A REVIEW OF GROUNDWATER QUALITY FOR DOMESTIC CONSUMERS' CONSUMPTION IN PERLIS

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ABSTRACT

Towards the 21st century, domestic consumer water demand has kept increasing from time to time. Groundwater may be an alternative source to fulfil this demand especially at the dry areas such as in Perlis. To serve the consumer demand using groundwater, the quality of the groundwater is a major factor to be considered as its contamination may be harmful to human health. In this study the quality of the groundwater currently abstracted from four different geological formations in Perlis which are the Chuping Limestone formation, Setul Limestone formation, Tertiary Bukit Arang formation and Kubang Pasu-Singa formation, are measured using onsite and laboratory tests techniques. From the tests carried on these samples, the groundwater quality is found differed with each other where iron, hardness, copper, chloride and COD concentrations were found high at certain locations. While several parameters were found to exceed the Malaysian Drinking Water Quality Standard. At all locations the groundwater contained total coliform and faecal coliform count. Water treatment methods have been proposed to ensure the groundwater is safe for consumer consumption especially regarding to human health concerns.

Keywords: Groundwater Quality, Domestic Consumer, Consumption, Perlis

Introduction

Groundwater forms one of the major sources of water supply in most countries. The increase in demand of safe water supplies has made it imperative to protect inadequate groundwater resources from contamination (Illangasekare & Saenton, 2004). Unfortunately groundwater is susceptible to pollutants due to the migration of contaminants from the surface such as leakage from septic systems, hazardous waste sites, landfills, fertilizers, pesticides, the widespread use of road salts and other chemicals (Rowe & Brooker, 1987; Kartha & Srivastava, 2008). A wide variety of materials have been identified as contaminants found in groundwater. These include synthetic organic chemicals, hydrocarbons, inorganic cations, inorganic anions, pathogens and radioactive material (Fetter, 1999). Most of these materials will dissolve in water to varying degrees, are mobile in the subsurface thus presenting danger to safe groundwater supplies (Sen & Khilar, 2006).

In Malaysia, surface water is the main source for fresh water supply. However groundwater forms an alternative to fulfill the water demand especially in the states of Kelantan and Perlis. Currently one-third of the water supply in Perlis comes from groundwater sources (Kamal, 2011). To serve the population with safe water from groundwater sources, the quality of the groundwater is a major factor to be considered as its contamination may be of human health concerns. According to Todd & Mays (2005) the principal chemical contamination in groundwater is due to presence of silica, iron, manganese, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulphate, chloride, fluoride and nitrite. Further the presence of fecal coliform also presents significant public health problems since it can cause severe damage to the linings of the human intestine (The Hartford Loss Control Department, 1998). Total coliform numbers have been used as an indicator of potentially harmful bacteria as well as other pathogenic organisms. By monitoring fecal coliform bacteria, it will give the exact number of potentially harmful bacteria in the water.

The Malaysian Raw Water Quality Criteria (RWQC) and Drinking Water Quality Standard (DWQS) forms a set of guidelines that have been set up for monitoring water quality in Malaysia by the government and its agencies to ensure that water is safe for any purpose.

However the parameters in the benchmark for groundwater quality established by the Department of Engineering (DOE) Malaysian Ministry of Health, is limited to certain parameters due to insignificance of the other parameters for the monitoring process. The guidelines give permissible limits of drinking water quality for the chemical parameters as ≤ 1.5 mg/L of ammonia, ≤ 1.0 mg/L of copper, 0.3 mg/L of iron, ≤ 0.1 mg/L of manganese, ≤ 10.0 mg/L of nitrate, ≤ 250 mg/L of sulphate, ≤ 0.05 mg/L chromium and ≤ 3 mg/L of Zn. As regards to the microbiological parameters, the critical level in terms of fecal pathogen indicator is 0 E. coli per 100 mL of water sample. Also other bacteria such as enterococci and total coliforms should also be 0 per 100 mL of water sample (WHO, 2006).

