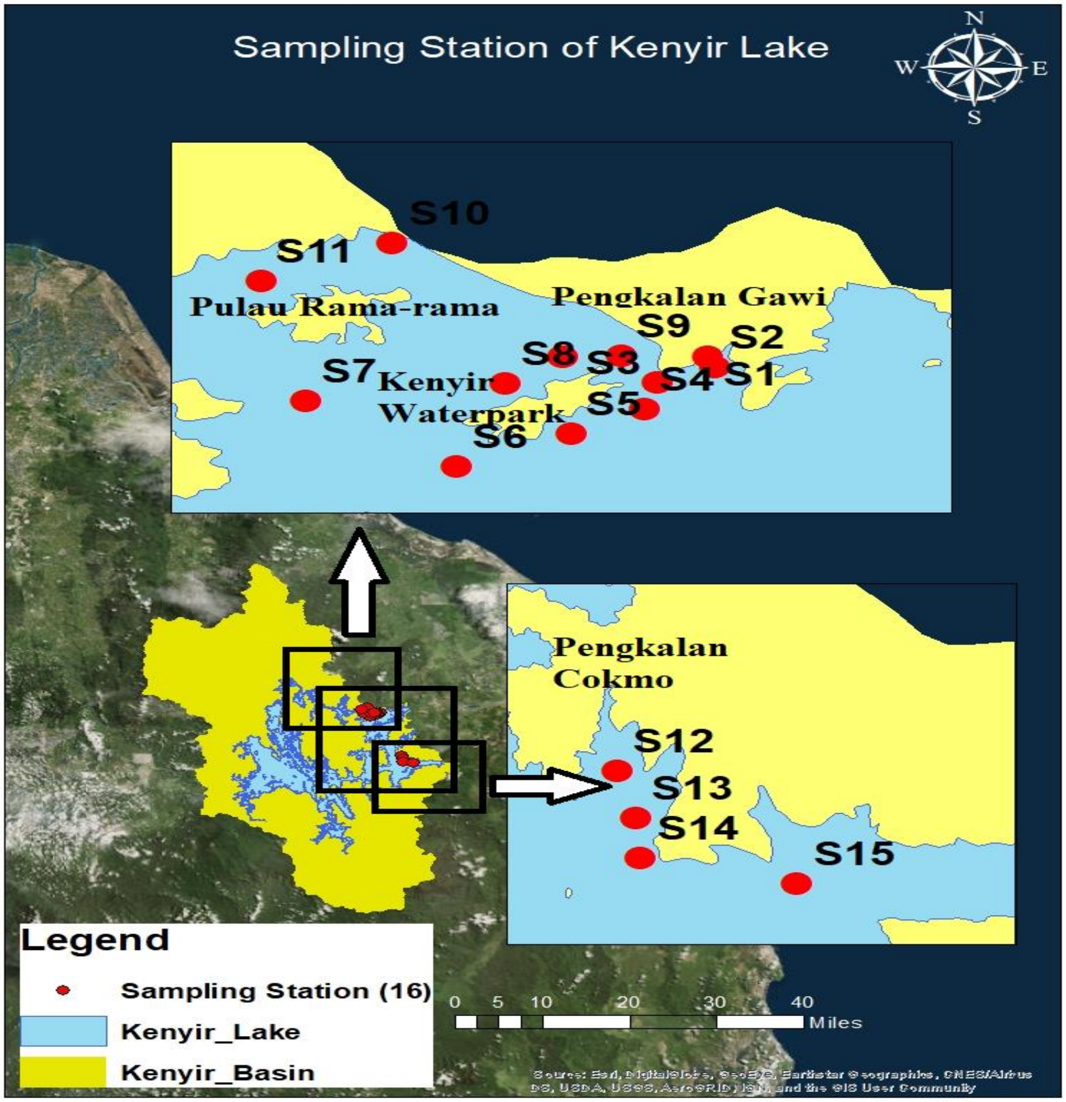

Figure 1. Sampling Stations at Kenyir Lake

Sample Collection

The surface water samples from the Kenyir Lake were collected (three replicates) in 500 mL acid-washed (in 5% HNO3) bottles at 16 sampling stations weekly (July to August 2017) at 16 sampling stations for metals analysis. The physicochemical parameters were measured in-situ, such as Temperature (Temp, °C), Total Dissolved Solids (TDS, mg/L), Conductivity (COND, µS/cm), Dissolved Oxygen (DO, mg/L), pH, Ammoniacal Nitrogen (AN, mg/L) and Oxidation-Reduction Potential (ORP, mV) by using the YSI Professional Plus multiparameter and the turbidity (TUR, NTU) was measured by using the portable turbidimeter (HACH 2100Q). The Biochemical Oxygen Demand (BOD, mg/L) was measured by using the portable BOD meter (Modern Water BOD). The samples then stored at 4°C before analysis.

