RESEARCH ARTICLE

Analyzing the major ions and trace elements of groundwater wells in Kuala Langat, Selangor

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Abstract

The analysis of trace elements and major ions on groundwater wells in Kuala Langat become the aim of this paper for the purposes to investigate the quality of the groundwater to be considered as a suitable alternative water source for domestic purposes. The groundwater sampling was conducted in thirteen stations of groundwater wells. The groundwater samples were taken from the groundwater wells which scatter in agricultural areas in Kuala Langat, Selangor. The major ions parameters have analyzed in the groundwater samples were calcium, magnesium, potassium, bicarbonate, chloride, and sulfate (Ca^{2+}, Mg^{2+}, K^+, Na^+, HCO_3^-, Cl^-, SO_4^{2-}). Meanwhile, the trace element parameters were aluminum, iron, manganese, strontium, zinc, and copper (Al, Fe, Mn, Sr, Zn, and Cu). Principal Component Analysis (PCA) was conducted to determine the influence of major ions and trace elements concentration in groundwater. Chloride, potassium, magnesium, strontium, calcium, and bicarbonate (Cl^-, Na^+, K^+, Mg^{2+}, Sr^{2+}, and HCO_3^-) were principal parameters in the first component of PCA analysis. The concentration of trace elements shows iron is the high concentration in groundwater samples. Hence, the concentration of iron in current sampling shows exceed the recommended level for raw water of the Ministry of Health. The influences from seawater intrusion and Sodium Adsorption Ratio (SAR) in groundwater also have been discussed.

Keywords: Groundwater, Kuala Langat, major ion, trace element, PCA, SAR

INTRODUCTION

As the important elements of the water resource systems and the eco-environment, groundwater is essential for water supply and the global hydrological cycle. However, groundwater contamination has become a serious nuisance in the entire world. With the anthropogenic activities and increased the human population, the quality of groundwater especially shallow groundwater is considered threatened. The contaminations from agricultural sites, manufacturing facilities, and landfills become the potential sources of groundwater pollution. Trace element naturally accumulates in water, soil, rock, and sediments due to anthropogenic activities such as agriculture, mining, and metal industries (Maiz *et al.,* 2000). Due to the water shortages and surface water pollution, the groundwater potentially can be alternative to the existing water sources in terms to accommodate the water demand.

Major ions in groundwater occur from the weathering of minerals within the rocks and determine the concentration of dissolved ions in groundwater. Therefore, the variations in major ion chemistry in

groundwater contribute to the determination of geochemical processes that identified the quality of groundwater (Rao and Rao, 2010). The mineral composition in groundwater significantly influenced by the geological condition due to the soil characteristics and mineral contents of the soil (Harun *et al.,* 2019). The understanding of the chemistry of major ions in groundwater assisting in the identification of the hydrogeochemical process and the evaluation of the groundwater quality (Li *et al.,* 2020). Hence, the analysis of major ions and trace elements in groundwater helps to identify the extent of the quality of the groundwater wells in Kuala Langat.

Major ions and trace elements are necessary to the human body in allowable levels but high concentration on trace elements may cause a health adverse effect. The concentration of trace element significantly contributes the human metabolism and importance to the plants and animals growth (Lu *et al.,* 2016). Copper is an essential nutrient for humans and animals hence the acute symptoms of toxicity can occur if there are high intake levels of copper concentration uptake by humans and animals (Bhupander and Mukherjee, 2011).

Manganese is an essential element for livings organisms where deficiency of manganese occurs a disease such as asthma, convulsions, and severe bad defect (Stancheva *et al.*, 2014). Manganese functions as assisting in the nervous system and normal reproduction. Zinc is an essential element to human health thus, once humans can tolerable a huge concentration of zinc, it also can cause adverse health effects such as anemia, skin irritations, stomach cramps, vomiting, and nausea if humans expose to the too high concentration of zinc. However, the excess of trace elements concentration occurs the toxicological effect on the human body (Purushotham *et al.*, 2013).

