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Hydrogeochemistry investigation on groundwater in Kuala Langat, Banting, Selangor

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Abstract: This paper emphasized the hydro geochemistry of groundwater in Banting, Kuala Langat, Selangor and the hydrogeological properties which contribute to the potential degrading of the quality of the groundwater. The groundwater characteristics in Banting, Kuala Langat, Selangor are influenced by aquifer types and the geomorphology of the area. Groundwater samples were collected at thirteen monitoring wells from February 2017 to January 2018. The thirteen selected monitoring wells for this study is scattered in agricultural areas. The investigation of groundwater measured the physical parameters which are total dissolved solid, electrical conductivity, salinity and chemical oxygen demands. Major ions such as chloride, calcium, magnesium, potassium, sodium bicarbonate and strontium were also calculated. Iron, manganese and zinc which are heavy metal elements together with phosphate, nitrate and sulfate were considered as inorganic parameters in this analysis. The groundwater samples have influences from the seawater intrusions as significantly high major ions concentration were detected. Non-point pollution from the agricultural practices does not deteriorate the groundwater quality even though the monitoring wells are located in agricultural areas. Groundwater sources in the current study are suitable for domestic use and agricultural irrigation.

Keyword: Groundwater, hydro geochemistry, seawater intrusion

INTRODUCTION

Groundwater is an essential natural resource to the whole living things sustainability. Water scarcity is a highlighted issue that has to be overcome in order to accommodate sufficient clean water sources for drinking and domestic purpose. Hence, sustaining the good quality of groundwater becomes crucial to ensure the groundwater source is safe to human health to avoid any health threat. This current research focused on the groundwater located near coastal areas. The monitoring wells in Banting, Kuala Langat are situated near Morib beach. Potential influence to the quality of groundwater through seawater intrusions therefore exists. This study aims to highlight the potential physicochemical properties which can affect the groundwater sources.

Groundwater geological aspects

Geological condition of an area has a significant influence on the mineral composition of groundwater as it is affected by the soil characteristics and mineral contents of the soil (Azlan *et al*., 2012). Pollutants which exist in the soil derived from heavy metals concentrations also has influence on the mineral contents of the groundwater and its quality. Alluvium soils which are soft soils usually exist in agricultural lands. This clayey type of soil with high water holding capacity and low porosity contains high mineral content and organic matter. Soil rich with organic matter and mineral content such as ammonia and sulfate are suitable for agriculture and plantations. However, these substances would also highly exist in the groundwater. The anthropogenic pollutants can potentially affect the aquifer systems and together with precipitation, will increase the hydro chemical composition of groundwater (Shamsuddin *et al*, 2015).

MATERIAL AND METHOD

Study area

Banting, located in the district of Kuala Langat, Selangor (857.65 km^2) and situated at latitude 2°48'34.4"N and longitude 101°30'11.8"E was chosen as the study area. Banting is known as an agricultural hub. The study area consists of oil palm plantations and a variety of crops as well as vegetable gardens. The study area represents a part of the Langat River Basin. The monitoring wells in this study are in alluvial areas. The geology of the area is represented by the quaternary geology, that consists of marine and continental deposits such as silt, sand and peat with minor gravels. ln the area of the monitoring wells, the groundwater recharge is from the hilly areas and mountains upstream. Generally, the aquifers are extensively disseminated in the flat lowlands. The Kuala Langat monitoring wells are divided into two sub-areas, i.e. Northern Kuala Langat and Southern Kuala Langat. Monitoring wells BKLTW12, MW01, MWD4, BKLEW2, MW05, BKLTW19, MWD2 and MWD5 are located in the Northern Kuala Langat area and are shallow in depth, approximately 4 to 35 meters. Monitoring wells BKLTW16, J7-1-4, BKLTW11, BKLTW15 and BKLEH29 are located in the Southern Kuala Langat area where the depth of wells are more than 60 meters. Figure 1 shows the locations of the thirteen monitoring wells.

Figure 1: Monitoring wells in Banting, Kuala Langat.

