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Groundwater Quality Aspect Owing to Urbanization in Langat Basin (Kajang, Semenyih) Malaysia

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Authors' contributions

This work was carried out in collaboration between both authors. Author SJH designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SJH and NR managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: Unrefined industrial sewerage and unplanned water use changes groundwater quality and pollutes environment which is vulnerable to Langat basin of Malaysia. This research has aimed to find the water pollution trend due to urbanization by analyzing the hydrogeological condition and ground water quality status of Langat basin giving emphasis on Kajang and Semenyih town.
Study Design: Geological, hydrochemical and statistical analysis.
Place and Duration of Study: Borehole log, pumping test and groundwater chemistry data were collected from Mineral and Geosciences Department, Selangor for two towns Kajang and Semenyih. Study areas are in Kenny Hill formation and the wells pumping water from four types of rock formation. Ten years data variation on population and water quality were used.
Methodology: Three types of analyses were performed by using collected data. The subsurface geological analyses, well water chemistry interpretation with Hydrochemical facies analysis and statistical analyses. All the analyses were done by using different software.
Results: EC, Alkalinity, Nitrite as Nitrogen and trace metals like Cd, Pb, Mn shows very high concentration in the Kajang groundwater. In Semenyih Fe and Nitrate as Nitrogen concentrations are high. Positive correlation of Nitrite as Nitrogen, Nitrate as Nitrogen and trace elements like Mn,

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Cd, Pb, Cr and Cu with population has a significant relationship of urban pollution in Kajang and Semenyih groundwater.
Conclusion: The study unveils the truth that urbanization not only impacts on the surface water but also same impact on groundwater although intensity varies with population size and subsurface condition. Finally, policy recommendations were drawn to minimize the impact of urbanization on groundwater.

Keywords: Groundwater quality; urbanization; hydrogeology; Langat basin; correlation analysis.

1. INTRODUCTION

Urbanization has been intimately connected with industrialization. The world is undergoing the biggest wave of urban expansion in history [1]. Urbanization is one of the most harmful forces distressing stream health and pollutes groundwater by altering levels of heavy metals and nutrients like phosphorus and nitrogen [2,3].

The Sungai Langat basin in Malaysia is of great importance as it is the fastest growing economic area of the country [4]. The Langat basin includes large state of Selangor which has the largest population in Malaysia, with a high standard of living [5]. The state contains some major urban centers like Kuala Lumpur, Kajang, Shah Alam, Semenyih and Bangi which are undergoing continuous development and expansion, as a result that cities are faced different environmental problem (Fig. 1).

By comparing the chemical characteristics of water (surface and ground) among sites, the effects of urban expansion and anthropogenic disturbances in the surrounding watershed can be determined. This study is tried to evaluate the urban impact on groundwater quality of Langat basin by analyzing the groundwater types and quality of two towns (Kajang and Semenyih) with some statistical analysis. All wells are selected from different industrial areas to identify the industrial pollution as well as anthropogenic intervention. The Objective of this study is to identify the urbanization affects on the groundwater quality by analyzing the hydrogeological condition and groundwater quality status of Langat basin, giving emphasis on Kajang, and Semenyih town.

1.1 Physiography, Geology and Climate

Langat Basin is located in south of Selangor and north of Negeri Sembilan within latitude 2°40′N to 3°20′N and longitude 101°10′E to 102°00′E [6] of Malaysia. Sungai Langat basin covers an area of 2,423km^2 and is 200 km in length. Topographically, Langat basin can be divided into three geographic regions, i.e. the mountainous area of the north, the undulating land in the centre of the basin and the flat flood plain at the downstream of Langat River [7]. The Selangor area within the Langat basin is situated on the west coast of Peninsular Malaysia. The study areas (Kajang and Semenyih) are situated within the Selangor area. Kajang, is a town in the eastern part of Selangor, Malaysia with location 2°59′35″N latitude and 101°47′20″E longitude [8]. The location of the Semenyih is 2° 57' 0" North and 101° 51' 0" East.