Trace elements contaminants such as copper (Cu), cadmium (Cd), chromium (Cr), lead (Pb), nickel (Ni), and zinc (Zn) mostly persistent than organic contaminants and potentially mobile in soils and leach into groundwater aquifers. A trace element such as lead (Pb) and iron (Fe) potentially seep in soil and aquifers naturally through soils and rocks and occur the harmful to human and living things (Othman and Asharuddin, 2020). The objectives of this paper are to investigate the groundwater quality as suitable alternative water sources for domestic purposes in Kuala Langat areas by analyzing the potential of the trace elements and major ions which potentially can deteriorating the quality of groundwater.

MATERIALS AND METHODS

Site of Study Area

Kuala Langat is known as an agricultural hub with the latitude 2°48'34.4"N and longitude 101°30'11.8"E of 857.65 km2. Kuala Langat consists of palm oil plantation and other varieties of crops and vegetables. The geology of the study area constitutes the quaternary period consist of sand, silt, peat, and minor gravel of marine and continental deposits (JICA, 2002). The regions in Peninsular Malaysia originated from igneous rocks and older bedrocks of the Mesozoic and Paleozoic eras (Hutchison, 1989). The geology of the current study originated from the alluvial soil and granite rocks occur a high potential of weathering process and contribute high iron concentration.

The groundwater recharges flow from the mountains upstream and hilly areas and disseminated in the flat lowlands. Groundwater wells in this study consist of two sub-area which are the Northern Kuala Langat area and Southern Kuala Langat area. Northern Kuala Langat area consists of shallow groundwater wells between 4 to 35 meters depth which is BKLTW12, MW01, MWD4, BKLEW2, MW05, BKLTW19, MWD2, and MWD5. Meanwhile, the deep groundwater wells in the Southern Kuala Langat area represent the BKLTW16, J7-1-4, BKLTW11, BKLTW15, BKLEH29 groundwater wells which more than 60 meters. Fig. 1 shows the thirteen groundwater wells in both the Northern and Southern Kuala Langat area.

Fig. 1 Groundwater wells in Kuala Langat, Selangor.

Groundwater Sampling

Thirteen groundwater samples were collected from thirteen wells at Kuala Langat from February 2016 to January 2018. The groundwater samples collected using acids washed polyethylene bottles according to the APHA methods (APHA, 2012). Sampling procedure and groundwater analysis followed the APHA guidelines and Mineral and Geosciences Department guidelines (APHA, 2012). The groundwater wells considered for groundwater sampling which includes the shallow groundwater which less than 22.0 m, intermediate was between 22.0 m to 40.0 m and deep aquifer were more than 40.0 m in depth (Sefie *et al.*, 2015). The groundwater depth was taken before and after the sampling process using groundwater level meter. The submersible pumps used to pump the groundwater samples and the stagnant was removes in 15 to 30 minutes to eliminate the unnecessary substances during the sampling procedures (Appelo and Postma, 2005).

The major ions and trace elements analysis required in field filtration and all groundwater samples were vacuum filtered using filters paper of Whatman cellulose Nylon-type Millipore with a pore size of 0.45-um. Sulfate was measured using the SulfaVer 4 pillows powder according to the HACH method. The sulfate concentration detected using the Portable Spectrophotometer HACH DR2800. Meanwhile, bicarbonate and chloride were analyzed using the titration method that was conducted in the laboratory. Major ions and trace elements were analyzed using inductively coupled plasma mass spectrometry (ICP-MS) model Nexion 300X, made by PerkinElmer from the United States of America (USA).