Groundwater sampling

The physicochemical characteristics of the groundwater samples were assessed to evaluate the effect on groundwater sources. The in-situ parameters were analyzed at each monitoring wells; the temperature and total dissolved solids using calibrated Myron L Ultrameter 6P. A Thermo Scientific Orion 3-star Portable pH meter was used to measure pH, while the YSI 30 Salinity and Conductivity meter was used to measure salinity and conductivity. Turbidity was measured using Thermo Orion AQ4500 Turbidity Meter. The groundwater sampling procedure and analysis were carried out following the guidelines by APHA and the Department of Mineral and Geoscience Malaysia (APHA, 2012). Groundwater samples were collected from thirteen monitoring wells with shallow aquifer (less than 22.0 m), intermediate (22.0 m to 40.0 m) and deep aquifer (more than 40.0 m in depth) (Sefie *et al*., 2015).

The sampling was conducted from February 2017 to January 2018. This field verification sampling was necessary to determine the selected groundwater quality parameters. The groundwater samples were pumped using the submersible groundwater pumps and the groundwater level meter was used to measure the groundwater depths before and after the sampling process. The purging pump was used to remove the stagnant groundwater for approximately 15 to 30 minutes to ensure the groundwater samples did not consist unnecessary elements during the sampling procedure (Appelo & Postma, 2005).

RESULTS AND DISCUSSION

Groundwater hydro geochemistry analysis

Physical characteristic and inorganic parameters

The collected groundwater samples were analyzed for physical characteristics, major ions, heavy metals and inorganic parameters. Sample from MDW5 monitoring well was most vulnerable to pollutants. This monitoring well is situated in Sungai Lang, Banting and is within an oil palm plantation. Results from the analysis indicate high pollutant content in this monitoring well for the parameters analyzed. Besides that, the electrical conductivity, salinity, chemical oxygen demands, nitrate and phosphate levels were also highest in MWD5 monitoring well. The electrical conductivity revealed high concentration in the groundwater among all the monitoring wells. The ion of dissolved salt from total dissolved solid concentration in the groundwater influencing the flow of electrical current was directly proportional to the increasing electrical conductivity in groundwater bodies. However, for the high electrical conductivity recorded in the groundwater bodies, there are several factors which need to be taken into considerations such as the land uses and geology around the monitoring wells. Electrical conductivity was high during dry season in a majority of the monitoring wells, similar to Awoyemi *et al*. (2014) in Lagos State, Nigeria. However, this finding contradicted the results of Reddy *et al.* (2011) where the increasing electrical conductivity was proportionate to the increasing water table whereas this study revealed that the electrical conductivity was high in low water table during the dry season.

The monitoring wells in the current study are scattered in agricultural areas. Nitrates and phosphates apparently derived from fertilizers and manure applications at the oil palm plantations were the general substances in the groundwater samples from agricultural areas. The high chemical oxygen demand in groundwater samples from the monitoring wells significantly showed the degradation process occuring due to the decomposing of inorganic pollutants. The presence of nitrate, phosphate, and potassium from fertilizers and manures application such as NPK fertilizer from agricultural practices and oil palm plantations have a great discharge into surface water through leaching, runoff and sedimentation. These substances are accumulated in surface water and then infiltrates into the groundwater. These substances then contribute to the increasing electrical conductivity and deteriorate the quality of groundwater. The finding is similar to Reddy *et al.* (2011) where nitrate showed a positive correlation with electrical conductivity in agricultural monitoring wells. The concentration of the physical properties in groundwater samples are graphically explained in Figure 2 to Figure 7.

