Pertanika J. Sci. & Technol. 20 (2): 371 - 379 (2012)

SCIENCE & TECHNOLOGY

Journal homepage: http://www.pertanika.upm.edu.my/

Groundwater from Fractured Granite and Metasedimentary Rocks in the West Coast of Peninsular Malaysia

Nasiman Sapari[1*], Raja Zainariah Raja Azie[2] and Hisyam Jusoh[1]

[1]*Department of Civil Engineering, Universiti Teknologi PETRONAS, Bandar Seri Iskandar, 31750 Tronoh, Perak, Malaysia*

[2]*Department of Management and Humanities, Universiti Teknologi PETRONAS, Bandar Seri Iskandar, 31750 Tronoh, Perak, Malaysia.*

ABSTRACT

Hard rock formations consisting of granite and metasedimentary rocks in Peninsular Malaysia, have been considered to be of poor aquifers. The map of shows the area underlain by hard rock as having poor to moderate potential for groundwater production (<230m^3/well/day). This paper presents a finding of productive hard rock aquifers in the west coast of Peninsular Malaysia. Data from tubewell drillings carried out for industrial water supply were analyzed. It was found that the hard rocks could yield fresh water up to a maximum of 890m^3/well/day. The wells were between 50 m and 200 m deep. High discharge rates of groundwater above 300m^3/well/day were encountered from wells that penetrate major fracture zones. The hard rocks are generally fractured at various depths. Groundwater in interconnected fractures has a steady flow that sustains production during pumping tests and actual usage of the wells. This phenomenon indicates that the groundwater is being recharged by infiltration of rainwater through the overlying weathered rocks and soils. Tubewells in hardrock of West Coast of Peninsular Malaysia were found to have an average discharge rates of 343m^3/well/day. However, deep tubewells penetrated only weathered granite, are generally non productive (<70m^3/well/day). Limited fracture openings and restricted recharge areas are likely to be the reason for the low discharge. Clay particles in fractures were observed to be the factor for the low success rate and poor quality of the water particularly in metasedimentary areas.

Keywords: Discharge rates, groundwater, granite, sedimentary rocks, tubewells, usage

INTRODUCTION

Groundwater in Malaysia is an important resource that can supplement the increasing demand of fresh water for various uses (Mohamed *et al*., 2009). Although groundwater has been used for many centuries, the usage

Article history:
Received: 8 April 2011
Accepted: 21 April 2011

Email addresses:
nasiman@petronas.com.my (Nasiman Sapari),
raja_zainariah@yahoo.com (Raja Zainariah Raja Azie),
hisyam.jusoh@yahoo.com (Hisyam Jusoh)
*Corresponding Author

ISSN: 0128-7680

is still limited to shallow unconfined aquifers using dug wells (Ang, 1994). Exploitation of groundwater from shallow aquifers is also very common in small islands (Aris *et al*., 2009). In Malaysia, deep tubewells in coarse sand aquifers were developed in the past 30 years for water supply of coastal towns, such as Kota Bharu (Sofner, 1989). The quality of the water is often described by the mineral composition, turbidity, colour, taste and odour. Iron and manganese, which are usually present in groundwater as divalent ions (Fe^{2+} and Mn^{2+}), are considered as contaminants mainly because of their organoleptic properties (Ellis *et al*., 2000). Other contaminants in groundwater may include ammonium, arsenic and phosphate. Fortunately, the method of treatment for the removal of these contaminants is available (Katsoyiannis & Zouboulis, 2004).

Recent development of tubewell drilling in Malaysia is driven by the expansion of industries and population growth in remote areas where connection to water supply mains is not available. Alternatively, groundwater becomes an attractive source of water supply. However, many of the factories are located in the areas that are underlain by hard rocks, where porosity and permeability is known to be very low (GSDM, 1992). However, fractured rocks have been reported to have relatively high hydraulic conductivity of between 0.001 to 10 m/day (Bouwer, 1979). It is important to note that the hard rocks in Malaysia have a wide distribution covering almost 90% of the country, particularly in undulating and hilly topography areas. The search for groundwater in these areas began in the mid eighties after the country experienced a long dry period in the early eighties (GSDM, 1987). Some initial studies of groundwater in fractured granite show that several industries in Malaysia have exploited the water for various uses (Sapari *et al*., 2010). This paper presents the findings of a study on the availability of groundwater in hard rocks in Malaysia. The objective of this study was to access the suitability of groundwater as an alternative source for the water supply to remote communities and industries. In addition, the quality of groundwater and its usage by industries were also examined.