RESULTS AND DISCUSSIONS

Major Ions Concentration in Groundwater

Groundwater mainly contains major ions consists of cations and anions which available from the minerals in the aquifers. The analysis of major ions in groundwater samples significantly resulted in a high concentration on several parameters. Magnesium, calcium, sodium, and potassium is a common cation that exists in groundwater sources. Anions in groundwater comprise of bicarbonate, chloride, and sulfate. The sources of major ions in groundwater derive from rocks weathering which contains chemical constituents. Sodium revealed the high major cation in Kuala Langat groundwater wells. The general dominance of cations was in the order of sodium (Na^+) > magnesium (Mg^{2+}) > potassium (K^+) > calcium (Ca^{2+}). Sodium shows a high concentration in MWD5 groundwater well of 2109.72 mg/L. The enrichment of sodium in groundwater associated with the interaction processes of water-rock whereas the high sodium introduced in volcanic rocks. The sodium generally occurs from the NaCl remnants or feldspathoids and sodic feldspar which present in rock and sediment (Sidibé *et al.*, 2019).

The location of the study area where near to the coastal areas also conjugate with the association of the high sodium concentration in the groundwater samples. Magnesium also abundantly present in groundwater samples in the Kuala Langat area where the magnesium revealed a high concentration in MWD5 groundwater well of 241.77 mg/L. The primary source mineral of magnesium is granite, chlorite, and biotite. The magnesium ion occurs due to the chemical weathering process and the dissolution of rocks, dolomite, and marls (Sidibé *et al.*, 2019). Meanwhile, calcium and potassium less abundance in groundwater samples for the current study. Generally, bicarbonate is an indicator of calcium and magnesium where the concentration of bicarbonate in groundwater mainly due to calcium and magnesium cations (Rapant *et al.*, 2017). The major cation of calcium and magnesium occur from the mineralization process in groundwater due to the dissolution of carbonates. Therefore, the low concentration of calcium in the current study accordingly with the low bicarbonate concentration in groundwater samples.

The major anions in groundwater samples show in order of chloride (Cl^-) > bicarbonate (HCO_3^-) > sulfate (SO_4^{2-}). The high chloride recorded in BKLTW11 groundwater well of 1923.22 mg/L. Chloride shows a high concentration among the groundwater wells in the Kuala Langat area. The high chloride in groundwater generally increases with the increasing of minerals contained in the aquifers

(Belgaum, 2011). According to Sawyer *et al.,* (2003), chloride occurs a high accumulation in lowland areas such as rivers and groundwater besides in the mountain and upland generally showed the lower chloride concentrations. The concentration of chloride mainly derives from natural and anthropogenic sources. Natural sources of chloride derive from the geogenic process, bedrock weathering, atmospheric deposition, soil surface, oceans, and geological deposits. The concentration of chloride in groundwater deposited from precipitation of natural weathering of rocks and minerals (Mullaney *et al.,* 2009). Chloride present naturally from rock weathering primary in sedimentary rock. Kuala Langat represents of Quaternary deposits of Simpang, Gula, and Beruas Formations in sedimentary bedrock of Kenny Hill Formations (Samsudin *et al.,* 2007).

Kuala Langat consisting of the Quaternary sediments were enriched with the important major ions and trace metals such as magnesium, calcium, potassium, chloride, and strontium (JICA, 2002). In addition, the concentration of chloride in groundwater principally due to the base exchange of sodium for calcium and magnesium occur from the agricultural return flow (Srinivasamoorthy *et al.,* 2014). Meanwhile, sulfate shows the exceptional concentration in BKLTW19 groundwater well was 592 mg/L. High sulfate is significant with the elevated iron concentration in this groundwater well where the high sulfate derives from the oxidation process of pyrite (Harun *et al.,* 2019). The high sulfate concentration in groundwater also the same as the finding of Lakshmanan *et al.,* (2003), where the increase of sulfate may associate with the sources of the area. However, sulfate in other groundwater wells stations showed low concentration. This situation derives from the sulfate reduction process and dissolution of gypsum where the sources of pyrite not detected were unable to enhance sulfate in groundwater (Datta *et al.,* 1997). Fig. 2 and Fig. 3 show the major ions for cations and anions concentration in Kuala Langat groundwater wells respectively.
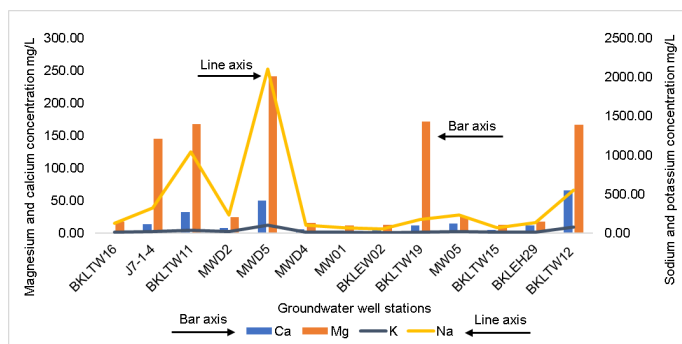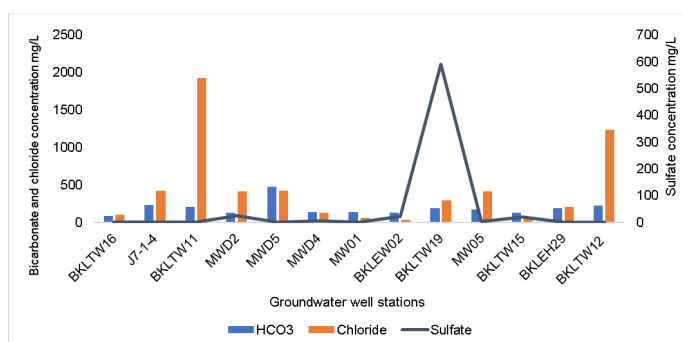