Major ions

Hydrogeochemistry in groundwater which is influenced by seawater intrusion and apparently from the geological formation presents a high concentration of major ions such as magnesium, calcium and sodium (Sajil *et al*., 2014). The hydrogeochemistry analysis of groundwater consists of analysis of the basic parameters i.e. chloride, calcium, magnesium, potassium, sodium and bicarbonate, and sulfate. These seven parameters represent 95% of the major ions in water solutes from a chemical aspect of groundwater

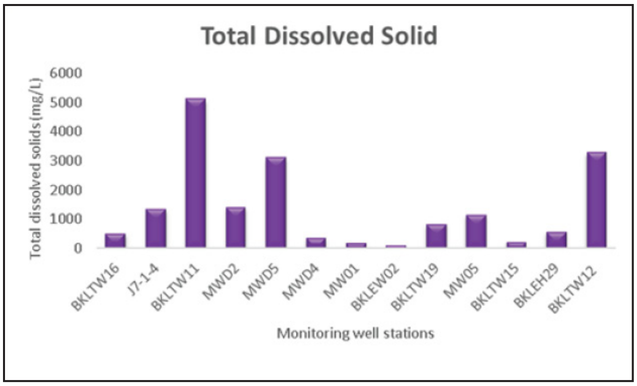

Figure 2: Total solid concentration in monitoring wells.

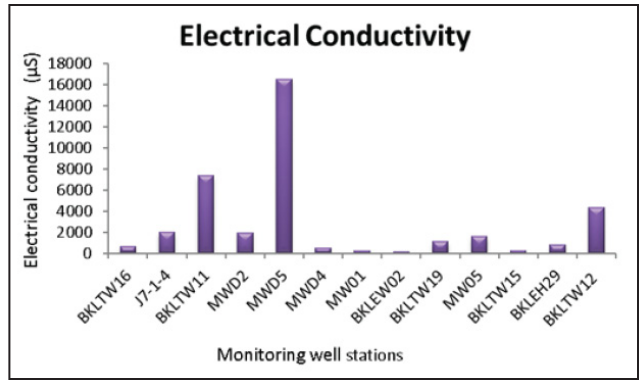

Figure 3: Electrical conductivity in monitoring wells.

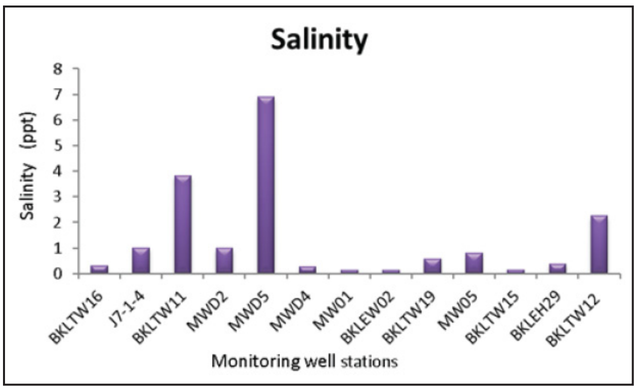

Figure 4: Salinity concentration in monitoring wells.

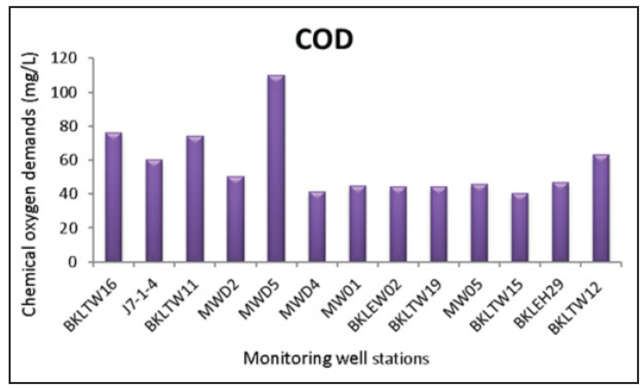

Figure 5: Chemical oxygen demand concentration in monitoring wells.