METHOD OF STUDY

The method of the study involves observation of drilling operations and analysis of water samples from the tubewells. One hundred and thirty six tubewells, drilled for industrial and drinking water supply in the west coast of Peninsular Malaysia, were examined in this study (see Fig.1). The tubewells typically penetrated though the soil or loose quaternary alluvium, weathered rocks and hard rocks until reaching the fractured zones that produce water in the hard unweathered part of the rock. The upper parts of the wells were provided with steel casings of 355 mm diameter while PVC pipe casings of 200 mm were used in the lower part when the wells reached the medium and hard rock. The drilling might reach a maximum depth of around 200 m unless a fractured zone that produces sufficient water with a minimum production rate of 100 m^3/day was encountered.

Three types of drilling methods were used, namely, Rotary Drilling with water circulation, Air Percussion Rotary and Air-Foam Rotary. The drilling by water circulation using the mud of bentonite or polimer was used for the upper soft residual soil and loose alluvium or weathered bedrock where the size of the well is 350 mm in diameter.

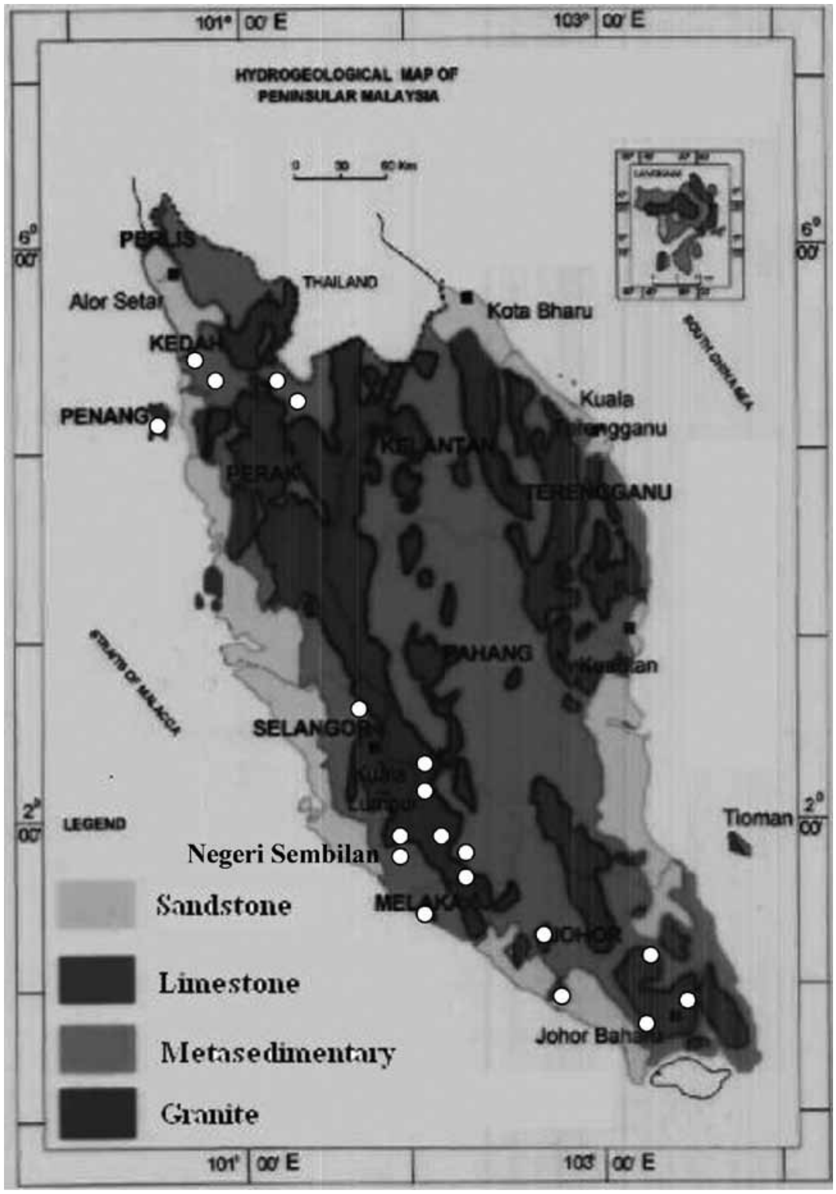

Fig.1: Location of wells and the study area in West Coast of Peninsular Malaysia

Meanwhile, the air percussion rotary drilling method was used for drilling in the medium hard of the semi-weathered and unweathered sections of the rock. Air compressor generating 1.7 MPa was used during drilling to bring the rock chips to the surface of the ground. In this section of the borehole, the size is 210 mm in diameter. The tubewells that met the required discharge rate were developed into production wells. The development was carried out by airlift method throughout the entire length of the borehole by blowing compressed air at two meter intervals from the top of the screen section downward to the bottom of the tubewell, and then upward again to the top of the top screen section. Development operation lasted for more 6 hours or until the air-lifted water was clear and sand free. A pumping test was also conducted on the developed wells. Both step drawdown and constant discharge rate methods were used to determine the optimum yield of the wells. The discharge rate was determined by measuring the height of the water flow over a 90^o V-notch weir using Equation (1):

$$Q = 1.34H^{2.48} \tag{1}$$

where,
Q = discharge rate, m^3/day.