The study areas are containing the oldest known rocks (Middle Cambrian or earliest Paleozoic) in the country. Bedrock in the mountainous area includes Permian igneous rocks and Pre-Devonian schist and phyllite of the Hawthornden Formation [9,10] and in the foothills are Permo-Carboniferous meta-sandstone, quartzite, slates, phyllites and quartz schist of Kenny Hill Formation. On the coastal plain, quaternary deposits consisting of Palaeocene through Holocene unconsolidated sediments of the Simpang, Kempadang Gula and Beruas Formations [9] present. Based on the geological map of the Geological Society of Malaysia, [11] the study area is located on the Kajang Schist Formation which is in the range of Silurian age up to Devonian. However, Nor, [12] put Kajang Formation in the Kenny Hill Formation because of similarities. Hydrogeologically Coarse to very-coarse sandy gravel of Simpang Formation (Palaeocene to Pliocene) at the base of the Quaternary strata is considered the main aquifer of the Langat Basin. The aquifer is typically several meters thick near the foothills, and varies from about 50 m to more than 100 m further toward the coast [10]. The Transmissivity of the aquifer is 450 m^2/day and Storativity is 4x10^{-3} [13].

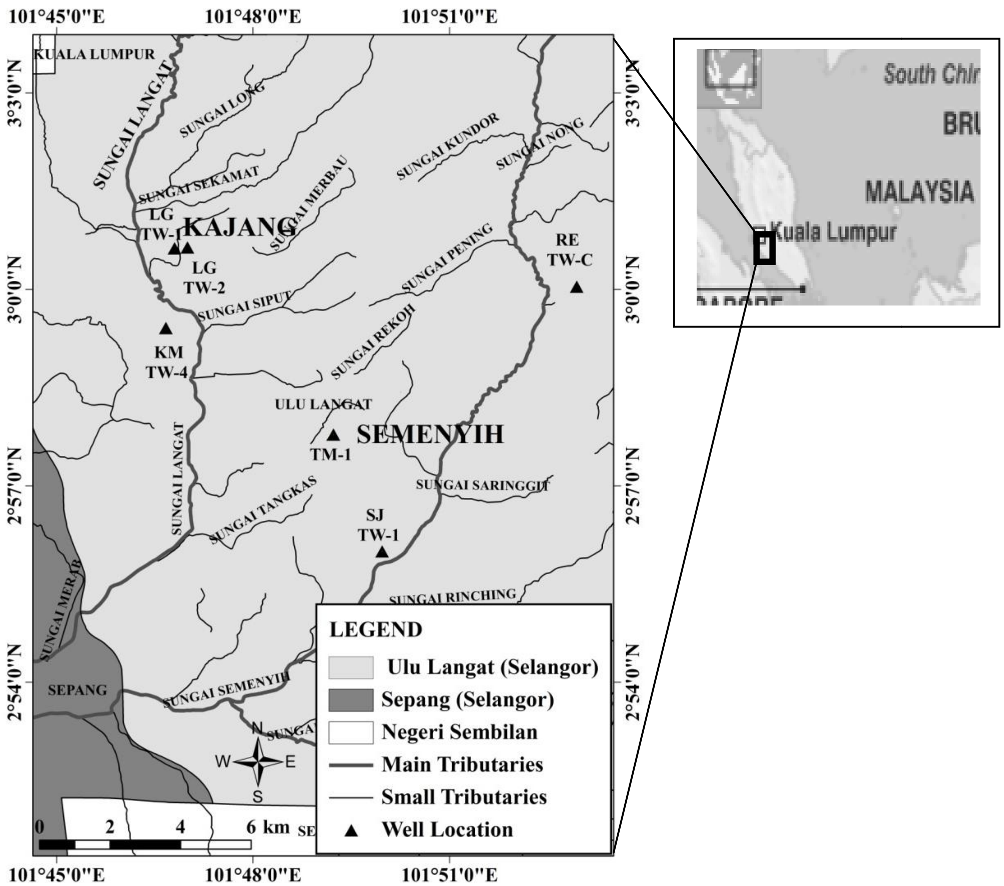

Fig. 1. Location map of the study area in Malaysia and Bangladesh (Compile from [14] & [15])

The climate of the study area is characterized by high average and uniform annual temperatures, high rainfall, and high humidity. The average rainfall is about 2400 mm [7].