Chemical Analysis

The chemical oxygen demand (COD) was analysed by using the COD Reactor Model HACH (DRB200) following APHA 5220B while the total suspended solids (TSS) were measured by following the APHA 2540D (gravimetric method). The calculation for the TSS is shown in Equation 1 (APHA, 2005):

$$TSS = (A - B) / V \qquad (1)$$

Remarks:
A = Mass of filter paper + dried residue (mg)
B = Mass of filter paper (tare weight) (mg)
V= volume of sample filtered (L)

Furthermore, Temp, TUR, AN, COND, TDS, BOD, DO, pH and ORP were done according to APHA 2550B, APHA 2130B, APHA 4500, APHA 2510B, APHA 2540C, APHA 5120B, 4500B, APHA 4500H and APHA 2580B respectively. The metals concentration was analysed according to the APHA 3125 standard method. The determination of the metals concentration aluminium (Al), arsenic (As), boron (B), barium (Ba), calcium (Ca), copper (Cu), iron (Fe), potassium (K), magnesium (Mg), manganese (Mn), nickel (Ni), selenium (Se), vanadium (V) and zinc (Zn) were carried out using inductively coupled plasma mass spectrometer (ICP-MS, Nexion) under standard operating procedures. The calibration of the standard was performed as the following concentrations shown in Table 1.

Table 1. The Metals Standard Concentration (mg/L) determined by ICP-MS

Metal	Standard 1	Standard 2	Standard 3	Standard 4
Ca	0.2	-	-	-
Fe	1.0	-	-	-
Mg	10	-	-	-
K	10	-	-	-
Al, As, B, BA, Cu, Mn, Ni, Se, V,	0.002	0.010	0.020	0.10

The certified reference material used was NIST 1643F (National Institute of Standard and Technology). All collected metals concentration data were expressed in µg/L. Besides, the standard solutions for each element prepared by dilution of 1000mg/L of certified standard solutions (Accustandard, USA) with deionized water and the acids and reagents used were of analytical grade.

Data Analysis and Statistical Method

The collected data were analysed by using Pearson's correlation coefficient to test the relationship of metals concentration and physicochemical parameters, with the level of significance at $p<0.05$ (Mustapha et al., 2013), using the XLSTAT software. All data were expressed as the mean ± standard deviation. Spatial distribution was carried out by means of ArcGIS.

Results and Discussion

Table 2 summarized the mean value, range and percentage standard deviation (%RSD) of physicochemical parameters and concentration of metals.

Table 2. Mean Value, Range and %RSD of Physicochemical Parameters and Metals Concentration

Parameter	Mean ± S.D	Range	%RSD
Temp (°C)	31.14±0.16	30.91-31.40	0.51
TDS (mg/L)	16.29±0.23	15.93-16.71	1.41
COND (µS/cm)	27.79±0.67	25.94-28.82	2.41
DO (mg/L)	4.75±1.54	2.28 -6.88	32.42
pH	7.03±0.08	6.84-7.13	1.14
TUR (NTU)	1.33±0.19	1.08-1.71	14.29
BOD (mg/L)	0.96±0.14	0.77-1.13	14.58
COD (mg/L)	6.48±1.29	4.70-8.20	19.91
AN (mg/L)	0.11±0.07	0.05-0.30	63.64
TSS (mg/L)	2.17±0.84	1.28-4.44	38.71
ORP (mV)	227.10±20.58	186.24-270.50	9.06
Al (µg/L)	23.0845±2.71	18.2748-28.6776	11.74
As (µg/L)	0.2983±0.03	0.2564 -0.3556	10.00
B (µg/L)	4.1711±0.06	4.0637-4.2826	1.44
Ba (µg/L)	5.0655±0.28	4.7235-5.5569	5.52
Ca (µg/L)	2033.4024±90.51	1911.6911-2247.0230	4.45
Cu (µg/L)	1.7407±0.37	0.9979-2.3579	21.26
Fe (µg/L)	43.7747±7.77	27.4709-52.4427	17.75
K (µg/L)	916.9054±19.76	891.1032-950.8119	2.16
Mg (µg/L)	456.7255±30.01	430.8243-517.3665	6.57
Mn (µg/L)	4.7387±0.35	4.2531-5.5967	7.38
Ni (µg/L)	0.3346±0.13	0.1699-0.7388	39.39
Se (µg/L)	0.5032±0.05	0.4285-0.6209	10.00
V (µg/L)	0.1428±0.01	0.1063-0.1627	7.14
Zn (µg/L)	1.6796 ± 0.41	1.0255-2.5341	24.40

The obtained values and metals recovery in NIST 1643F were 124.8 ± 93.27, 55.4 ± 96.48, 131.4 ± 86.28, 457.7 ± 91.80, 26303.2 ± 89.38, 20.6 ± 95.11, 80.5 ± 86.15, 1678.8 ± 86.8, 6784.3 ± 91.01, 34.3 ± 92.35, 57 ± 95.32, 9.5 ± 81.20, 32.5 ± 90.10 and 74.2 ± 99.73 respectively as stated in Table 3, which suggest the efficiency of the methods used.