Fig. 2 Major cations in groundwater samples.

Fig. 3 Major anions in groundwater samples.

Trace Elements Concentration in Groundwater

Trace elements concentration mainly high in groundwater which accumulates from the mineral existed in the aquifer. The deterioration of groundwater quality associated with the increase of urbanization and population expands. Anthropogenic activities contribute to the trace elements pollution to groundwater sources such as agricultural activities, atmospheric deposition, geological weathering, corrosion products from the industrial and residential which increase the

occurrence of trace elements in groundwater (Lu *et al.,* 2016). The general dominance of trace elements was in the order of iron (Fe) > manganese (Mn) > strontium (Sr) > aluminium (Al) > zinc (Zn) > copper (Cu). Iron shows a high concentration in BKLTW19 groundwater well of 36.14 mg/L. Iron is abundant which generally found in soil and important macro elements for plants. Iron also identified as slow release multi micronutrient fertilizer (Bandyopadhyay *et al.,* 2014). The Kuala Langat consisted of the agricultural hubs in the peatland areas (JICA, 2002). Iron in groundwater contributed from the criteria of peat soil where the iron content in soil significantly affected by the composition of the soil (Jamil *et al.,* 2014). Iron potentially high accumulates in high organic matter such as peat soils which have high cation exchange capacity with significantly high in hydrogen ions (Isahak, 1992).

The high organic matter in peat soil contributes to the high iron in soil and infiltrates into groundwater bodies. The high organic matter in peat soil elevates iron concentration due to the mechanism of iron retention to the organic matter which increases the saturation in peat soil (Norrstrom, 2009). Elevation of iron in soils contributes from the higher iron oxide occurs the reddish color earth materials in high topographical areas (Jamil *et al.,* 2014). The previous research also showed the high iron content detected in peat soil agricultural fields due to the high organic carbon content (Jamil *et al.,* 2014). Besides, the peat area also consists of humic acid whereas elevated to the high iron concentration in groundwater (Zulfikar *et al.,* 2014). Meanwhile, The low pH value in groundwater revealed the high iron and sulfate significantly from the high acidity occur form the weathering of pyrites and leach out to ferralitic soils approximately below 5.5 (Jusop *et al.,* 2014). The chemical weathering process occurs by the iron speciation in agricultural land affected from the iron precipitates and iron oxyhydroxides formation (Jamil *et al.,* 2014). The weathering process of rocks released the ferrous (Fe2+) and ferric (Fe3+) and disseminated to the environment (Kampf *et al.,* 2000). In addition, the rock weathering process in humid tropical regions such as Malaysia enhances the ultisols and oxisols formation (Jamil *et al.,* 2014).