1.2 Urbanization History

In Malaysia, the total urban population has increased to 58.8 percent in the year 2000 [16] and some of the states in the Peninsular has achieved the urbanization level of developed countries i.e. 80 percent of the total population. As a result the number of population of Kajang and Semenyih also increased at the same rate from the year 1970 to 2010 (Fig. 2). In the year 1970, Kajang and Semenyih town contains 48,993 and 12,140 people respectively. After 40 years the increasing urban population reached the number 342,657 and 99,669 respectively [17]. In 1974, 97% of the land was rural (including 53% agriculture, 44% forest) 1% urban and 2% others area. In 2001, 70% of the land was rural (including 56% agriculture and 24% forest) whereas urban is 14% and others is 4% [18].

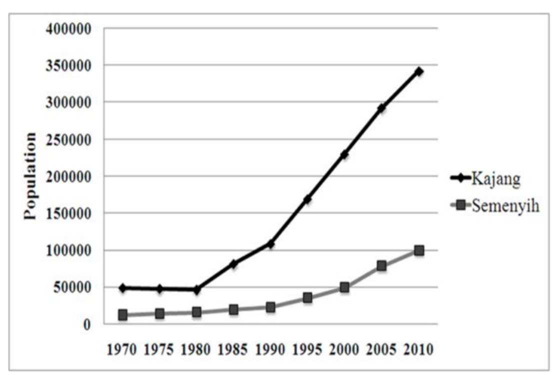

Fig. 2. Increasing populations of Kajang and Semenyih.(Source: [17])

2. METHODOLOGY

Borehole log, pumping test and groundwater chemistry data were collected from JMG

(Jabatan Mineral dan Geosains, Selangor/ Mineral and Geosciences Department). Three types of analyses were performed by using these data. Firstly, the subsurface geological analyses on the study areas were done by using the software Strater Demo4. Secondly, for well water chemistry interpretation, water chemistry data were collected from water quality record data sheets of JMG. Hydrochemical facies analysis on the study areas were done by using the software AquaChem 2014.2 Demo. Lastly statistical analyses, which include correlation of water quality with urbanization, were done by using both Excel 2007 and EViews7. Temporal water quality data were necessary for this analysis. For Kajang and Semenyih, ten years data variation on population and water quality were used.

3. RESULTS AND DISCUSSION

3.1 Geological Interpretation Using Well Logs

To analyze the urbanization effect on groundwater quality of the study areas, identification of subsurface geology is necessary since, most of the water quality parameters are influenced by subsurface geology as well as urbanization. In Kajang area, two wells in Laglove (M) Sdn Bhd area show same subsurface lithology (Fig. 3) and both wells collected water from hard rock (granite) formation. The thickness of the water bearing layer is more than 152 m. Another well of Kajang located in Kima Sdn Bhd area has 23 m thick water bearing formation which is completely weathered dark grey friable shale (Fig. 3).

In Semenyih, within Terus Maju Services Sdn Bhd area the well TM-1 is collected water from sedimentary rock which is less than 4 m thick light grey, medium grained clayey sand (Fig. 4). The well is in shallow depth (16.75 m) and is not penetrates the granite bed rock formation. In Sejati Konkrit Sdn Bhd area, the TW1 well is also extract water from soft alluvium formation with a thickness of 30 m and also penetrates lower medium hard bed rock (granite) (Fig. 4). The well situated in Recycle Energy Sdn Bhd area (Semenyih, C) is deeper than the other two well of that area. The water bearing formation is weathered and fractured granite with a thickness of more than 65 m.