H = vertical distance from the crest of weir to the free water surface, m

The water samples were collected during the pumping tests for water quality analysis according to the Standard Method (APHA, 1981). The analyzed parameters include pH, major cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+), major anions (HCO^-_3, SO^{2-}_4 and Cl^-), conductivity, total dissolved solids, iron, manganese, hardness. The characteristics of the developed wells were recorded in terms of their discharge rate, water quality and the intended use. The locations of the wells were also recorded which are often limited by the boundary of the land owned by the industry, except for the government wells. In fact, the site were located randomly based on the availability of the land space within the boundary of the property that belonged to the industry.

RESULTS AND DISCUSSION

The results derived from the drilling operations are shown in Fig.2 whereby the depth of the successful wells varies from 29 to 201 m with an average of 149 m. From one hundred and thirty six drilling records examined, one hundred and three were found to be successfully developed into production wells, with a minimum flow rate of 100 m^3/ day. Thus, the success rate of the drilling operation was 75 percent.

The maximum yield obtained from the wells was around 890 m^3/day, and the average from 128 wells was 349 m^3/day. The average drawdown during the pumping test was 40 to 50 m.

Water Quality

The results from the water quality analysis for the total dissolved solids (TDS) are shown in Fig.3. The results indicate that 67% of the wells in hard rocks produce water with total dissolved solids between 101 and 200 mg/L. At this TDS level, the water can be classified as fresh water according to Hem (1970) and Bouwer (1979). Therefore, the water is suitable for various uses including agriculture, industry and domestic water supply.

A detail analysis carried out on ions content in the water samples from the wells in Selangor, Melaka, Kedah and Negeri Sembilan is shown in the bar diagram below (*see* Fig.4). The water sample from Selangor is found to be Sodium Bicarbonate while the water from Melaka, Kedah and Negeri Sembilan is Calcium Bicarbonate type. There are minor differences between the four states in terms of the cations content. Calcium and magnesium were higher in the water samples taken from Kedah's and Melaka's tubewells, while higher iron was found in the water samples from Negeri Sembilan. The average combined content of calcium and magnesium in