Table 3. Percentage Recovery of Metals by Certified Reference Materials

Metal	**Trace elements in water (NIST CRM 1643F)**		
	Certified value (µg/l)	**Measured value (µg/l)**	**Metals Recovery (%)**
Al	133.8 ± 1.2	124.8	93.27
As	57.42 ± 0.38	55.4	96.48
B	152.3 ± 6.6	131.4	86.28
Ba	518.2 ± 7.3	475.7	91.80
Ca	29430 ± 330	26303.2	89.38
Cu	21.66 ± 0.71	20.6	95.11
Fe	93.44 ± 0.78	80.5	86.15
K	1932.6 ± 9.4	1678.8	86.87
Mg	7454 ± 60	6784.3	91.01
Mn	37.14 ± 0.60	34.3	92.35
Ni	59.8 ± 1.4	57	95.32
Se	11.700 ± 0.081	9.5	81.20
V	36.07 ± 0.28	32.5	90.10
Zn	74.4 ± 1.7	74.2	99.73

The obtained metals concentration and physicochemical parameters were then compared with NWQS (Table 4(a) and Table 4(b) while Figure 3 illustrated the comparison of the average total concentration of metals and physicochemical parameters with NWQS (DOE, 2010).

Table 4(a). Water Classes and Uses (DOE, 2010)

Class	**Uses**
Class I	Conservation of natural environment. Water Supply I – Practically no treatment necessary Fishery I – Very sensitive aquatic species
Class IIA	Water Supply II – Conventional treatment. Fishery II – Sensitive aquatic species
Class IIB	Recreational use body contact.
Class III	Water Supply III – Extensive treatment required. Fishery III – Common, of economic value and tolerant species; livestock drinking
Class IV	Irrigation
Class V	None of above

Table 4(b). National Water Quality Standards for Malaysia (NWQS)

Parameters	Unit	Classes					
		I	IIA	IIB	III	IV	V
NH_3-N	mg/L	0.1	0.3	0.3	0.9	2.7	2.7
BOD	mg/L	1	3	3	6	12	12
COD	mg/L	10	25	25	50	100	100
DO	mg/L	7	5-7	5-7	3-5	3	1
TSS	mg/L	25	50	50	150	300	300
pH 6.5-8.5		5-7	5-7	3-5	3	1	
Colour (TUC)		15	150	150	-	-	-
Elect. Conductivity	µS/cm	1000	1000	-	-	6000	-
Floatables		NV	NV	-	-	-	-
Odour		NOO	NOO	NOO	-	-	-
Salinity	%	0.5	1	1	-	-	-
Taste		NOT	NOT	NOT	-	-	-
Total Dissolved Solids	mg/L	25	50	50	150	300	300
Temperature	°C	normal	normal	Normal	-	-	-
Turbidity	NTU	5	50	-	-	-	-
Faecal Coliform	count/100mL	10	100	50	5000	5000	>5000
Total Coliform	count/100mL	100	1000	5000	50000	50000	>50000
Al	mg/L	-	-	-	0.06	0.5	-
As	mg/L	-	0.05	0.05	(0.4) (0.05)	0.1	-
Ba	mg/L	-	1	1	-	-	-
Cd	mg/L	-	0.01	0.01	0.01*(0.001)	0.01	-
Cr (III)	mg/L	-	-	-	2.5	-	-
Cu	mg/L	-	0.02	0.02	-	0.2	
Hardness	mg/L	N	250	250	-	-	N-
Ca	mg/L	A	-	-	-	-	A
Mg	mg/L	T	-	-	-	-	T
Na	mg/L	U	-	-	-	-	U
K	mg/L	R	-	-	1	1	R
Fe	mg/L	A	1	1	-	-	A
Pb	mg/L	L	0.05	0.05	0.02*(0.01)	5	L
Mn	mg/L		0.1	0.1	0.1	-	
Hg	mg/L	L	0.001	0.001	0.004(0.0001)	0.002	L
Ni	mg/L	E	0.05	0.05	0.9*	0.2	E
Se	mg/L	V	0.01	0.01	0.25(0.04)	-	V
Ag	mg/L	E	0.05	0.05	0.0002	-	E
Sn	mg/L	L	-	-	0.004	-	L
U	mg/L	S	-	-	-	-	S
Zn	mg/L	-	5	5	0.4*	2	-
B	mg/L	-	1	1	3.4	-	-
Cl	mg/L	-	200	200	-	80	-
CN	mg/L	-	0.02	0.02	0.06(0.02)	-	-
F	mg/L	-	1.5	1.5	10	1	

Notes
* = At hardness 50 mg/l CaCO3
NV= No visible floatable materials/debris
NOT= No objectionable taste
NOO= No objectionable odour

The bar graph in Figure 2(a) shows the examples of physicochemical parameters and metals concentration comparison with NWQS where it falls within Class I (B, Ba, Fe, Temp, TDS, COND, TSS, TUR, BOD, COD) and Class IIA (pH and AN) showed in Figure 2(b).