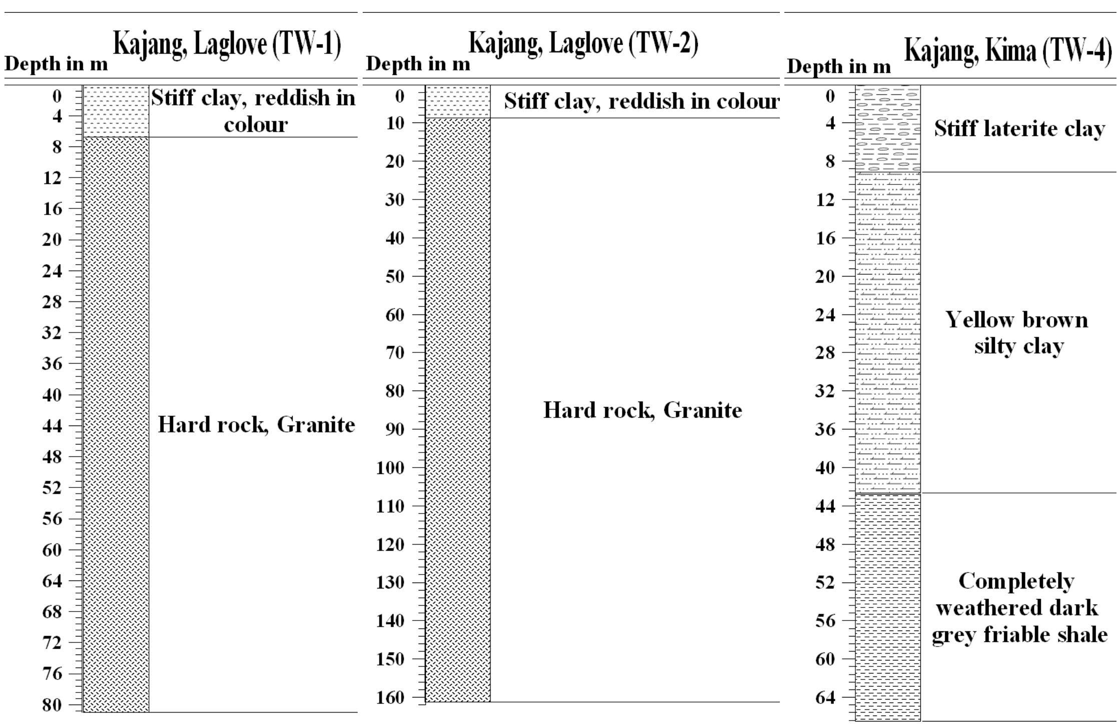

Fig. 3. Subsurface well logs of Kajang Town

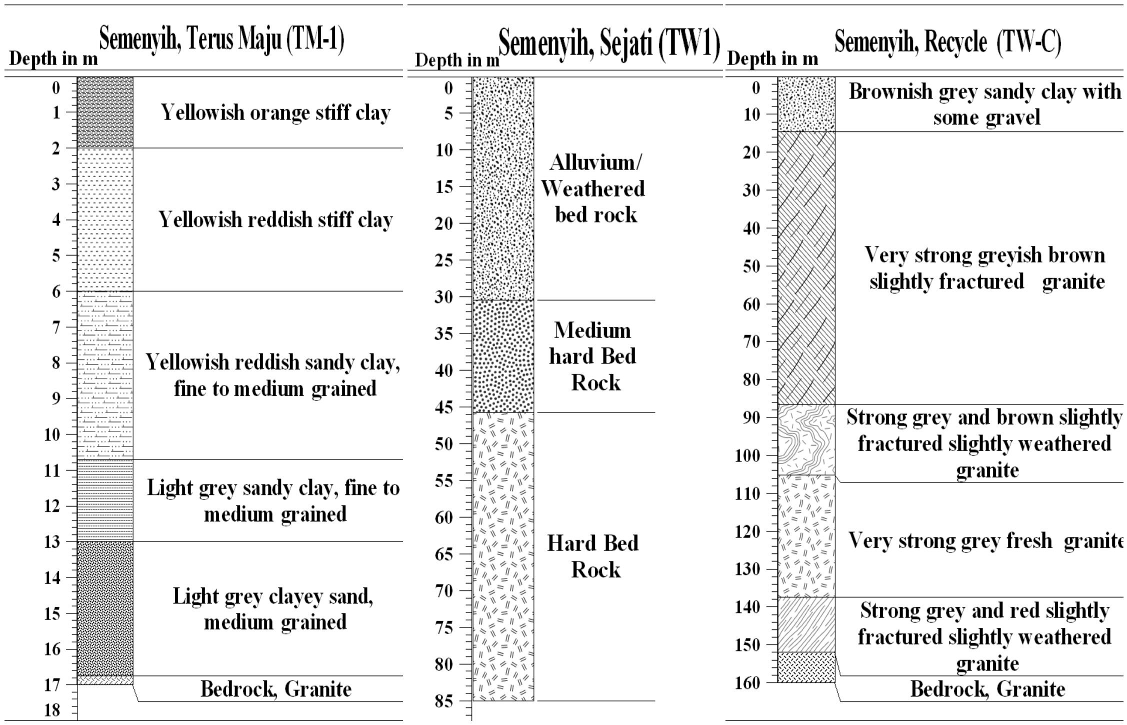

Fig. 4. Subsurface well logs of Semenyih Town

3.2 Hydrochemical Facies Identification

The piper diagram clarifies that, hydrochemical facies of the ground water in Malaysia is mostly Ca-HCO_3 type (Fig. 5). In this classification alkali cations (Na^+ and K^+) are called primary constituents and the alkaline earth cations (Ca^{2+} and Mg^{2+}) are called secondary constituents. The strong acid anions (SO_4^{2-} and Cl^-) are treated as saline constituents and CO_3^{2-} and HCO_3^- are treated as weak acids. Mutual balancing of these anions and cations determine the chemical character of water. From Piper diagram plot, Ca is the dominant cation while HCO_3^- is dominant anion in most of the samples.