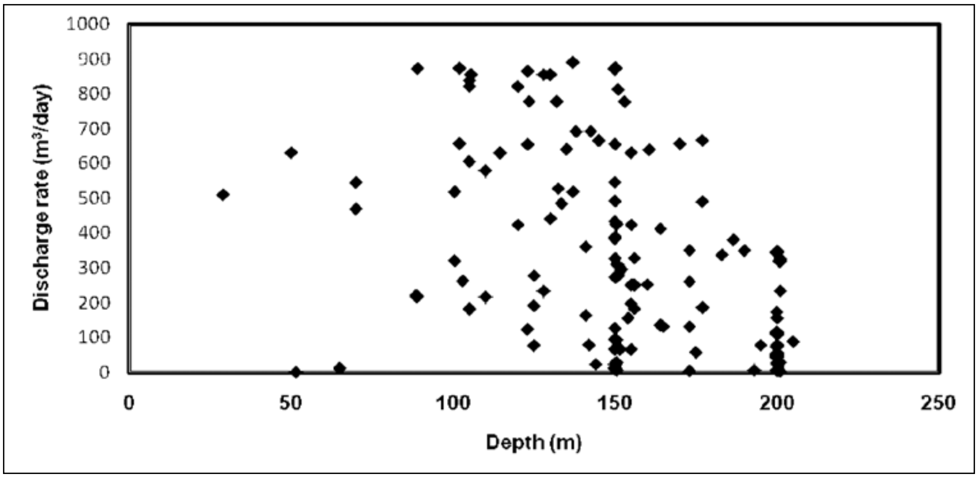

Fig.2: The depth of the wells and their optimum yield

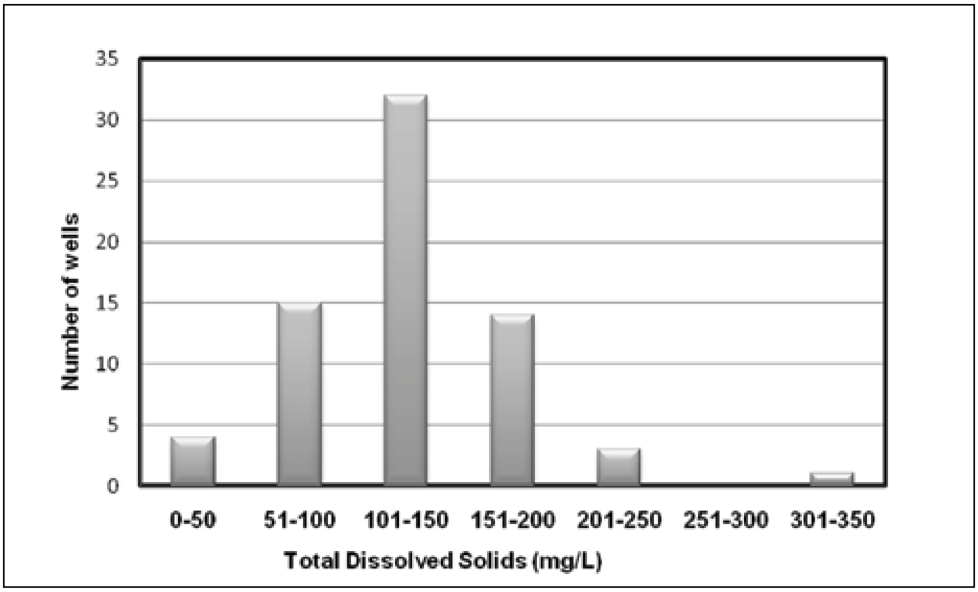

Fig.3: The total number of wells and the TDS levels (from 69 wells)

the groundwater from Melaka and Kedah was 1.86 meq/L and 1.65 meq/L, respectively. The average content of calcium for the groundwater from Penang and Johor was 0.11 meq/L and 1.59 meq/L, respectively. The water from Johor however contained higher potassium with an average of 0.79 meq/L, while the water from Penang had only 0.07 meq/L.

The results for the hardness analysis of the water sample from 52 wells, including the wells from hard rocks, are shown in Fig.5. The level ranges from 9.01 mg/L to 353 mg/L, with an average value of 76.18 mg/L.