The high manganese found in the groundwater samples in current study areas showed the manganese occurs from the weathering of the rocks were higher in peat and alluvium due to the manganese oxide accumulation resistance in the topsoil surfaces (Jusop *et al.,* 2014). The occurrence of kaolinite and oxides from the fraction of clay in ultisols formation contributes high of iron and aluminum in soil (Jusop, *et al.,* 2009). Meanwhile, zinc and copper showed a low concentration in groundwater samples from groundwater wells stations. The agricultural practices not significantly influenced by the zinc and copper concentration to the deterioration of groundwater quality. The concentration of zinc and copper generally low in groundwater which difficult to extract in soil and retained easily in the solid phase (Malecki *et al.,* 2016). Besides, the copper shows lower concentration compare to iron and manganese in agricultural soils especially in Peninsular Malaysia due to the acidity of soil from the oxidation of iron as well as the high organic matter content and existence of clay minerals in soils (Jamil *et al.,* 2014). Fig. 4 showed the concentrations of trace element for each sampling station in Kuala Langat groundwater wells.
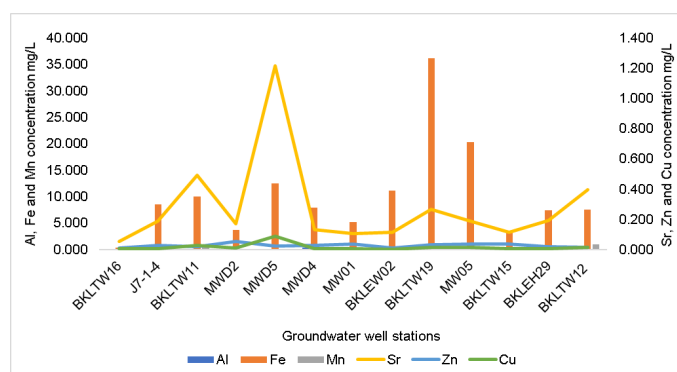

Fig. 4 Trace elements in groundwater samples.

Principal Components Analysis

Three components were extracted from the Principal Component Analysis (PCA) influenced the hydrogeochemistry in groundwater. Chloride, sodium, potassium, magnesium, strontium, bicarbonate, and calcium demonstrated in the first component from the PCA analysis. The PCA of the major ions and trace elements reveals that 75.38 % of the total variance is explained by three components. The relations between factors is explainable using the varimax orthogonal rotation to determine the interrelated with each other. PC1 explained 32.20 % of the total variance and had strong loadings on major ions. In addition, PC2 explained 19.92 % of the total variance, which had strong loadings on soil characteristics. Meanwhile, PC3 revealed 18.80 % strong loadings on agricultural practices.

The first component of PC1 extracted from PCA analysis revealed the cations and anions were influencing the groundwater. The bedrock weathering process contributes to the high major ions in the aquifer. The sources of major ions are naturally derived from the precipitation of rocks and minerals in groundwater. The high concentration of chloride and sodium was revealed in the first component of PCA analysis shows there were has an influence from the seawater in the groundwater samples in Kuala Langat. The location of groundwater samples in this study significantly near to the coastal area in Morib Island. Therefore, this becomes the main contribution of the high chloride and sodium concentration in the groundwater samples.

The PC2 showed there was the existence of pollution from the agricultural areas such as zinc, copper, aluminum, and sulfate were in the groundwater samples. These study areas located in the agricultural areas where such consists of oil palm plantations, crop plantations as dragon fruits, vegetables, and fruits. The presence of fertilizers, manures, and pesticides that occur from agricultural practices have the potential to accumulates in groundwater from the sedimentation and infiltrations into aquifers from the agricultural fields. The mobility of zinc and copper significantly influenced by the organic matter reactions, minerals precipitation, and dissolution, and oxidation-reduction processes and ion exchange (Malecki *et al.*, 2016). The sorption process of trace element such as zinc, copper, and aluminum occur by organic matter in the soil. According to previous research, organic matter also has the potential to absorb trace element content such as zinc and copper in soil and leaching to groundwater (Covelo *et al.*, 2007). Meanwhile, the PC3 explained the strong loading of iron and manganese provides a significant influence on soil and geology. Iron and manganese originated from the peat soil in current agricultural areas. Groundwater wells in this study originated from peat soil areas significantly enrich with organic matter. Peat soil characteristic naturally contains high iron and contributes to the elevated iron concentration in groundwater. The total variance is explained by three components that were explained in Table 1. The rotated component matrix for three components of PC1, PC2, and PC3 was elaborated in Table 2.

