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Groundwater Quality Improvement by Using Aeration and Filtration Methods

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***Abstract*—**An experiment was conducted using two aeration methods (water-into-air and air-into-water) and followed by filtration processes using manganese greensand material. The properties of groundwater such as pH, dissolved oxygen, turbidity and heavy metal concentration (iron and manganese) will be assessed. The objectives of this study are i) to determine the effective aeration method and ii) to assess the effectiveness of manganese greensand as filter media in removing iron and manganese concentration in groundwater. Results showed that final pH for all samples after treatment are in range from 7.40 and 8.40. Both aeration methods increased the dissolved oxygen content. Final turbidity for groundwater samples are between 3 NTU to 29 NTU. Only three out of eight samples achieved iron concentration of 0.3mg/L and less and all samples reach manganese concentration of 0.1mg/L and less. Air-into-water aeration method gives higher percentage of iron and manganese removal compare to water-into-air method.

***Keywords*—**Aeration, filtration, groundwater, water quality.

I. Introduction

THE increasing in population growth, urbanization, industrialization and the surface water pollution has led to rapid growing demands for water supply and safe water. However, statistic of water reserves in Malaysia showed indirectly proportional with water demand which is stated almost no reserve water by 2025. Thus, an alternative way to cover up the demand is by groundwater extraction.

Groundwater is often seen as a reliable source of clean water that is available close to the point of consumption, making it an ideal source for meeting the demand for potable water in urban areas. Unfortunately, the rapid development which is parallel to the increase in population and increase in the demand for the domestic water supply has consequently exposed the groundwater to contaminations.

Iron and manganese are naturally occurring elements commonly found in groundwater. Iron and manganese often occur naturally in deeper wells where the groundwater may have little or no oxygen, and in areas where groundwater flows through soils rich in organic matter. The concentration of iron and manganese in well water can fluctuate seasonally and vary with the depth and location of the well and the geology of an area. For industrial water use, these metals tend to oxidize and precipitate in piping systems reducing their hydraulic capacities [1].

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In general, the groundwater was treated with the process as aeration and filtration for removing iron and manganese [1]-[5]. Several studies focused on removal of iron content in groundwater [6]-[9] and some of it studied the efficient ways to treat manganese [10], [11] and other pollutants such as ammonia and hydrogen sulfide [2], [7], [12]. Recently, there are many researchers focused on the treatment of groundwater by using biological methods [13]-[17] or combining physico-chemical and biological [18].

Filtration process is varied either by using sand/ silica/ quarts [4], [5], [19], [20] or manganese oxide-coated [10] and natural manganese sand [11] as a filtration media. The used of microfiltration [6], [21] also have been carried out to enhance the removal of pollutants present in groundwater for the purpose of drinking water.

In this study, the conventional method (aeration and filtration) process will be carried out in order to determine the effective aeration method based on the optimal operation parameters of aeration and filtration such as pH, dissolved oxygen (DO) and turbidity concentration after treatment process. The aeration process will be focused on two different approaches; either introduces air into the water or water into the air. The usage of manganese greensand in filtration process will be applied and the effectiveness of greensand as filter media in removing iron and manganese concentration in groundwater will be assessed.

II. Materials and Methods

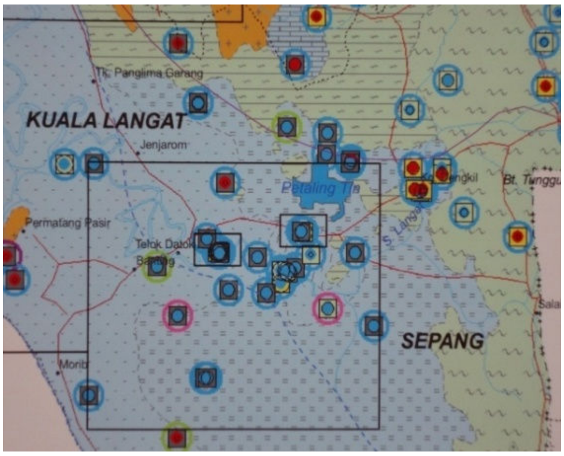
Groundwater samples for this study will be collected in Selangor area. The location of groundwater sampling varied by two types of aquifer is shown in Table I.

TABLE I
GROUNDWATER LOCATION AND TYPE OF AQUIFER

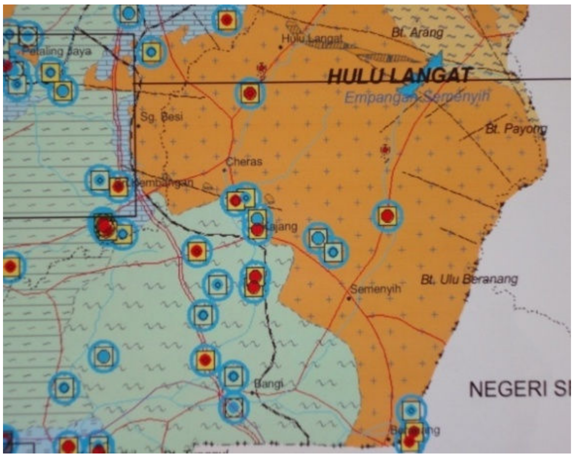
Sample	Location	Type of Aquifer
A	Dengkil	Unconfined (alluvium/soil)
B	Banting	Unconfined (alluvium/soil)
C	Bangi	Confined (Hardrock)
D	Batang Berjuntai	Confined (Hardrock)

Sample A and B are lying on unconfined aquifer (alluvium/ soil) and sample C and D are lying on confined (hardrock) aquifer.