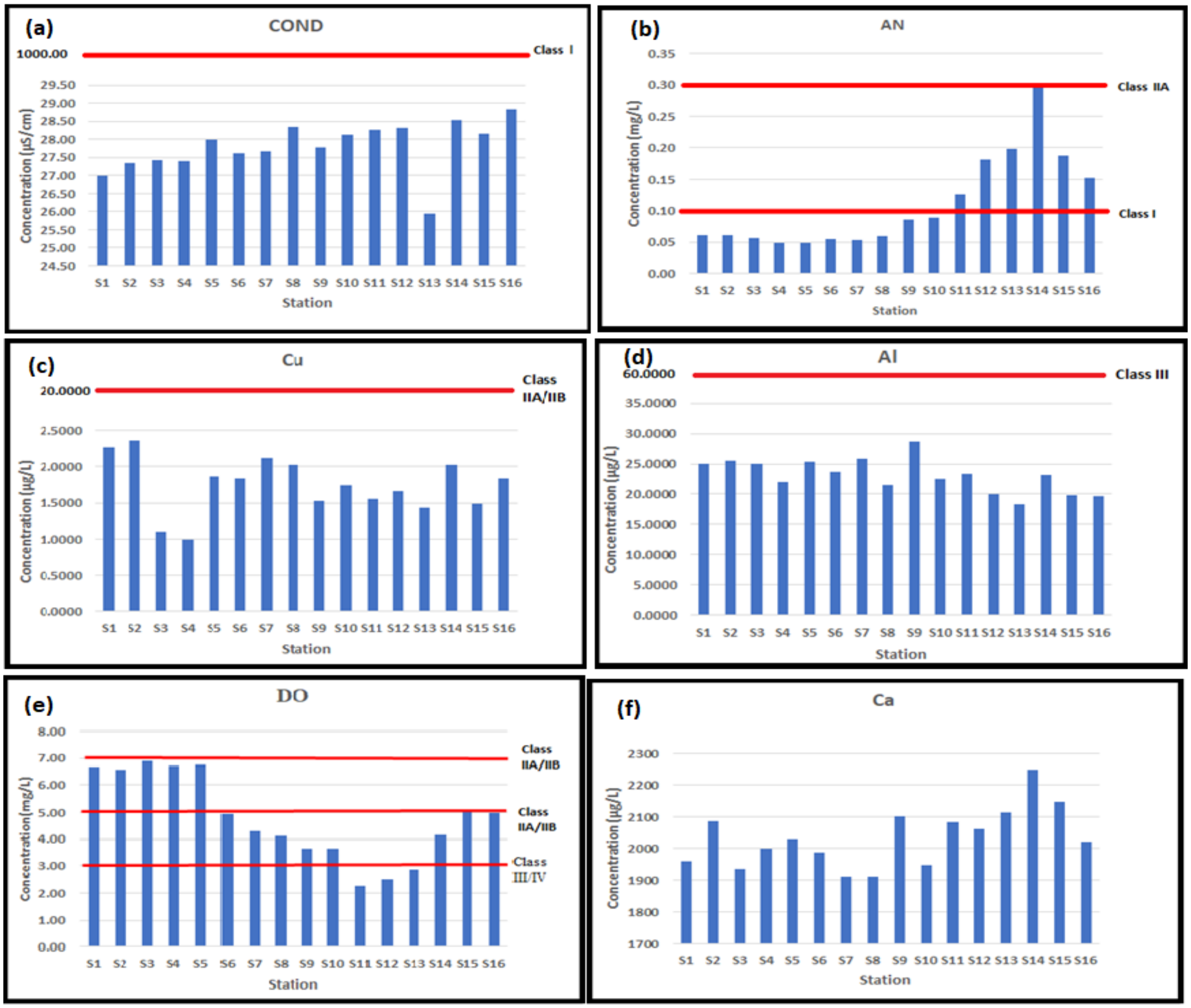

Figure 2. Comparison of Metals Concentration and Physicochemical Parameters with NWQS

According to past studies, increase BOD values indicate the received of the heavy load of organic matter discharge with the high volume of agricultural and sewage discharge from various sources (Abdel Daim, 2000). It could be related to the area near the Taman Rama-Rama which started and sewage discharge from the boathouse that releases food waste directly into the lake. In addition, it reflects the shipload of bacterial and microbial activity (El-Alfy, 2011; El-Sonbatti et al., 2012). On the other hand, pH value affected by the presence of carbonate magnesium and calcium in the water and creates an alkaline condition (Begum et al., 2009; Reza and Singh, 2010). The magnesium concentrations are lower than the baseline data observed from Kota Marudu River (Aris et al., 2014) while the calcium concentrations are higher than Maliau basin (Mokhtar et al., 2009) which suggests occurring from natural weathering. The natural condition of any water body usually yields pH range between 6.0 and 8.5 (Garg et al., 2010) which is an ideal pH range for the survival of fish and safe to use for drinking water.

Furthermore, Figure 2(c) demonstrates that As, Cu, K, Mn, Ni, Se and Zn can be categorized below Class IIA/IIB while Figure 2(d) shows that Al falls below Class III of NWQS. Besides, potassium also occurs widely in the environment and exists in various minerals such as feldspars and clay minerals, thus it may dissolve through weathering processes. The natural processes comprising both catchment erosion and oxidation-reduction related dissolution of Mn-containing minerals at or near the sediment-water interface may be sources of manganese in the aquatic environment (Abesser and Robinson, 2010; Antweiler et al., 2012). Besides, the probable source of pollutants where Mn are being introduced into the waterbodies are attributed with discharges of municipal wastewater, sewage sludge, mineral and mining processing and emissions from iron, alloy and steel industries (Alsaffar et al., 2016).