The purpose of this study was to assess the chemical, physical and microbiological quality of groundwater and its variations in the capture zone of Perlis from samples taken in the study area. From the results of the study, an appropriate water treatment method was proposed for that specific location. Currently in Perlis, there are 3 sources of major groundwater abstraction for domestic purpose; Arau, Felda Chuping and Semadung. The groundwater is abstracted using tubewells before being treated by sedimentation and disinfection process for the Arau source. While in Felda Chuping source, the groundwater is treated by filtration and disinfection process after abstraction. Meanwhile at Semadung source, the groundwater is abstracted and then treated by disinfection process only before being supplied directly to the consumers. However, groundwater abstraction is not treated at other minor locations due to the usage is for agriculture activities only.
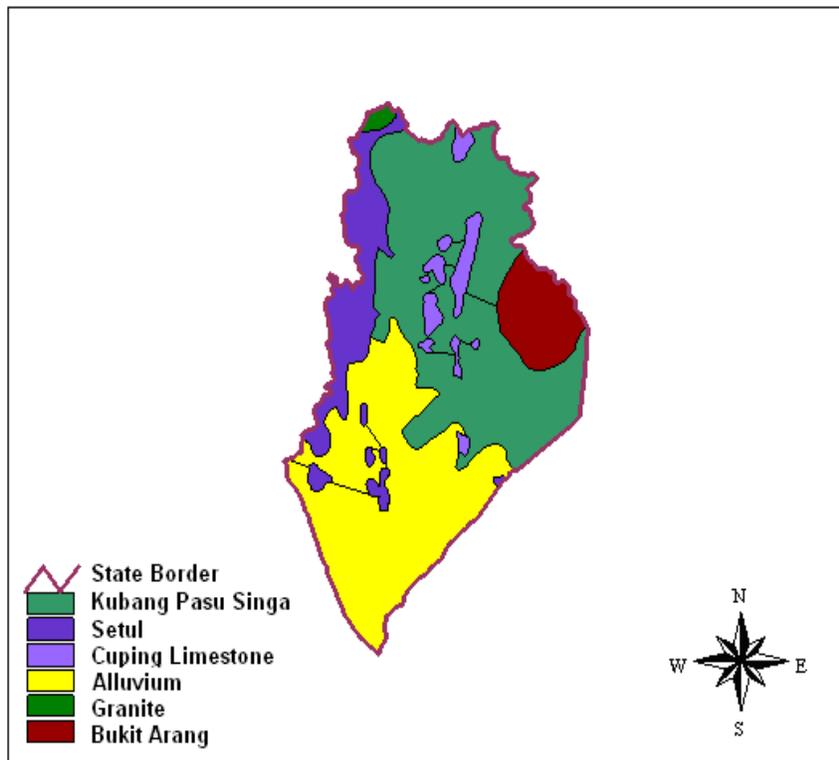

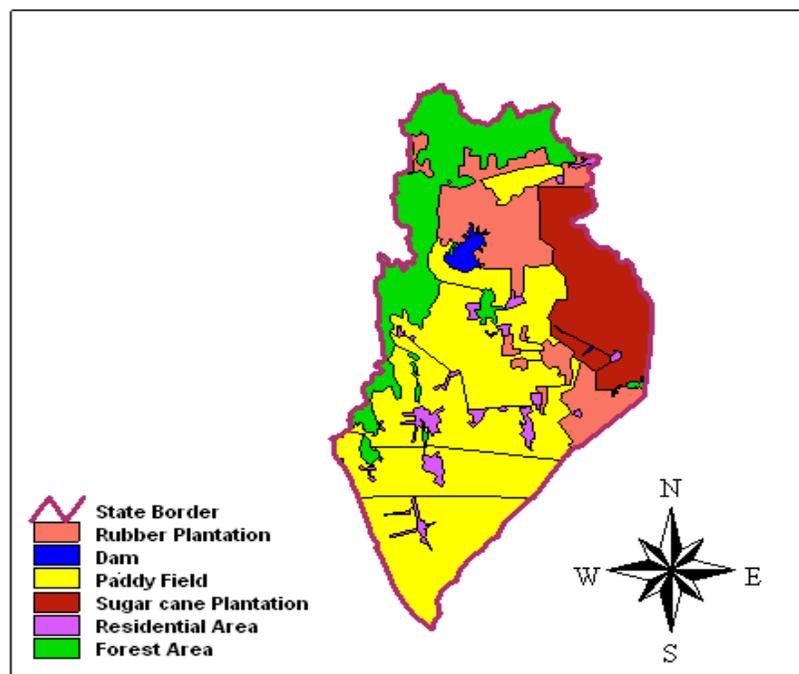**Figure 1: Geological Map of Perlis (source: Kamal, 2011)**

Figure 2: Land use Map of Perlis (source: Kamal, 2011)

Method

Samples of the groundwater were taken according to the different rock formations in Perlis and also depending on the accessibility of the abstraction site. The four (4) rock formations that came under study were the Setul limestone formation, Kubang Pasu-Singa formation, Chuping limestone formation and Tertiary Bukit Arang formation. Samples of groundwater were taken from boreholes or tubewells to represent each formation.