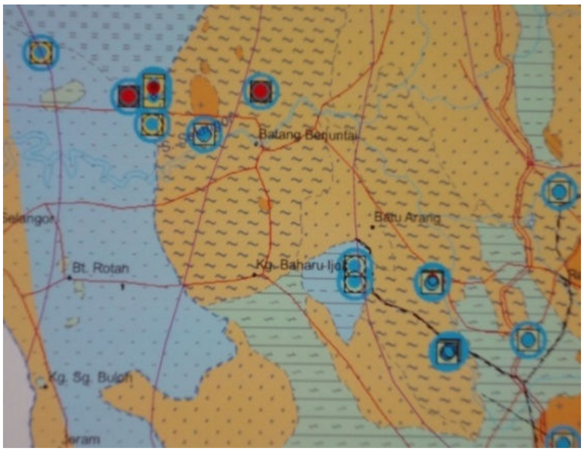
From hydrogeological map shown in Fig. 1 (a), Dengkil area is high aquifer potential with sediment and metamorphic rocks which is phyllite, while Banting is very high aquifer potential with unconsolidated deposits (clay and silt). Fig. 1 (b) shows the hydrogeological map for Bangi area. It is a high aquifer potential with sediment and metamorphic rocks of phyllite. Fig. 1 (c) shows the hydrogeological map for Batang Berjuntai area. It is a medium aquifer potential with sediment and metamorphic rocks of schist and sandstone. For the time being these wells are active and most are for industrial and domestic purposes.



(a)



(b)



(c)

Fig. 1 Hydrogeological map for (a) Dengkil and Banting (b) Bangi and (c) Batang Berjuntai

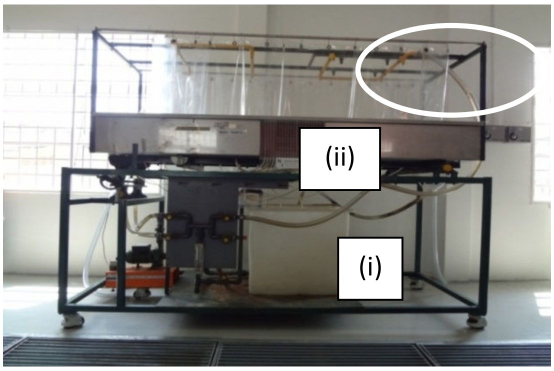
The volume of water for the purpose of the treatment processes is about 100 liters per methods: (a) aeration (water-into-air) and (b) aeration (air-into-water) followed by manganese greensand filtration for both treatment processes. Manganese greensand is formulated from a glauconite greensand which is capable of reducing iron, manganese and hydrogen sulfide from water through oxidation and filtration. The equipments used during the water sampling collection are high-density polyethylene plastic containers (20 liters each) and a pipe hose. The pipe hose is used to connect the tap from the tube well to the containers.

(a)

(b)

Fig. 2 Samples of groundwater (a) collected from unconfined aquifer and (b) collected from confined aquifer

Figs. 2 (a) and (b) show the groundwater collected from two types of aquifer; unconfined and confined respectively. It can be seen that the confined groundwater sample is more clear compare to unconfined sample. Unconfined aquifer does not have an impermeable layer which will act like a filter system, which mean the water seeps from the ground surface directly above the aquifer. If anything leaks or spills into the soil above the unconfined aquifer it will seep into and pollute the water. The initial properties were taken for each of samples such as pH, dissolved oxygen, turbidity and heavy metals concentration (iron and manganese) by using the following equipments; pH meter, dissolved oxygen meter, turbidity meter and atomic absorption spectrometer (AAS- Thermo Scientific 3000 series), respectively.



(a)

(b)

Fig. 3 (a) Equipment set up for aeration followed by filtration processes (b) Pipe manifold with spray nozzles

The groundwater sample was filled in the storage tank and the pump is used to make sure the flow rate is set at 10 liter/min and the process is set to flow for 7 hours continuously. This amount of water is adequate for water recycling condition (zero discharge). There are two general methods of aeration; (a) water-into-air or (b) air-into-water. Both methods were used in this experiment to determine which method can achieve good water quality result. Spray nozzles were used for water-into-air method. This type of aeration has one or more spray nozzles connected to a pipe manifold as shown in Fig. 2 (b). Moving through the pipe under pressure, the water leaves each nozzle in a fine spray and falls through the surrounding air, creating a fountain affect. While for air-into-water method, air diffusion aerators were used. Air diffusion systems were function by pumping air into water through perforated pipes, strainers, porous plates, or tubes. This process will be occurred in water tank as shown in Fig. 3 (a)-i.