The average water hardness indicates a moderate hardness, 48% of the wells produced soft water with hardness less than 61 mg/L. Only twenty four of the wells produced hard

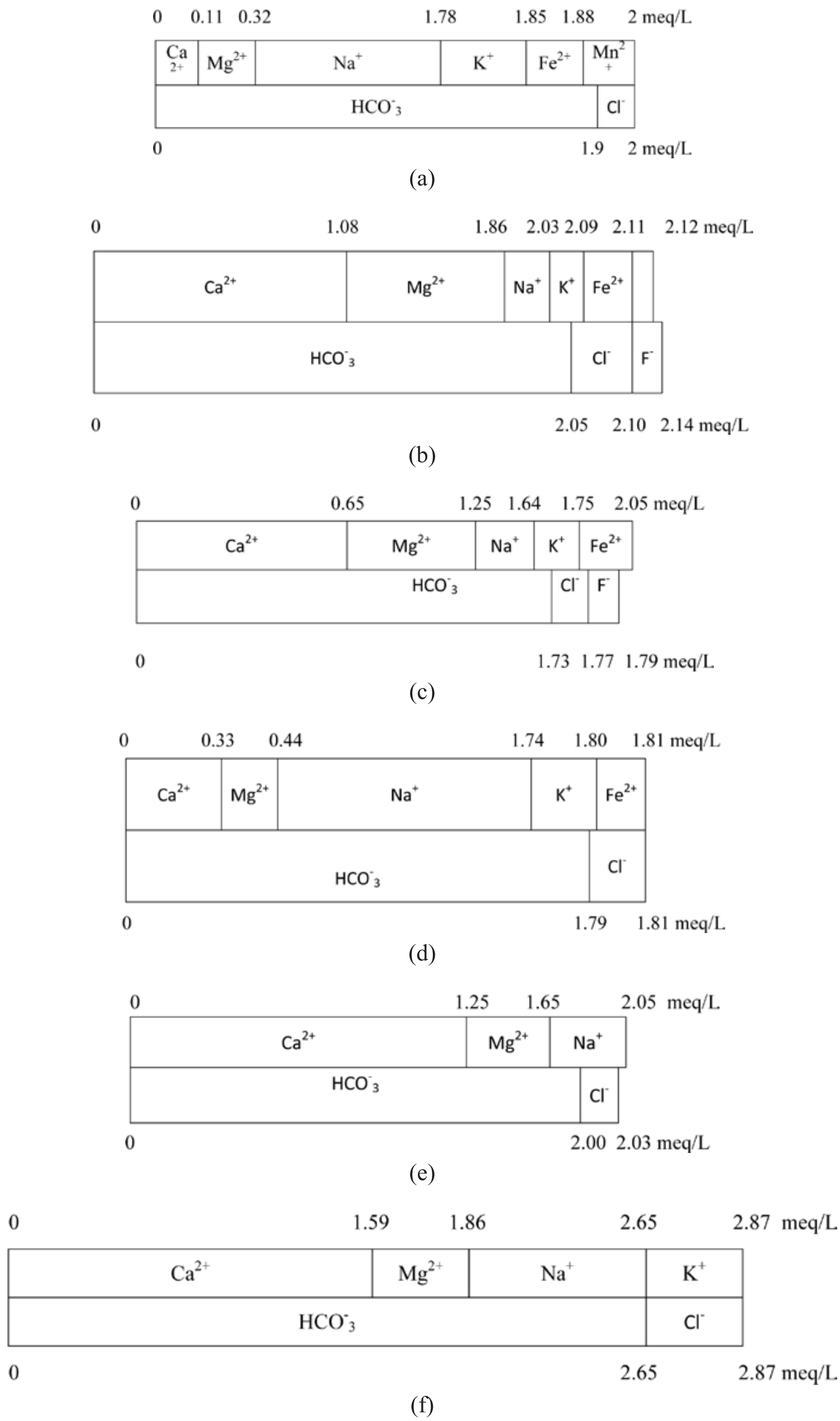

Fig.4: A Bar Diagram of the water; (a) Johor; (b) Melaka; (c) Negeri Sembilan; (d) Selangor; (e) Kedah; and (f) Penang