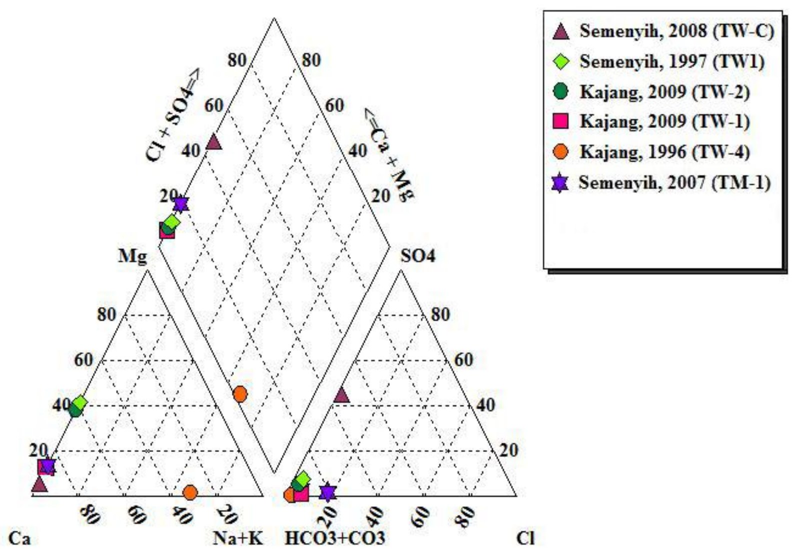

Fig. 5. Hydrochemical piper diagram of Kajang and Semenyih

3.3 Well Water Chemistry Interpretation

Water chemistry of the study area is more or less uniform except some parameters. Groundwater of Kajang and Semenyih shows very high ranges of electrical conductivity which exceeds the WHO standard of drinking water quality (Table 1). Alkalinity in Kajang area contains high value (Kajang, 2009 (TW-1):261 mg/l) compared to other area. Alkalinity comes from rocks and soils, salts, certain plant activities, and certain industrial wastewater discharges [19]. If subsurface geology contains huge amount of calcium carbonate ($CaCO_3$, limestone), water bodies tend to be more alkaline but granite bedrock is deficient in alkaline materials to buffer acidic inputs [20]. So, high alkalinity indicates infiltration of industrial effluent. Magnesium is high in groundwater of Kajang town but not exceed the WHO standard.

Nitrate as nitrogen is high in Semenyih town and very close to the both standard (permissible limit; Malaysia 10 mg/l and WHO 11 mg/l) (Fig. 6). Kajang town contains high concentration of nitrite as nitrogen which also very closes to the standard (WHO 0.9 mg/l). Both nitrates as nitrogen and nitrite as nitrogen concentration in groundwater are increased due to urbanization, agricultural activity and human and animal excreta, including septic tanks [19]. Iron concentration is extremely high in Semenyih area which may be for subsurface geological condition (permissible limit; Malaysia and WHO 0.3 mg/l). Concentration of manganese is also very high in groundwater of Kajang and Semenyih which exceeds both standards of Malaysia and WHO (0.1 mg/l and 0.4 mg/l respectively). Both iron and manganese are most abundant metals in Earth's crust but manganese also can infiltrated from industrial effluent [19]. Cadmium and lead concentration is very high in Kajang Town (WHO standard: Cadmium; 0.003 mg/l, Lead; 0.01 mg/l, Chromium 0.05 mg/l, Copper 1 mg/l, and Arsenic 0.01 mg/l). Trace element increased in the groundwater due to industrial waste water infiltration.