The outlined bar graph from Figure 2(e) shows that DO was categorized into Class III (S6, S7, S8, S9, S10, S14, S16) and Class IV (S11, S12, S13). Class III required extensive treatment for water supply and suitable for common, of economic value and tolerant species fish while Class IV suitable use for irrigation only. Since the sampling was done during the summer, Yang et al. (2007) opine that low DO values in summer were associated to the high activities of microorganisms that use up a great amount of oxygen to carry out their metabolizing activities as well as degradation of organic matters. Besides, the previous examples show that a decrease in DO content was associated with organic wastes in an aquatic ecosystem that decompose organic materials in the water (Ngoye and Machiwa, 2004). On the other hand, Figure 2(f) shows the example that Ca, Mg, V and ORP which are not classified in any classes of NWQS. The flows of water in rivers which passes over the rocks largely contributed to the presence of calcium in surface water (Jamie and Richard, 1996; APHA, 2005) including limestone, gypsum, calcium carbonate and other calcium-containing rocks and minerals.

In addition, the spatial distribution map showed in Figure 3(a), Temp, TDS, TSS, As, Ba, Ca, K and Mg have the same pattern where a high concentration of metals and physicochemical parameters were focusing at the area S8, S9, S12, S13, S14, S15 and S16. S12, S13, S14 and S15 were located near the aquaculture cage while S9 and S16 located near bridge construction and Kenyir Waterpark while S8 located at the natural condition. Dissolved calcium and magnesium salts largely contribute to natural water (Ikomi and Emuh, 2000). In addition, the existent of dissolved materials in the aquatic ecosystem such as fuel, solvent and detergents which hard to discard either by general or conventional filtration was related to TDS (Avvannavar and Shrihari, 2007). This could be related to the direct discharge of sewage from boathouse that contains dishwashing liquid, soap and oil spill in the surrounding area.

Furthermore, the distribution map from Figure 3(b) showed that B, Cu, Fe, V and DO have the same pattern where their concentration increased starting from S6 to S1. Area S1, S2, S3 and S4 are located near the houseboat and landfill area. Changes in dissolved oxygen is an early sign in which water body condition is having an alteration (Bartram et al., 1996). Besides, past studies conducted by Water Stewardship Division (2008) found that weathering of rocks contribute to the natural occurrence of iron in waters. Moreover, TUR, Zn, Se and COD showed a similar distribution pattern with Figure 3(c) around the sampling stations where Zn naturally existed in water in a very minute amount due to the low solubility of Zn oxides and its free metal in water (Sundaray et al., 2012). On the other hand, Figure 3(d) displayed the same distribution pattern for BOD, AN, Ni and Al. Industrial activities, particularly chemical and petrochemical industries around the area have led to an accelerated level of ammoniacal nitrogen (Wang et al., 2010). On the other hand, Figure 3(e) display the same spatial distribution pattern for Mn, COND, pH and ORP. Moreover, low conductivity value usually associated with water acidity since ions concentration largely influences conductivity (Bartram et al., 1996).