Nineteen (19) water quality parameters have been chosen and were tested in this study. On site testing had been conducted on the samples to determine the values of conductivity, dissolved oxygen (DO), pH, temperature and total dissolved solid (TDS). While for the remainder of the parameters, consisting of ammonia, chloride, chromium, chemical oxygen demand (COD), colour, copper, hardness, iron, manganese, nitrate, sulphate, zinc, total coliform and fecal coliform, the samples were transported to the Environmental Laboratory at UiTM Pulau Pinang for analysis. Hardness in water may be Permanent hardness which is hardness (mineral content) that cannot be removed by boiling. It is usually caused by the presence of calcium and magnesium sulphates and/or chlorides in the water. While Temporary hardness is a type of water hardness caused by the presence of dissolved

carbonate minerals (calcium carbonate and magnesium carbonate).

For on-site testing, a TDS meter was used to measure the TDS and conductivity, adissolved oxygen (DO) meter was used to measure the DO, a thermometer was used to take the sample temperature level and finally a pH meter was used to measure the pH of the groundwater samples.

For transportation to the laboratory samples from each location were packed in 1.5 litre plastic bottles. These bottles were screwed tightly, labelled and transported to laboratory with preservation consideration. The samples were kept at low temperatures between 4°C to 10°C to reduce any microbes activities in the water sample. For the laboratory analysis, a DR2400 spectrophotometer was used to determine the chemical oxygen demand (COD) and chromium reading, while a photometer was used to measure ammonia, colour, copper, hardness, iron, manganese, nitrate, sulphate and zinc. Turbidity level was measured using a turbidity meter. Also for the determination of chloride concentration, titration technique was applied where the method being used was the Mohr's method. While for the microbiological analysis on total coliform and fecal coliform, these were measured using the ELE Paqualab System.

Results and Analysis

Table 1 below shows the summary of values obtained for each parameter from the tests carried out on the four samples of groundwater taken at Kubang Pasu-Singa Formation, Setul Limestone Formation, Tertiary Bukit Arang Formation and Chuping Limestone Formation.

The results from this study were compared with the Raw Water Quality Criteria (RWQC) and Drinking Water Quality Standard (DWQS). The values indicated in the coloured boxes showed the parameters which exceeded the recommended values from both criteria. These tests results gave valuable information for the proposed suitable groundwater treatment method for that particular area.

Table 1: Summary of groundwater properties at Kubang Pasu Formation, Setul Limestone Formation, Tertiary Bukit Arang Formation and Chuping Limestone Formation

Parameter	Unit	Titi Tinggi	Sg Batu Pahat	Felda Chuping	Arau	Raw water quality criteria	Drinking water quality standard
		Kubang Pasu- Singa formation	Setul Limestone formation	Bukit Arang formation	Cuping limestone formation		
DO	mg/L	0.84	4.1	4.75	3.75	-	
pH		6.8	7.3	5.6	6.9	5.5 - 9	6.5 – 9
TDS	mg/L	432	352	41.9	787	1500	1000
Conductivity	µS/cm	641	530	63.2	1117	-	-
Turbidity	NTU	26	3.09	0.72	0.01	1000	5
Feacal coliform	colony/100ml	9	33	23	14	-	absent in 100ml
Total coliform	colony/100ml	1	17	12	2	5000	absent in 100ml
Ammonia	mg/L	0.28	0.38	0.01	0.26	1.5	1.5
Copper	mg/L	1.45	0.02	0	0.02	1	1
Hardness	mg/L	530	185	5	185	500	500
Iron	mg/L	5.7	0.02	0.3	0.03	1	0.3
Mangenese	mg/L	0.021	0.004	0.075	0.018	0.2	0.1
Nitrate	mg/L	0.1	0.29	0.6	0.24	10	10
Sulphate	mg/L	45	6	5	35	250	250
Zinc	mg/L	0.1	0	0.02	0.02	3	3
COD	mg/L	6	10	3	2	10	-
Chloride	mg/L	39	39	39	168	250	250
Chromium	mg/L	0.01	0.02	0.03	0.03	0.05	0.05
Colour	TCU	45	<10	<10	<10	300	15

Kubang Pasu-Singa Formation

The groundwater samples from Kubang Pasu Formation were collected from the borehole located at Titi Tinggi. The groundwater was slightly acidic with a pH value of 6.8 and adissolved oxygen (DO) content of 0.84 mg/L.

The hardness from this location was rather high with a value of 530 mg/L (Todd & Mays, 2005). From visual observation, the water colour was brownish which could indicate the presence of iron and other small amount of impurities. This gave its colour value of 45 TCU and a turbidity value of 26 NTU. After the groundwater sample was filtered using filter media, the

colour of the water sample became clear and the value was found to be <10 TCU. In addition, the test results for copper, iron, sulphate and chloride concentration were found to exceed the permissible standard with a value of 1.45 mg/L, 5.7 mg/L, 45 mg/L and 39 mg/L respectively.