3.4 Correlation with Urbanization

Conductivity (EC) and total dissolved solids (TDS) positively correlated in the groundwater of Kajang and Semenyih town (Table 2). In both areas, alkalinity shows strong positive relation with population. Magnesium exhibits strong positive relation in Kajang's groundwater, on the other hand population of Semenyih town strongly related with sodium, potassium and calcium. Sulphate, nitrite as nitrogen, manganese, cadmium, lead, chromium and copper shows strong positive relation with population in Kajang's groundwater. In Semenyih town, nitrate as nitrogen, nitrite as nitrogen, fluoride, cadmium, lead, chromium, copper and mercury are positively related with population and among these parameters nitrate as nitrogen, nitrite as nitrogen, fluoride, chromium and mercury shows strong positive relation. Positive relation of trace metals with population indicates very high industrial pollution [21].

Table 1. Physical and chemical properties of the study wells

Tube well no	pH	TDS (mg/l)	EC (µs/cm)	Alkalinity (mg/l)	Ca (mg/l)	Mg (mg/l)	Zn (mg/l)	Cl (mg/l)	SO_4 (mg/l)
Semenyih, 1997 (TW1)	6.81	108.0	-	-	-	-	0.11	7.10	68.40
Semenyih, 2007 (TM-1)	6.19	68.0	-	25.0	0.24	0.08	0.01	1.10	0.50
Semenyih, 2008 (TW-C)	6.38	372.0	584.0	182.0	16.80	0.43	-	3.90	0.05
Kajang, 1996 (TW-4)	7.40	203.0		140.0	44.78	3.80	0.05	7.10	1.00
Kajang, 2009 (Lg TW-1)	8.20	270.0	422.0	261.0	44.25	16.45	0.01	6.60	14.30
Kajang, 2009 (Lg TW-2)	7.50	276.0	432.0	238.0	39.60	16.98	0.01	7.10	19.20
WHO Standard for Drinking Water	6.5-9	1000 (1984)	250 µs/cm (1993)	_	200	150	3	*(desirable limit 250 mg/l)	*(desirable limit 500 mg/l)

TDS: Total Dissolved Solid; EC: Electrical Conductivity; Alkalinity: Total Alkalinity as $CaCO_3$; Ca: Calcium; Mg: Magnesium; Zn: Zinc; Cl: Chloride; SO_4: Sulphate.
**No health-based guideline value*

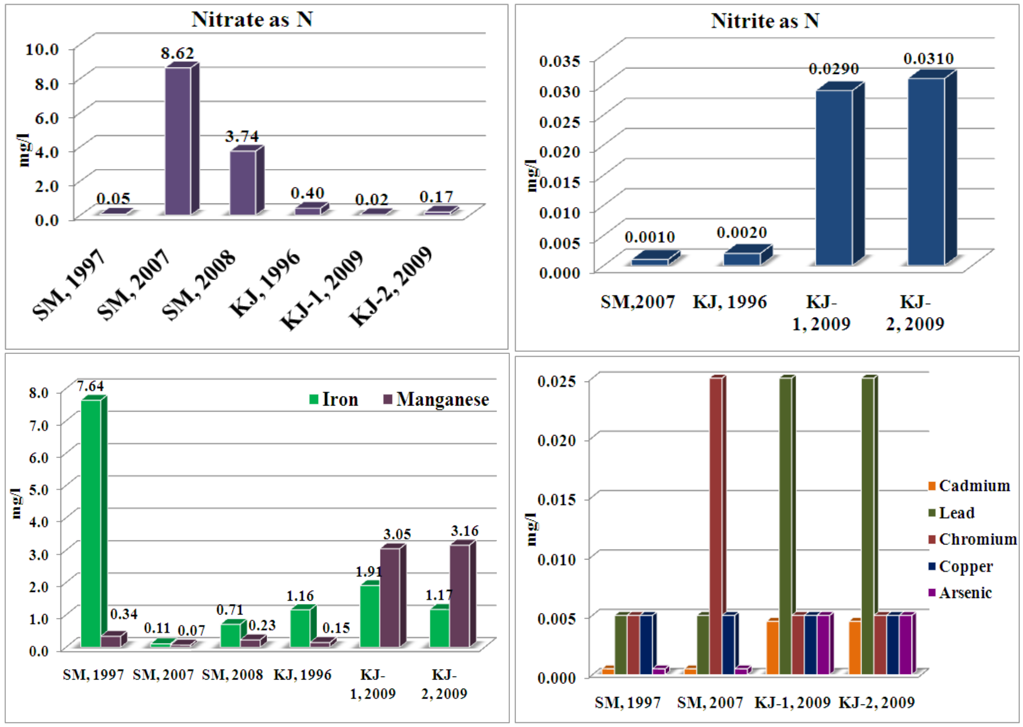

Fig. 6. Nitrate, nitrite, iron, manganese and trace element concentrations of the wells