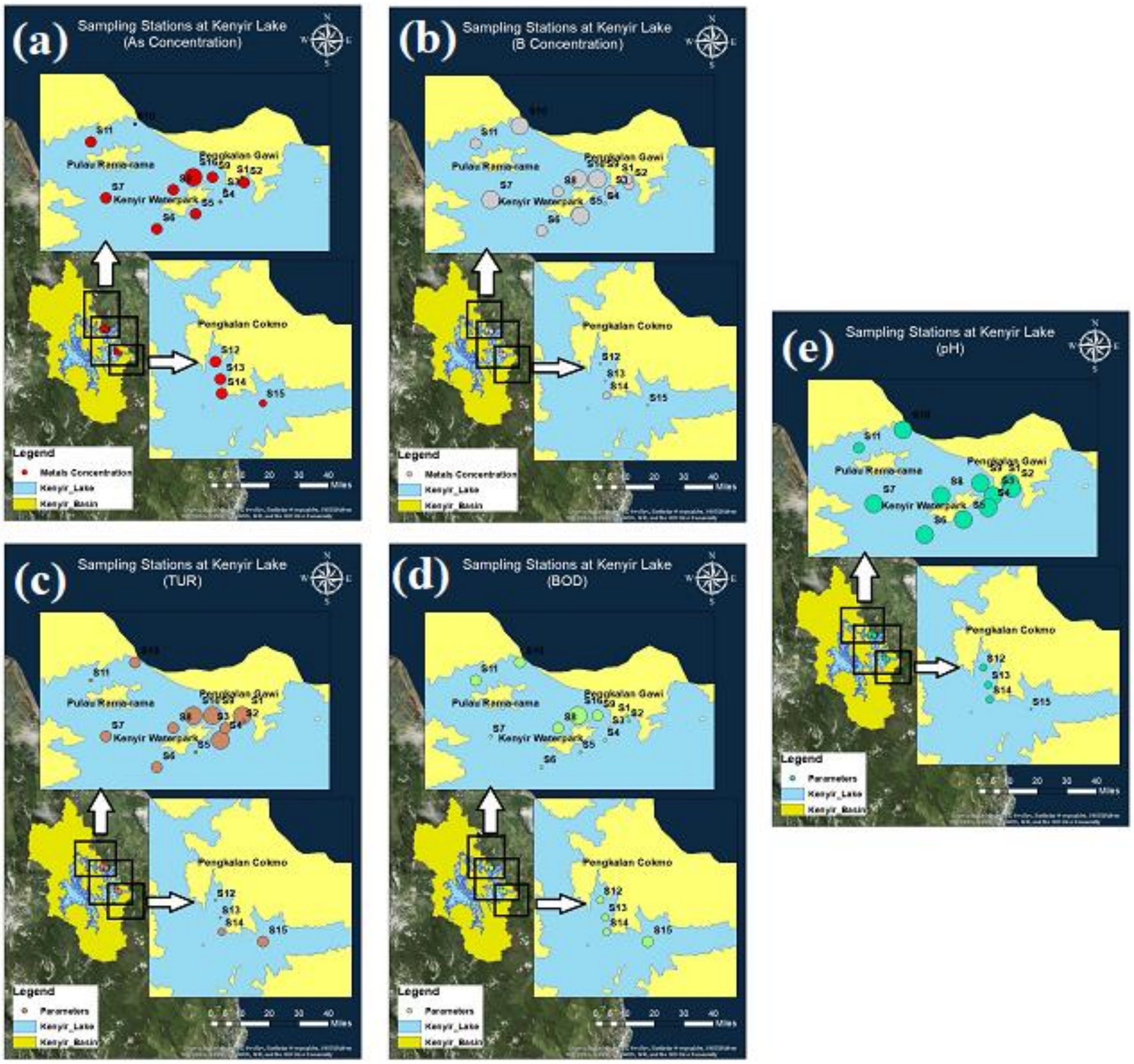

Figure 3. Spatial Distribution of Physicochemical Parameters and Metals Concentration at Kenyir Lake

Correlation Coefficient Analysis

In this study, the correlation coefficient was applied to physicochemical parameter and metals concentration of Kenyir Lake surface water to better understand possible variability and to determine the relationship between variables. Relationships between metals concentration in surface water and physicochemical parameters were studied using the Pearson correlation coefficient (Table 5). From the results, it shows that there is a linear relationship between two variables when the p-value is below than 0.05.

The correlation analysis between physicochemical parameters and metals concentration in surface water showed that a very significant correlation ($p<0.05$) were found between Temp, DO, BOD, COD and Al; between Temp, TDS, DO, pH, BOD, COD, AN and As; between Temp, TDS, DO, pH, BOD, COD, ORP and B; between Temp, BOD, COD, TSS, TDS, pH and Ba; between TDS, pH, BOD, COD, AN and Ca; between AN and Fe; between Temp, pH, DO, BOD, COD, ORP and K; between Temp, DO, BOD, COD, ORP and Mg; between Temp, DO, pH, BOD and Mn; between Temp, DO, BOD, ORP and Ni; between DO, pH, BOD, COD, AN, ORP and V. High correlation between specific physicochemical parameters and metals suggest that they may originate from the same sources. Moreover, previous studies by Barlas et al. (1999) showed that dissolved oxygen, pH and temperature can influence heavy metal toxicity. It is further supported by Hellawell (1988) that proved an increase in pH will decrease the solubility of toxic heavy metals. Besides that, there are no significant correlations were found between the metals and both COND and TUR while Cu, Se and Zn have no significance with any physicochemical parameters. The results from the study area demonstrates that different physicochemical parameters influence the concentration of some metals in the surface water.

Moreover, the correlation coefficient of physicochemical parameters relationship (Table 6) in surface water showed that Temp and TUR, Temp and ORP, TDS and COND, TDS and DO, TDS and TUR, TDS and COD, TDS and BOD, COND and COD, DO and BOD, DO and COD, DO and AN, DO and TSS, pH and TUR, pH and BOD, pH and COD, BOD and COD, BOD and AN, BOD and TSS, BOD and ORP and AN and TSS are statistically significant ($p<0.05$). The correlation between Temp and TUR can be associated with increased turbidity influences water temperature and affects heat distribution in the waterbody. Shading action increase surface water temperature and reduce subsurface water. Besides that, water tends to appear murkier when a high content of suspended solid presents in the water, therefore increase water turbidity. TDS concentration is directly proportional with the electrical conductivity of water where the capability of water to conduct an electric can be measured (Simeonov et al., 2003) stated that non-point sources such as agricultural activities and forest areas affect BOD and COD which are considered organic factors.