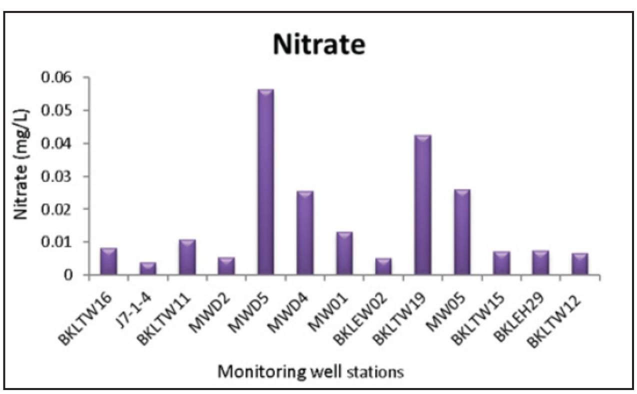

Figure 6: Nitrate concentration in monitoring wells.

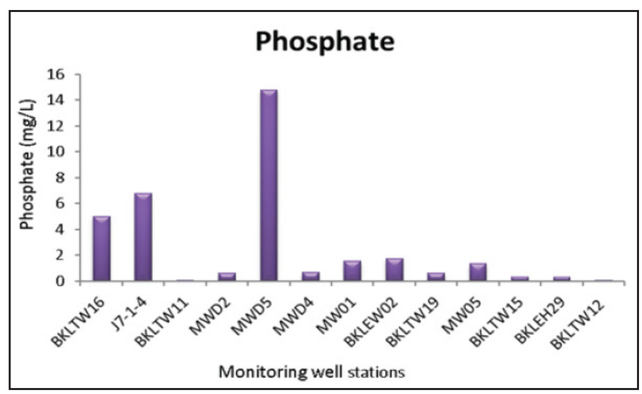

Figure 7: Phosphate concentration in monitoring wells.

chemistry (Kura *et al.,* 2015). Referring to Figure 8, major ions such as chloride, bicarbonate and sodium showed high concentrations in MWD5 monitoring well. This condition supported the increasing major ions and heavy metals which also showed high concentrations in most of the monitoring wells. The highest sulfate concentration was recorded in sample from BKLTW19 monitoring well. The high sulfate content in the groundwater was also due to the surrounding soil characteristics, apart from seawater intrusions into groundwater. The study area consists of peat soil that is high in iron concentration. The high iron content significantly increases with the increase of sulfate. Sulfate showed higher concentration in the groundwater at BKLTW19 monitoring well due to the oxidation of pyrite. Pyrite is abundantly distributed in the sedimentary rocks, thus the concentration of iron is also concurrently increasing with sulfate, hence the high iron concentration in groundwater (Samsudin *et al*., 2007).

Heavy metal

The characteristics of peat soil enhance the accumulation of heavy metal in groundwater. Iron, manganese and zinc are generally found in peat soil areas. High concentrations of iron in the groundwater sources originated from the geological formation of the study area that consists of peat soil that has high iron content. In addition, the high iron concentration in groundwater with high sulfate was recorded at BKLTW 19 monitoring well. The iron concentration is apparently highest in BKLTW 19 monitoring well, as well as sulfate. The high turbidity of groundwater in a majority

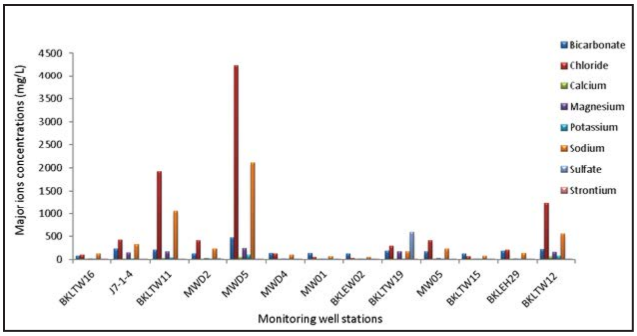

Figure 8: Major ion concentration in monitoring wells.