Table 2 Rotated component matrix.

Variables	Rotated Component Matrix		
	Component		
	1	2	3
Chloride	0.918		
Sodium	0.899	-0.152	
Potassium	0.867		
Magnesium	0.734		0.489
Strontium	0.682		0.539
Bicarbonate	0.675		-0.214
Calcium	0.665	0.296	0.577
Zinc		**0.920**	0.146
Copper	0.128	**0.901**	
Aluminum		**0.643**	0.402
Sulfate	-0.287	**0.478**	0.261
Manganese		0.263	**0.875**
Iron	-0.193	0.286	**0.714**

Seawater Intrusion

The investigation on major ions in groundwater also significant to the influence of the seawater. According to Khaki *et al.*, (2016), sodium, bicarbonate and chloride significantly high in groundwater samples from Kuala Langat groundwater well stations due to the aquifers are near to the coastal area (Khaki *et al.*, 2016). Meanwhile, the hydrochemistry on groundwater in agricultural land in Tamil Nadu resulted in the calcium and sodium are dominant in the groundwater samples (Lakshmanan *et al.*, 2003). The finding however showed the investigation on major ions in groundwater samples in Tamil Nadu is far from the coastal area. Groundwater well stations in Kuala Langat significantly shows high sodium, chloride and magnesium concentration in the groundwater samples.

The location of groundwater wells in the current study near the coastal area contributes to the main reason for the seawater intrusion to the groundwater sources. Kuala Langat is significantly showing the importance of brackish and freshwater transition point (Sapari *et al.*, 2011). Chloride is a good indicator of seawater intrusion in groundwater sources. According to Fass *et al.*, (2007), the increase of chloride associated with seawater intrusion due to over-pumping activities. The excessive concentration of chloride toxicity in human bodies has not observed and the affected sodium chloride metabolism potentially causes heart failure (WHO, 2003). The high chloride concentration among the groundwater wells also resulted in the saltwater influence in the groundwater sources. The deep horizon of the aquifer showed the vulnerability of saltwater mixing where the chloride concentration showed significantly higher chloride concentration in the groundwater sources. The seawater intrusion into groundwater occurs when the over-pumping activities in accommodating the groundwater sources especially in coastal aquifers for touristic areas cause the decreasing of groundwater table and the seawater level able to increase (Christina and Alexandros, 2014).

The situation lowering the freshwater level and aquifers are intruded by the seawater. Chloride, sodium, and magnesium show influential major ions in the groundwater samples for cation and anion respectively. However, the correlation analysis has been done to indicate the reliability of the seawater intrusion on the groundwater sources in the Kuala Langat area. Chloride exhibited a very strong correlation (0.803) with potassium between these two cations and anions respectively. The correlation of the parameters was equal to or greater than 0.5 considered as significant values (Ayuba *et al.*, 2013). The strong correlation between chloride and potassium significantly shows the groundwater in Kuala Langat influences from the seawater intrusion. The correlation coefficient matrix was presented in Table 3.

Table 1 Total variance and matrix of principal components analysis.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.73	36.41	36.41	4.73	36.41	36.41	4.45	34.20	34.20
2	3.48	26.76	63.17	3.48	26.76	63.17	2.59	19.92	54.12
3	1.27	9.75	72.92	1.27	9.75	72.92	2.44	18.80	72.92
4	0.80	6.15	79.07						
5	0.68	5.22	84.29						
6	0.52	4.03	88.32						
7	0.40	3.06	91.39						
8	0.31	2.39	93.78						
9	0.26	1.99	95.76						
10	0.19	1.47	97.23						
11	0.15	1.19	98.42						
12	0.13	1.01	99.43						
13	0.07	0.57	100						

Table 3 Correlation coefficient matrix of groundwater quality parameters.