Table 5. Correlation Matrix between Metals and Physicochemical Parameters

Variable	**Al**	**As**	**B**	**Ba**	**Ca**	**Cu**	**Fe**	**K**	**Mg**	**Mn**	**Ni**	**Se**	**V**	**Zn**
Temp	**0.0013**	**0.0343**	**0.0106**	**< 0.0001**	0.8748	0.7805	0.0600	**< 0.0001**	**< 0.0001**	0.6116	**0.0009**	0.4471	0.6011	0.2885
TDS	0.4352	**0.0037**	**0.0477**	0.7644	**0.0269**	0.3539	0.2209	0.1305	0.1901	0.1824	0.6587	0.6380	0.4832	0.2057
COND	0.7256	0.8550	0.9199	0.7794	0.1909	0.8771	0.1374	0.9268	0.7323	0.6286	0.5574	0.5573	0.3712	0.5845
DO	**0.0093**	**< 0.0001**	**0.0019**	0.2815	0.1294	0.1674	0.4900	**0.0206**	**0.0102**	0.0574	**0.0212**	0.5396	**0.0396**	0.2746
pH	0.1351	**0.0068**	**0.0115**	0.1846	**0.0223**	0.1473	0.4822	**0.0418**	0.0535	**0.0398**	0.3067	0.9783	**0.0164**	0.4418
TUR	0.8382	0.6747	0.6697	0.2495	0.9390	0.9001	0.6916	0.4598	0.7172	0.4521	0.1535	0.4267	0.4409	0.7477
BOD	**< 0.0001**	**< 0.0001**	**< 0.0001**	**0.0004**	**< 0.0001**	0.4466	0.6440	**< 0.0001**	**< 0.0001**	**0.0001**	**< 0.0001**	0.5849	**< 0.0001**	0.0637
COD	**0.0008**	**0.0005**	**0.0009**	**0.0161**	**0.0023**	0.6052	0.3009	**< 0.0001**	**0.0004**	0.1903	0.2560	0.7248	**0.0421**	0.5258
AN	0.9675	**0.0013**	0.2548	0.0505	**0.0011**	0.2810	**< 0.0001**	0.8252	0.9484	0.2161	0.8312	0.2326	**0.0007**	0.1657
TSS	0.7259	0.7009	0.5436	**0.0141**	0.1165	0.4036	0.8387	0.8996	0.9019	0.2880	0.1791	0.7646	0.6121	0.7985
ORP	0.3722	0.1260	**0.0452**	0.0767	0.5768	0.3777	0.4536	**0.0190**	**0.0189**	0.7839	**0.0283**	0.5379	**0.0042**	0.9802

Values in the bold show a significance level alpha<0.05

Table 6. Correlation Matrix between Physicochemical Parameters

Variable	**Temp**	**TDS**	**COND**	**DO**	**pH**	**TUR**	**BOD**	**COD**	**AN**	**TSS**	**ORP**
Temp	**0**	0.7172	0.3710	0.4997	0.7870	**0.0019**	0.0632	0.7385	0.1805	0.9208	**0.0081**
TDS	0.7172	**0**	**< 0.0001**	**0.0069**	0.5371	**0.0433**	**0.0008**	**0.0024**	0.1444	0.2206	0.5415
COND	0.3710	**< 0.0001**	**0**	0.1298	0.7027	0.6773	0.0669	**0.0039**	0.5843	0.9593	0.2989
DO	0.4997	**0.0069**	0.1298	**0**	0.5896	0.0616	**< 0.0001**	**0.0263**	**0.0013**	**< 0.0001**	0.7661
pH	0.7870	0.5371	0.7027	0.5896	**0**	**0.0022**	**< 0.0001**	**0.0054**	0.2498	0.2245	0.8984
TUR	**0.0019**	**0.0433**	0.6773	0.0616	**0.0022**	**0**	0.0529	0.9291	0.4469	0.9265	0.9905
BOD	0.0632	**0.0008**	0.0669	**< 0.0001**	**< 0.0001**	0.0529	**0**	**< 0.0001**	**0.0200**	**0.0346**	**0.0002**
COD	0.7385	**0.0024**	**0.0039**	**0.0263**	**0.0054**	0.9291	**< 0.0001**	**0**	0.9988	0.3177	0.8288
AN	0.1805	0.1444	0.5843	**0.0013**	0.2498	0.4469	**0.0200**	0.9988	**0**	**0.0154**	0.2613
TSS	0.9208	0.2206	0.9593	**< 0.0001**	0.2245	0.9265	**0.0346**	0.3177	**0.0154**	**0**	0.9853
ORP	**0.0081**	0.5415	0.2989	0.7661	0.8984	0.9905	**0.0002**	0.8288	0.2613	0.9853	**0**

Values in the bold show a significance level alpha<0.05

The matrix of the linear coefficient relationship between metals in surface water is shown in Table 7.