Table 2. Correlations between population and water quality parameters

Kajang		Semenyih	
	Pop		**Pop**
pop	1	Pop	1
Turbidity	0.984738	Turbidity	-0.09663
EC	0.95221	EC	0.66100
pH	0.59604	pH	-0.92392
TDS	0.99725	DO	-0.57489
TS	0.75592	TDS	0.47158
TSS	0.5	Alkalinity	1
Alkalinity	0.98385	Sodium	1
Hardness	0.41931	Potassium	1
Calcium	-0.57836	Calcium	1
Magnesium	0.99936	Magnesium	1
Zinc	-1	Zinc	-1
Chloride	-0.5	Chloride	-0.04001
Sulphate	0.96556	Sulphate	-0.64346
Nitrate as Nitrogen	-0.92003	Nitrate as Nitrogen	0.76967
Nitrite as Nitrogen	0.998092	Nitrite as Nitrogen	1
Iron	0.510033	Iron	-0.31488
Manganese	0.999481	Manganese	-0.39241
Cadmium	1	Fluoride	1
Lead	1	Cadmium	0.574888
Chromium	1	Lead	0.574888
Copper	1	Chromium	1
		Copper	0.574888
		Mercury	1

**Electrical Conductivity=EC; Dissolved Oxygen=DO; Total Dissolved Solids= TDS; Biochemical Oxygen Demand=BOD, Total Solids=TS; Total Suspended Solids =TSS*

Calcium and chloride concentration of Kajang town groundwater shows negative correlation with population. Chloride in drinking-water originates from natural sources, sewage and industrial effluents, urban runoff containing de-icing salt and saline intrusion [19]. Zinc and nitrate as nitrogen shows strong negative relation with population in this area. In Semenyih town, dissolved oxygen (DO), zinc, chloride, sulphate, iron and manganese indicates negative relation with population and among these parameters zinc and sulphate shows strong negative relation with population.

Because the aim of this study is to identify the relationship between different parameters of groundwater with the population (urbanization), the relationship of different parameters with each other not incorporated here (Table 2).

4. CONCLUSION

Well log interpretation reveals that the study wells collected water from four different types of aquifer material that are, hard rock, weathered sedimentary or metasedimentary, shallow sedimentary and combination of alluvium and hard rock. Hydrochemically the aquifer of the Langat Basin contains mostly $Ca\text{-}HCO^3$ type water. Chemical analysis of the ground water shows that concentrations of EC, Alkalinity, Nitrite as Nitrogen and trace metals like Cd, Pb, Mn are very high in the Kajang area, Fe and Nitrate as Nitrogen concentrations are high in Semenyih. Both urban pollution and lithological variations within the subsurface are cause for these high concentrations. Water qualities parameter found deteriorating trend in most of the Study Areas. Some of the parameters are significantly related to urbanization in groundwater (i.e nitrate and trace metals). Correlation analysis of hydrochemical parameters with population on study areas indicates that parameters like chloride, sulphate, nitrate, nitrite, phosphate, manganese, zinc, cadmium, chromium, lead, copper, cobalt and fluoride are directly related with urban pollution. Among them concentrations of manganese, zinc and fluoride are also controlled by subsurface geological condition. In Kajang town, magnesium, sulphate, nitrite as nitrogen, manganese, lead, chromium and copper are strongly correlated with population. In Semenyih, magnesium, nitrate as nitrogen, nitrite as nitrogen, fluoride, cadmium, lead, chromium and copper are positively correlated with population. So, all the result indicates that trace elements are strongly correlated with urbanization and both study areas shows increasing trend of concentration. Regional analysis of this study gives the path way to the water planner to formulate proper policy recommendations. Installation of Effluent Treatment Plants (ETPs) in every industry must mandate. Additionally, sewage treatment plants should be upgraded, and the water authorities should publicly release regular monitoring reports. So, intensive management should require for the solution of the deteriorating groundwater condition.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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