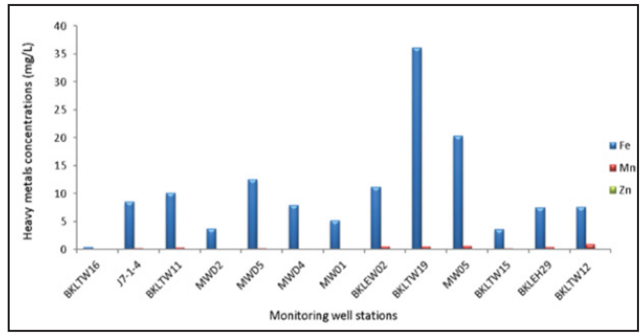

Figure 9: Heavy metal concentration in monitoring wells.

of the monitoring wells was due to humus presence in the groundwater that was formed by the decomposition of organic matter by soil microorganisms. In addition, the peat soil in the study area which has high iron content is also a factor to the increased turbidity in the groundwater. Peat soil consists of high organic matter where the mechanism of iron retention by organic matter contributes to the high iron content in soil (Norrstrom, 1995). Therefore, the high iron content in peat soil areas enhances the increment of iron concentration in groundwater through infiltration process. Meanwhile, manganese concentration is also high in samples from several monitoring wells. The high levels of manganese in groundwater is also contributed by the criteria of the peat soil which enhanced manganese oxide accumulation (Jusop *et al*., 2014). The occurrence of rock weathering in peat soil areas enhances the manganese concentration in groundwater. However, zinc revealed low concentrations in the groundwater samples, possibly due to the fact that applications of pesticides or fertilizer containing zinc are carried out following the regulations of good agricultural practice in agriculture areas. Figure 9 shows the heavy metal concentrations in samples from the monitoring well stations.

Principal component analysis

A principal component analysis (PCA) was carried out on samples from the thirteen monitoring well stations for physicochemical properties that include temperature, total dissolved solids, electric conductivity and salinity. The PCA is suitable for this analysis upon data that is normalized. Bartlett's test of sphericity is statistically significant ($p < 0.000$) for the purposes of indication where the data is factorizable. PCA for physicochemical properties revealed three components that have eigenvalues greater than one and which explained 45.12, 61.43 and 71.53 % of the total variance, respectively (Table 1). The visualized scree plot indicates that three components should be retained which explained 71.53 % of the total variance. The orthogonal rotation Varimax is used to eliminate the relevance effects between components and therefore the main variables for each component can be identified.

The scree plot and factors loadings illustrated the three components retained in this analysis for dominant parameters accumulated in groundwater samples in Banting, Kuala Langat. The physicochemical properties of samples from the monitoring wells explained 43.78 % of the total variance on rotation sums of square loading. These results appeared the strong loadings on electrical conductivity, chloride, salinity, sodium, potassium, total solid, magnesium, calcium and strontium performed in PC1. These parameters can be classified as seawater intrusions. However, PC2 only showed iron, manganese and zinc were dominant with 16.65 % of total variance on rotation sums of square loading. The significantly high heavy metal components in PC2 described the soil characteristic in the current study areas. Iron, manganese and zinc concentration existence originated from the peat soil which had infiltrated into the groundwater. The peat soil areas generally contain high iron concentrations and these components were also high in groundwater sources. Meanwhile, PC3 showed 11.099 % of the total variance on rotation sums of square loading. The nitrate and phosphate revealed in PC3 apparently come from point or non-point source of pollution, where the land use of this area is under agriculture. The Principal Component analysis showed the groundwater chemistry in the current study is most influenced by the major ions and physical characteristic which had dissolved in the groundwater. However, referring to the dominant parameters obtained in PC1, the characteristics of groundwater in the current study was dominantly influenced by the seawater intrusion. The evaluation of seawater intrusion in groundwater can be determined by the existence of calcium, magnesium, sodium, potassium, chloride, bicarbonate, strontium and sulfate (Sudaryanto & Naily, 2018). The rotated component matrix in Table 2 showed the dominant parameters in groundwater samples.

Permissible limit in groundwater

The groundwater quality in the current study area was compared with the Recommended Raw Water Quality by the Ministry of Health and National Water Quality Standards for Malaysia (NWQS) for electrical conductivity. The electrical conductivity of NWQS for Class I and Class IIA in raw water which is suitable for domestic purposes is 1000 µS/cm. MWD5 monitoring well showed the highest electrical conductivity of 16535.47 µS/cm and a majority of the monitoring wells in the current study exceeded the NWQS water quality guidelines. The high electrical conductivity in

Table 1: Total variance of hydrogeochemistry in thirteen moniring well stations in Banting, Kuala Langat, Selangor.