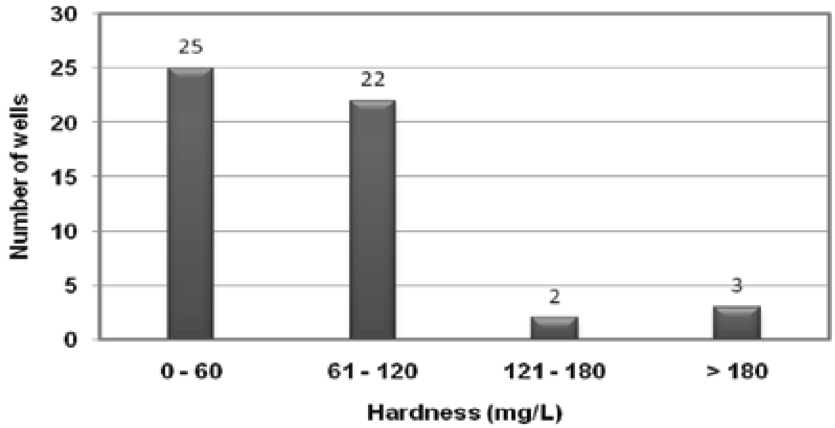

Fig.5: The number of wells and the hardness levels of the water from 52 wells

groundwater with hardness level up to 180 mg/L, and three wells produced very hard water with hardness level up to 350 mg/L.

The results of the analysis conducted on iron content are shown in Fig.6. The concentration of the total iron varies from undetectable level to as high as 14.8 mg/L. The average iron content from 59 wells is 1.81 mg/L. Therefore, treatment for iron removal is necessary prior to usage. However, about 42% of the wells contain iron less than the WHO's drinking water standard of 0.3 mg/L (Rowe *et al*., 1985). As shown in Fig.6, the distribution of the iron content in the water from different wells does not show any correlation with the depth of the wells. The treatment method currently used by the industries is adsorption by granular activated carbon or impregnated sand materials. The adsorption capacity of activated carbon for Fe(II) and Mn(II) were 3.6010 and 2.5451 mg/g, respectively (Jusoh *et al.*, 2005).

Water Usage

The usage of groundwater from the successfully developed wells is shown in Table 1. The locations of the industries are distributed all over the Peninsular. The presence of groundwater in fractured hard rocks will potentially fulfil the demand for water by various industries and

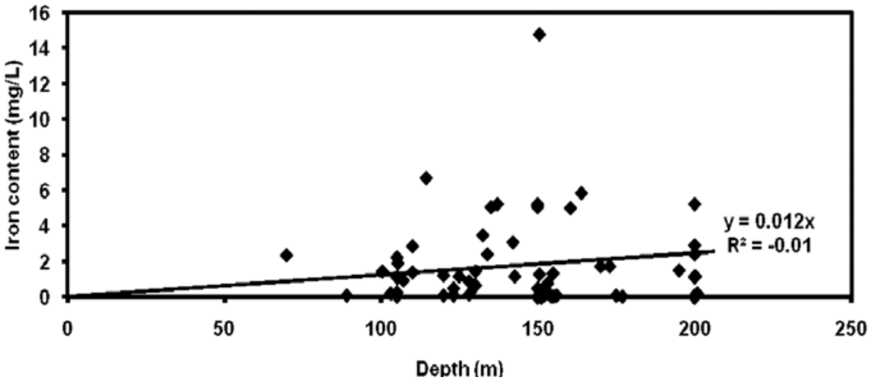

Fig.6: The concentration of total iron in the water samples from 59 wells of hard rocks

the rural communities. The advantage of using groundwater is that it is available at the site without the need of transporting and extensive piping system. The highest usage of groundwater is in manufacturing and construction industries followed by agriculture and domestic water supply. The manufacturing sector that consumes high quantity of water includes paper and textile industries. As drinking water supply, groundwater is used for domestic purposes and mineral water bottling. In other sectors, latex processing plant and golf course are the main consumers of groundwater.

Table 1: The number of wells from hard rocks and their uses

Classification of usage*	Number of wells	Percentage (%)
Agriculture	19	19
Domestic	15	15
Industrial	62	60
Monitoring	3	3
Natural mineral water/bottled drinking water	3	3
Total	102	100

*The classification of usage is based on the hydrogeological map, JMG (2008).