Parameters	Calcium	Magnesium	Potassium	Bicarbonate	Chloride	Sulfate	Aluminum	Iron	Manganese	Srontium	Zinc	Copper
Calcium	1											
Magnesium	0.757	1										
Potassium	0.571	0.621	1									
Bicarbonate	0.345	0.318	0.499	1								
Chloride	0.553	0.635	**0.803**	0.486	1							
Sulfate	0.064	0.02	-0.158	-0.256	-0.26	1						
Aluminum	0.387	0.313	0.062	-0.08	-0.009	0.262	1					
Iron	0.357	0.147	-0.152	-0.081	-0.182	0.274	0.367	1				
Manganese	0.584	0.395	0.04	-0.164	0.019	0.33	0.449	0.639	1			
Srontium	0.719	0.746	0.457	0.384	0.558	-0.106	0.248	0.121	0.394	1		
Zinc	0.34	0.12	-0.005	-0.033	-0.097	0.425	0.612	0.357	0.369	0.037	1	
Copper	0.408	0.202	0.138	0.096	0.029	0.294	0.494	0.303	0.32	0.033	0.774	1

However, the groundwater in the current study has moderate salinity derives from the seawater intrusion according to the chloride concentration of groundwater quality classification by Soulios, (2004). The concentration of chloride in Kuala Langat groundwater wells were 438.75 mg/L revealed average salinity of classification of chloride concentration in groundwater between 300-500 mg/L. The strong correlation between chloride and potassium in Kuala Langat groundwater wells however revealed the seawater intrusion does not deteriorate the groundwater quality due to the salinity in groundwater under the maximum range. Table 4 shows the classification of chloride concentration of groundwater quality according to Soulios, (2004).

Table 4 Classification groundwater quality based on chloride concentration Soulios, (2004).

Chloride (mg/L)	Groundwater Quality
<300	Good
300-5000	Moderate salinity
>5000	Seawater

Sodium Adsorption Ratio (SAR)

The Sodium Adsorption Ratio (SAR) has been conducted on this study due to the high sodium concentration in groundwater samples. Sodium is introducing into the aquifer through the dissolution from rocks and from rainwater. Nevertheless, sodium is considered one of the main factors that regulate irrigation water due to its effects on soil and plants (Oborie and Nwankwoala, 2014). Generally, ion toxicity, crop sensitivity, trace element toxicity, and salinity has evaluated on the quality of irrigation water (Wilcox, 1955). High electrical conductivity in water normally revealed unsuitability for irrigation. The recommended electrical conductivity for irrigation water generally lower than 700 µS/cm and suitable for irrigation purposes (Asadi *et al.,* 2020). Basically, the salinity and the sodium adsorption ratio (SAR) are the two common constituents that influence the infiltration. Magnesium, calcium, and sodium have been used to calculate the sodium adsorption ratio (SAR) for the water samples. The ratio is used to evaluate the suitableness of the water for irrigation. The SAR value of irrigation water is computed as:

$$SAR = \frac{Na^+}{\sqrt{\frac{1}{2}(Ca^{2+} + Mg^{2+})}}$$

The Sodium Adsorption Ratio (SAR) in groundwater samples in the Kuala Langat area revealed the high concentration of SAR was 59.37 mg/L. The SAR shows a low concentration in the water when the value is below 10 mg/L and suitable for irrigation (Johnson and Meyer, 1975). However, the high SAR of more than 10 mg/L occurs the magnesium and calcium displacing by sodium and damaging the soil structure. Nevertheless, sodium ions tend to be absorbed by clays particles and replacing the magnesium and calcium ions

(Nwankwoala, 2016). Therefore, the groundwater in Kuala Langat resulted in the unsuitability for irrigation purposes.