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	7.220	45.124	45.124	7.220	45.124	45.124	7.005	43.782	43.782
2	2.609	16.308	61.432	2.609	16.308	61.432	2.664	16.653	60.435
3	1.616	10.103	71.534	1.616	10.103	71.534	1.776	11.099	71.534
4	.977	6.104	77.638						
5	.758	4.737	82.375						
6	.581	3.634	86.009						
7	.510	3.188	89.197						
8	.366	2.290	91.487						
9	.332	2.075	93.562						
10	.283	1.767	95.328						
11	.256	1.603	96.931						
12	.172	1.073	98.004						
13	.141	.881	98.885						
14	.080	.501	99.386						
15	.062	.388	99.774						
16	.036	.226	100.000						

Table 2: Principal Component Analysis for hydro geochemistry in groundwater.

Variables	Component Matrix			Rotated Component Matrix		
	PC1	PC2	PC3	PC1	PC2	PC3
Total Solid	.803			.820		
Conductivity	.942			.945		
Salinity	.895			.882		
COD	.659			.648		
Chloride	.903			.935		
Phosphate			.691			.691
Nitrate			.794			.868
Calcium	.751	.544		.655	.640	
Magnesium	.792			.739	.457	
Potassium	.860			.858		
Sodium	.864			.910		
Strontium	.701			.664	.450	
Iron		.808			.795	
Manganese		.847			.900	
Zinc		.653	.458		.596	.523
Bicarbonate	.538			.545		

groundwater showed the influence of seawater intrusion. The high electrical conductivity concentration in groundwater bodies is also possibly due to the influence of other conditions such as land use and geological conditions as well as its location near to the coastal area.

The groundwater samples from all monitoring wells showed the chemical oxygen demand concentrations exceeded the recommended level by the Ministry of Health for raw water. The high chemical oxygen demand concentration in groundwater at all monitoring wells exists due to degradation process. Existence of organic and inorganic substances might come from the pollutants which entered the groundwater, such as agricultural pollutants and sediments. The concentration for several parameters in the groundwater samples were compared with the recommended level of raw water by the Ministry of Health. The average concentration of chloride, chemical oxygen demand and sodium apparently exceeded the permissible limits, i.e. 731.60, 57 and 403.84 mg/L respectively are over the recommended levels of 250, 10 and 200 mg/L respectively. The groundwater samples have been influenced by the seawater intrusions because these major ions were higher at a majority of the monitoring stations. However, other parameters were below the permissible limits such as magnesium which was 79.5 mg/L in average, not exceeding 150 mg/L for raw water as recommended by MOH. The magnesium concentration in the groundwater samples is still within the acceptable range even though this major ion is abundant in the groundwater and keeps accumulating each year. lnorganic parameters such as nitrate and sulfate were also below the recommended levels, and total dissolved solid was also within the recommended level. However, the average iron content exceeded the permissible limit in raw water of 1 mg/L by MOH, being 10.34 mg/L. The monitoring wells in the study is in peat soil that is rich in iron concentration, thus the high iron accumulation in groundwater due to infiltration process. The peat soil is enriched with organic matter from the rock weathering process which enhances the pyrite content. Thus, the groundwater samples from certain monitoring wells were brackish and have high turbidity. The discoloration of the groundwater is due to the organic matter decaying in the soil that increases the acidity and turbidity of groundwater sources (Hamzah *et al.*, 2006). Meanwhile, the concentration of zinc was below the permissible level in raw water of 3 mg/L by MOH. However, manganese showed higher levels than the permissible level of 0.2 mg/L by MOH in raw water at several monitoring well stations. The high manganese content in groundwater is generally derived from rock weathering processes in peat soil, due to the resistance of manganese at topsoil surfaces (Jusop *et al*., 2014). Therefore, the groundwater sources in Banting, Kuala Langat showed influences from seawater in the groundwater bodies. Table 3 and Figures 10 to 12 show the comparison of groundwater parameters concentration with the Recommended Raw Water Quality by the Ministry of Health.