SUMMARY AND CONCLUSION

Groundwater in interconnected fractured granite and metasedimentary rocks in Malaysia has a steady flow that sustains production during pumping test and actual usage of the wells. The depth of the wells varies from 21 to 201 m with an average of 149 m. The average yield from the wells is 349 m^3/day. The water is generally fresh water with TDS levels between 100 and 150 mg/L. The hardness of the water is also low, i.e. around 60 mg/L or less. Only about 9% of the wells produced hard water with hardness levels over 120 mg/L. The average iron content of the groundwater is 1.81 mg/L. In addition 42% of the wells contain iron lower than the WHO's drinking water standard of 0.3 mg/L. Groundwater in fractured hard rocks is available in almost every place underlain by the rocks. All hard rocks in Malaysia are fractured and they receive a high rate of recharge from rainwater infiltration. The readily available groundwater has supported the development of industries and domestic water supply in the remote areas and the industries include manufacturing, agriculture and mineral water bottling. In conclusion, groundwater from fractured hard rocks has high potential to be further exploited for water supply.

REFERENCES

Ang, N. K. (1994). Hydrologic Framework and Groundwater Resources Utilisation in Peninsula Malaysia. *Proceedings of Groundwater Forum. No. 4*, Geological Society of Malaysia, 11th, January 1994, 1.1-1.5

APHA. (1981). *Standard Methods for the Examination of Water and Wastewater* (15th ed.). Washington D.C.: American Public Health Association.

Aris, A. Z., Mohd Harun Abdullah, & Sarva Mangala Praveena (2009). Evolution of groundwater chemistry in the shallow aquifer of a small tropical island in Sabah, Malaysia. *Sains Malaysiana, 38*(6), 805–812.

Bouwer, H. (1979). *Groundwater Hydrology.* Kogakusha, Japan: McGraw-Hill.

Ellis, D., Bouchard, C., & Lantagne, G. (2000). Removal of iron and manganese from groundwater by oxidation and microfiltration. *Desalination, **130***, 255 – 264.

Geological Survey Department of Malaysia, GDSM. (1992). *Potential of Groundwater Resources in Malaysia and Recommendation for their Planned Development*. Report No. CRU 4/1992, department of Geological Survey, Kuala Lumpur.

Geological Survey Department of Malaysia, GDSM. (1987). Groundwater Resource Study of Seri Gading Area, Johor & Rembau-Tampin-Gemas Ara, Negeri Sembilan: Fourth Malaysian Plan (1981-1985) Project Report Department of Geological Survey, Kuala Lumpur.

JMG. (2008). *Hydrogeological Map of Peninsular Malaysia* (1st ed.) Director General Minerals and Geoscience Department, Malaysia.

Jusoh, A.b., Cheng,W. H., Low,W. M., Ali, N., & Megat Mohd Noor, M. J. (2005). Study on the removal of iron and manganese in groundwater by granular activated carbon. *Desalination 182*, 347 – 353.

Katsoyiannis, I. A., Zikoudi, A., & Hug, S. J. (2008). Arsenic removal from groundwaters containing iron, ammonium, manganese and phosphate: A case study from treatment unit in northern Greece. *Desalination, 224*, 330-339.

Mohamed, A. F., Wan Yaacob, W. Z., Taha, M. R., & Samsudin, A. R., (2009). Groundwater and Soil Vulnerability in the Langat Basin Malaysia. *European Journal of Scientific Research*, *27*(4), 628-635.

Peavy, H. S, Rowe, D. R., & Tchobanoglous, G. (1985). *Environmental Engineering.* Singapore: McGraw-Hill.

Sapari, N., R. J. Raja Azie, & H. Jusoh. (2010). Groundwater in fractured granite for water supply to remote areas in Malaysia. *Water Practice & Technology 5*(2).

Sofner, B. (1989). *Groundwater Monitoring and Groundwater Protection in North Kelantan and Perlis, Malaysia* (p. 85). No. 88.2225-6, Hannover: Fed. Inst. Of Geosciences and Natural Res.