Table 7. Correlation Matrix between Metals

Variable	Al	As	B	Ba	Ca	Cu	Fe	K	Mg	Mn	Ni	Se	V	Zn
Al	**0**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	0.1998	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0003**	**0.0025**	**0.0155**
As	**< 0.0001**	**0**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**0.0003**	0.2282	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**0.0023**	**< 0.0001**	**0.0069**
B	**< 0.0001**	**< 0.0001**	**0**	**< 0.0001**	**< 0.0001**	**0.0172**	**0.0116**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**0.0019**	**< 0.0001**	**0.0153**
Ba	**< 0.0001**	**< 0.0001**	**< 0.0001**	**0**	0.2845	**0.0220**	**0.0003**	**< 0.0001**	**< 0.0001**	**0.0010**	**< 0.0001**	**0.0004**	**< 0.0001**	**0.0026**
Ca	**< 0.0001**	**< 0.0001**	**< 0.0001**	0.2845	**0**	0.0862	**0.0019**	**0.0002**	**< 0.0001**	**0.0027**	**0.0035**	0.3769	**< 0.0001**	0.3458
Cu	0.1998	**0.0003**	**0.0172**	**0.0220**	0.0862	**0**	0.4289	**0.0051**	**0.0017**	0.1319	0.3977	0.5076	**0.0003**	0.1089
Fe	**< 0.0001**	0.2282	**0.0116**	**0.0003**	**0.0019**	0.4289	**0**	**0.0056**	**< 0.0001**	**< 0.0001**	0.3994	0.5563	**0.0052**	0.1899
K	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**0.0002**	**0.0051**	**0.0056**	**0**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**0.0007**	**< 0.0001**	**0.0001**
Mg	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**0.0017**	**< 0.0001**	**< 0.0001**	**0**	**< 0.0001**	**< 0.0001**	**0.0002**	**< 0.0001**	**0.0007**
Mn	**< 0.0001**	**< 0.0001**	**< 0.0001**	**0.0010**	**0.0027**	0.1319	**< 0.0001**	**< 0.0001**	**< 0.0001**	**0**	**< 0.0001**	**0.0038**	**0.0123**	0.0828
Ni	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**0.0035**	0.3977	0.3994	**< 0.0001**	**< 0.0001**	**< 0.0001**	**0**	**< 0.0001**	**< 0.0001**	**0.0387**
Se	**0.0003**	**0.0023**	**0.0019**	**0.0004**	0.3769	0.5076	0.5563	**0.0007**	**0.0002**	**0.0038**	**< 0.0001**	**0**	**0.0055**	0.4096
V	**0.0025**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**0.0003**	**0.0052**	**< 0.0001**	**< 0.0001**	**0.0123**	**< 0.0001**	**0.0055**	**0**	0.6064
Zn	**0.0155**	**0.0069**	**0.0153**	**0.0026**	0.3458	0.1089	0.1899	**0.0001**	**0.0007**	0.0828	**0.0387**	0.4096	0.6064	**0**

Values in the bold show a significance level alpha<0.05

The results indicate that almost all metals correlate with each other and statistically significant ($p<0.05$) except for Al and Cu, As and Fe, Ba and Ca, Ca and Cu, Ca and Se, Ca and Zn, Cu and Fe, Cu and Mn, Cu and Ni, Cu and Se, Cu and Zn, Fe and Ni, Fe and Se, Fe and Zn, Mn and Zn and lastly, V and Zn. The observed relationships suggest a common source of the metals which originate from natural weathering. Afiukwa (2013) stated that the relationships are possible if the elements are having a similar chemical environment or absorptive pathways, thus the existence of such relationships between the metals influence the development and absorption of the other or the toxicants might chemically associate together to create additive, synergistic or antagonistic effects. Besides that, previous studies noted that no correlation between heavy metals means that analysed heavy metal components do not influence by a single factor but by a combination of phase biogeochemistry of the heavy metals elements (Suresh et al., 2011; Suresh et al., 2012). Moreover, K and Mg have a relatively high positive correlation coefficient ($r=0.9323$, $p<0.05$) which indicates that an increase in K concentration will increase Mg concentration. Previous studies reported by Garret (2000) showed that background levels of trace elements in rocks produce plentiful of common rock-forming minerals. Earth’s crust contained more than 30% of the overall content of major cations which known as Ca, Mg, Na and K (Alloway, 1995). A high concentration of K and Mg are highly associated with natural weathering and not due to anthropogenic activities.

Conclusion

This study has shown that the physicochemical parameters and metals concentration at all sampling stations near Lake Kenyir is within Class I and Class II of Malaysia National Water Quality Standard (NWQS) except for DO where S6, S7, S8, S9, S10, S11, S12, S13, S14, S15 and S16 were within Class III and Class IV. The factor where the study area is having low DO level could be associated with high activities of microorganisms that use up a great amount of oxygen to carry out their metabolizing activities as well as degradation of organic matters. Based on the observation during sampling, S6 and S7 were located near Butterfly Park, S8 nearby the chalet, S9 situated near Kenyir Water Park, S10 near the houseboat, S14 near the aquaculture and S16 near the bridge construction. Furthermore, the spatial distribution map from Figure 2 showed that the physicochemical parameters and metals concentration were classified into five types of pattern distribution. Besides that, from correlation coefficient analysis between metals and physicochemical parameters, there are no significant correlations were found between the metals and both COND and TUR while Cu, Se and Zn have no significance with any physicochemical parameters. Furthermore, K and Mg have a relatively high positive correlation coefficient ($r=0.9323$, $p<0.05$) which indicates that an increase in K concentration will increase Mg concentration. Besides, some physicochemical parameters significant with each other while almost all metals correlate with each other and statistically significant since $p<0.05$. The observed relationships suggest a common source of the metals. Overall, the results indicate that surface water of Lake Kenyir is still within Class I (conservation of natural environment and need no treatment for water supply) and Class IIA (need conventional treatment and suitable for sensitive aquatic species) while Class IIB (suitable for recreational use body contact). For future studies, it needs a continuous monitoring due to present anthropogenic activities surrounding the area. Besides, this study will be useful as baseline data for future references.

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