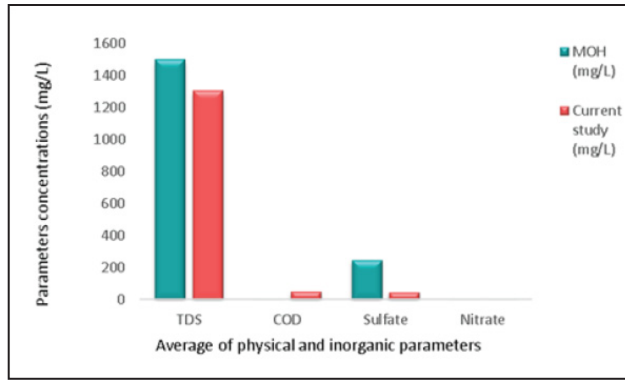

Figure 10: Comparison of groundwater quality for physical and inorganic parameters with recommended levels by the Ministry of Health for raw water.

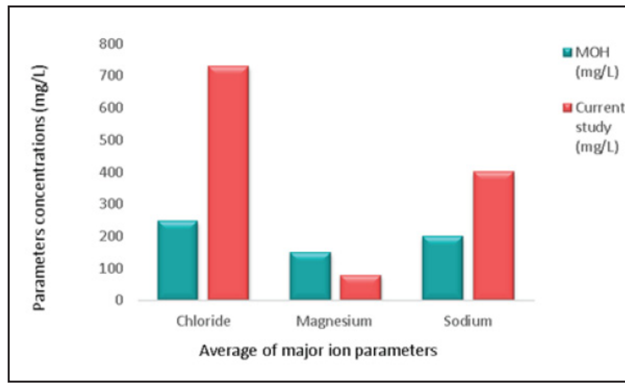

Figure 11: Comparison of groundwater quality for major ion with recommended levels by the Ministry of Health for raw water.

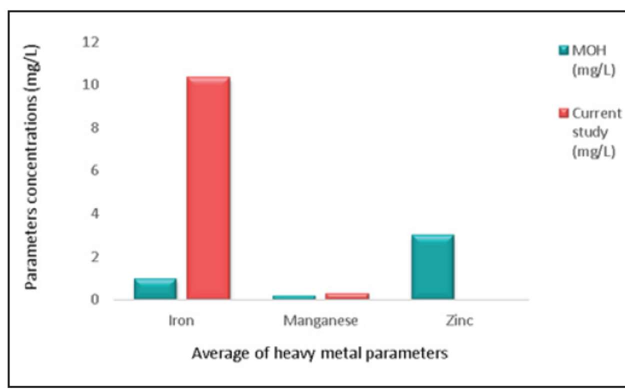

Figure 12: Comparison of groundwater quality for heavy metal with recommended levels by the Ministry of Health for raw water.

Seawater intrusion in groundwater

Excessive groundwater abstraction resulted in seawater intrusion and thus influences the quality of groundwater. The groundwater in the current study apparently showed high electrical conductivity. The increased salinity and total dissolved solids indicate the presence of mineral salts in the groundwater bodies which indicates the influence of seawater intrusion (Kura *et al*., 2015). Sodium concentrations in the groundwater varied between 52.66 and 2109.72 mg/L. However, several monitoring wells revealed high sodium concentrations that exceeded MOH recommended level for raw water of 200 mg/L. The highest level of sodium was

Table 3: Permissible limit for distinguish monitoring wells using Ministry of Health for raw water.