This trend may be due to groundwater sources from the Titi Tinggi borehole was contaminated by human activities around the Kubang Pasu-Singa Formation. The total coliform and fecal coliform indicating contamination by bacteria were also indicated in this borehole with a value of 1 colonies/100mL and 9 colonies/100mL respectively. From Figure 1 and Figure 2 it can be seen that the Kubang Pasu-Singa Formation is surrounded by paddy fields, rubber plantation and sugar cane plantation. The fertilizers or pesticides used in these activities may easily seep into the groundwater aquifers. Thus it is suggested that the groundwater sourced from these boreholes needed an advanced monitoring and treatment system.

Setul Limestone Formation

Samples of groundwater from the Setul Limestone Formation were collected at the Sg. Batu Pahat borehole. It was found that the groundwater had a neutral pH with a value of 7.3 and adissolved oxygen (DO) concentration of 4.1 mg/L. The groundwater sample was considered as hard water since the hardness that obtained from the test showed an average of 185mg/L. From visual observation, the water sample was clear and contained only a small amount of impurities where its colour value was excellent at <10 TCU and a turbidity value of 3.09 NTU. The remaining physical and chemical water quality parameters for that location were below the permissible limit. However, the value of total coliform bacteria and faecal coliform for this sample showed the highest values compared to other locations. The activity of land use may influence the results due to the fact that Setul Limestone Formation are mainly covered with forest (Refer to Figure 1 and Figure 2) where the bacteria can grow and sustain longer in this unpolluted area. In addition, the COD value may indicate presence of food to the bacteria for their metabolism.

Tertiary Bukit Arang Formation

Refering to Table 1 for groundwater water quality from the Tertiary Bukit Arang Formation, the groundwater samples had been collected at the borehole located at Felda Chuping which lies in this Bukit Arang Formation. The groundwater was acidic which a pH value of 5.6 and a dissolved oxygen (DO) concentration of 4.75 mg/L. The groundwater sample can be considered as soft water since its hardness that obtained from the hardness test was 5mg/L (Todd & Mays, 2005). From visual observation, the water was very clear and contained only a small amount of impurities which gave its colour value as <10 TCU and its turbidity value of 0.72 NTU. However the groundwater sample also contained bacteria which were proved from the test that was carried out. From the test, its total coliform bacteria were found at 12 colonies/100mL and faecal coliform bacteria were found at 23 colonies/100mL. This shows that its coliform count had exceeded the Drinking Water Quality Standard. Another parameter that had exceeded the standard was its pH but this was still within the range of the Raw Water Quality Criteria. Other parameters that were tested were within the set limits.

Since the test results showed that the sample was within the set limits of raw water quality, the most suitable treatment to be proposed would be the conventional treatment which contained the process of aeration, coagulation, flocculation, sedimentation, filtration, disinfection and fluoridation. The bacteriological properties can be treated by the the disinfection process while the low pH value can be adjusted by doing the pH correction in the coagulation process (Gray, 2005). Further the low concentration of dissolved oxygen in the groundwater can be increased by using the aeration process.

Chuping Limestone Formation

The groundwater quality from the sample taken at the Chuping Limestone Formation was almost at a neutral value with a pH value of 6.9 and a dissolved oxygen (DO) concentration of 3.75 mg/L. The tests carried out may classify the water as hardwater and salty since the value of hardness was 185mg/L and the chloride concentration was found to be 168 mg/L. From visual observation, the water was very clear and contained only a small amount of impurities which gave the colour value of <10 TCU and the turbidity value of 0.01 NTU. However its sulphate concentration was high where the value was found at 35 mg/L. From the microbiological analysis, total coliform bacteria were found at 2 colonies/100mL and faecal coliform bacteria were found at 14 colonies/100mL. However the dissolved oxygen (DO) content is considered low when compared with the content in surface water which is 9.0 mg/L at the temperature of 20°C (Dojlido & Best, 1993). To increase the DO content in the water, the addition of the aeration process is proposed to the water treatment system.

Conclusion

In conclusion, groundwater sources have become important alternative water sources for both developing and developed country like Malaysia. It is important to continuously monitor the groundwater resources to make sure there will be adequate supply of water fit for human consumption. From this study carried out in Perlis, out of 4 samples taken from selected 4 active producing boreholes, only one of them had shown that it was of considerably low quality that was from the Kubang Pasu-Singa Formation. This may be due to the infiltration of pesticides and fertilizer from the agricultural activities in the nearby rubber plantations, sugar cane plantations and paddy fields. In addition, all of the borehole samples showed the existence of total coliform and fecal coliform which had exceeded the permissible limits set by the DWQS.

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