Maximum Permissible Limit

The trace elements and major ions in groundwater were compared to the recommended raw water quality of the Ministry of Health Malaysia. Trace elements in groundwater show only iron concentration exceeds the maximum recommended level of the Ministry of Health Malaysia were 10.34 mg/L which compared to the recommended acceptable value of 1 mg/L. However, other parameters of trace elements in this study revealed under the maximum recommended level of the Ministry of Health Malaysia. Meanwhile, only chloride shows exceed the Ministry of Health Malaysia was for major ions 250 mg/L while chloride concentration in the current study shows 438.75 mg/L. Another major ion parameter in groundwater not exceeds the maximum recommended level of the Ministry of Health Malaysia.

The exceeding of iron and chloride in groundwater revealed to the natural factor of soil characteristic and bedrock weathering. High iron concentration groundwater significantly derives from the origin of peat soil characteristic which contains high iron due to the high contents of organic matter and the formation of pyrite. The bedrock weathering process contributes to the increase of chloride naturally in groundwater. The existence of the metals in groundwater exceeds the recommended level may occur the groundwater infeasible for consumable (Othman and Asharuddin, 2020). However, the groundwater sources in Kuala Langat significantly can be used for domestic purposes and not possess a threat to human health referring to the recommended level by the Ministry of Health Malaysia for raw water. Fig. 5 and Fig. 6 show the trace elements and major ions concentration with the acceptable value of the Ministry of Health for raw water.
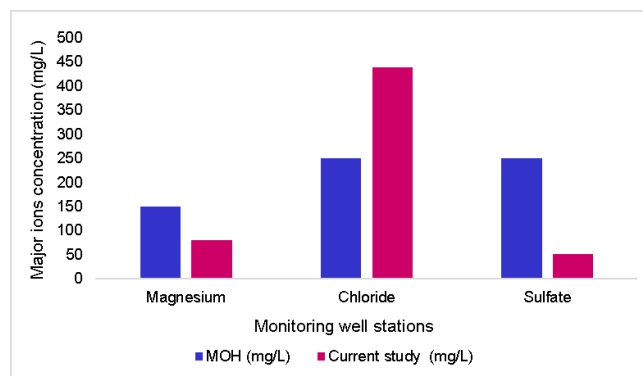

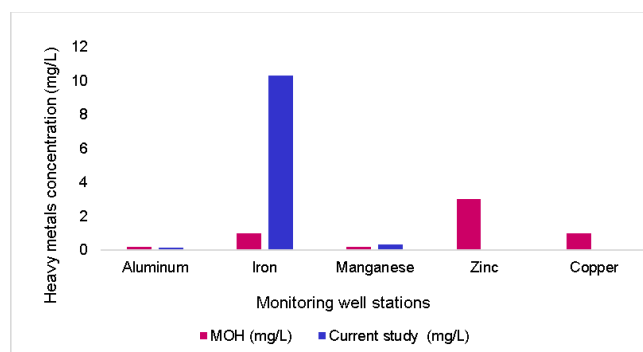**Fig. 5** Maximum permissible limit of major ions.

Fig. 6 Maximum permissible limit of trace elements.

CONCLUSION

The analysis of trace elements and major ions on groundwater in Kuala Langat shows that the major ions were highly influential in groundwater sources compare to the trace element concentration. Major ions in groundwater sources derive naturally from the aquifer

type of sedimentary rock. The elevated sodium, magnesium, and chloride of major ions in groundwater also occur from the natural rock weathering process. The high iron in groundwater contributes to forming the peat soil which enriches organic matter and increasing the iron accumulation in soil. The PCA analysis revealed the groundwater in Kuala Langat is dominated by the major ion parameters. However, only iron and chloride were exceeding the maximum recommended level of the Ministry of Health Malaysia. Meanwhile, the groundwater in Kuala Langat has influenced by seawater intrusion with moderate salinity. The trace elements and major ions not significantly deteriorate the quality of groundwater. The groundwater in Kuala Langat is suitable for alternative water sources for domestic purposes.

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