Parameter	RECOMMENDED RAW WATER QUALITY MOH (mg/L)	BKLTW16	J7-1-4	BKLTW11	MWD2	MWD5	MWD4	MW01	BKLEW2	BKLTW19	MW05	BKLTW15	BKLEH29	BKLTW12
Total Dissolved Solids	1500	485.27	1240.33	4807.33	1311.00	2934.07	343.66	164.79	95.48	761.14	1055.42	191.34	522.91	3019.67
Chemical Oxygen Demand	10	76.09	60.06	74.01	50.26	109.86	41.49	44.67	44.32	44.15	45.74	40.17	47.01	63.21
Nitrate	10	0.01	0.00	0.01	0.01	0.03	0.06	0.01	0.01	0.04	0.03	0.01	0.01	0.01
Sulfate	250	1.10	0.31	1.75	25.21	1.79	4.34	1.82	23.40	592.00	1.94	20.73	1.01	0.26
Chloride	250	98.90	419.95	1923.22	409.91	4230.33	130.73	54.39	31.53	289.86	415.37	68.47	203.41	1234.75
Sodium	200	126.25	326.25	1044.03	238.36	2109.72	106.70	68.79	52.66	178.67	234.22	72.87	138.73	552.60
Manganese	0.2	0.10	0.21	0.32	0.09	0.17	0.10	0.10	0.47	0.48	0.57	0.15	0.41	0.93
Magnesium	150	17.74	145.82	167.82	24.55	241.77	15.64	12.14	13.04	171.80	24.87	13.34	18.19	166.82
Iron	1	0.37	8.56	10.08	3.66	12.49	7.91	5.15	11.15	36.14	20.30	3.57	7.44	7.58
Zinc	3	0.01	0.03	0.02	0.05	0.02	0.03	0.04	0.01	0.03	0.04	0.04	0.02	0.01
Electric Conductivity	1000 (µS/cm) *(NWQS)	633.00	1999.50	7356.50	1944.80	16535.47	536.42	251.77	159.47	1130.93	1585.96	281.64	793.66	4353.00

recorded in MWD5 monitoring well, located at the northern part of the study area approximately 12.7 km from Morib. The result indicate a significant seawater influence to the groundwater at this station.

Another factor of the salinization of the groundwater sources in Kuala Langat is sea level rise. The groundwater salinization in Banting, Kuala Langat significantly showed that there has been an influence from seawater intrusion, based on the current finding. This is similar to Jamaluddin *et al.* (2016) which revealed that there were threats of high salinity in groundwater affected by sea level rise in Kuala Langat. The findings from the hydrogeochemistry analysis in the current study revealed that the groundwater sources in Kuala Langat indicate the influence of seawater intrusion. The extent of significant parameters contributed by seawater intrusion especially for major ions and that these parameters deteriorate the quality of groundwater is notably shown through the statistical analysis. However, salinity and total dissolved solids were not exceeding the recommended levels of the Ministry of Health guidelines.

CONCLUSIONS

The groundwater in Banting, Kuala Langat that is near coastal areas revealed the influence of seawater intrusion. The groundwater samples however are not vulnerable to the pollutants derived from agricultural practices such as fertilizers and manures. The inorganic parameters such as nitrate and phosphates did not influence the groundwater quality. The low influence from agricultural practices in the current study is mainly due to the implementation of Good Agricultural Practices in the agricultural fields that has obtained the certification scheme of Malaysian Good Farm Practice Scheme (SALM) from the Department of Agriculture. However, well MWD5 showed very high levels of most of the significant parameters, which were derived from the agricultural fields. Meanwhile, well BKLTW19 revealed the highest sulfate and iron levels, that originated from the peat soil agricultural areas. The groundwater from the monitoring wells can be used for domestic purposes such as irrigation of agricultural fields as the salinity of the groundwater is below the recommended level of the Ministry of Health for raw water.

RECOMMENDATION

Good Agricultural Practices should be emphasized in every agricultural fields to ensure the sustainability of groundwater quality. Moreover, planting of cover crops on the soil surface will also help in controlling pollutants from agricultural activities from infiltrating into the groundwater. However, the intensive treatments of the plants are necessary for human consumptions.

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