The next process is filtration by using manganese greensand which was placed and spread uniformly in wide basin as shown in Fig. 3(a)-ii. After the water has passed through the aeration process, then the water will flow through the filter sand by gravity force**.** At the bottom of the basin, there are a few small tubes which will convey the filtrated water into the storage tank and the recirculation process will be carried out for about 7 hours. The final properties were taken for each of samples such as pH, dissolved oxygen, turbidity and heavy metals concentration (iron and manganese).

III. Results and Discusson

Table II has shown the summary of results of groundwater samples collected from unconfined and confined aquifer. These results will be compared to standard has been used in Malaysia for drinking water purposes.

According to the regulations in Malaysia [22], [23], the acceptable values for each parameter for the purpose of drinking/ water supply are referred:

- pH acceptable value is in the ranges 6.5 – 9.0
- Dissolved oxygen (DO) acceptable value is in the ranges5 – 7mg/L
- Turbidity value should be less than 5 NTU
- Iron concentration must not exceed 0.3mg/L
- Manganese concentration must not exceed 0.1mg/L

Table II shows the summary of results for groundwater sample of unconfined and confined aquifer. Groundwater samples collected from unconfined and confined aquifer have final pH ranges from 7.40 to 8.40 which are stated as a neutral to low alkalinity condition. The values are acceptable for drinking purposes.

Dissolved oxygen content results show that water-into-air aeration method for most samples resulted higher oxygen content compared to air-into-water aeration method based on percentage increased. The percentages of dissolved oxygen content in the following order which is sample A (52.27%) > sample C (14.36%) > sample D (6.16%) > sample B (5.94%). Dissolved oxygen content for air-into-water method decreased with respect to the frequency and the efficiency of air pump used in this study.

After 7 hours of treatment process, unconfined aquifer samples obtained final turbidity more than 15 NTU with near 30% removal. This is due to high initial turbidity so that the aeration and manganese greensand filtration could not treat the samples efficiently. Additional treatment process is recommended in order to reduce the turbidity up to 5 NTU and below to follow the Malaysia National Drinking Water Quality Standard. On the contrary, most of the final turbidity from confined aquifers samples could achieve less than 5 NTU after treatment process with near 40% removal.

For iron and manganese removal; the aeration and manganese greensand filtration processes removed manganese concentration from all samples to achieve 0.10mg/L and below. But for removal of iron concentration, there are only three out of eight samples that achieved 0.30mg/L and three samples indicated zero values of iron concentration for final stage. As a conclusion, manganese greensand is more effective in removing manganese compare to iron in these samples.

IV. Summary and Conclusions

The investigations of the groundwater samples had given the result of the water properties such as pH, dissolved oxygen, turbidity and heavy metals concentration (iron and manganese). From the laboratory tests results, the following conclusions can be drawn:

- Final pH values for all samples (unconfined and confined aquifers) were in the range of the acceptable values by Ministry of Health, Malaysia (2004) and Department of Environment, Malaysia (2008) regarding to drinking water quality standard.
- Final dissolved oxygen (DO) content showed an increasing for both aeration methods applied (water-into-air and air-into-water). However, water-into-air method is more effective in order to increase DO content in these samples.
- Most of the samples from confined aquifer achieved values below 5 NTU.
- The usage of manganese greensand as a filter media showed a removal of manganese concentration below 0.1 mg/L. However, for iron concentration removal, only a few samples achieved the concentration 0.3 mg/L and less.

It can be concluded that water-into-air aeration method can supply more dissolved oxygen content than air-into-water aeration method. The effectiveness of greensand as a filter media approved in removing iron and manganese to the drinking water quality standard.

TABLE II
SUMMARY OF GROUNDWATER SAMPLES RESULT COLLECTED FROM UNCONFINED AND CONFINED AQUIFER

Type of Aquifer	Sample	Type of Aeration	pH		Dissolved Oxygen (mg/L)		Turbidity (NTU)		Iron Concentration (mg/L)		Manganese Concentration (mg/L)	
			Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Unconfined	A	Water-into air	7.06	8.34	5.34	5.92	39.20	29.30	0.98	0.71	0.17	0.03
		Air-into water	6.61	8.39	3.52	5.36	25.20	20.80	3.37	2.05	0.64	0.08
	B	Water-into air	7.04	8.38	6.14	7.30	27.40	19.09	0.79	0.46	0.10	0.00
		Air-into water	7.16	8.39	6.06	6.42	24.60	18.69	0.91	0.48	0.40	0.01
Confined	C	Water-into air	4.88	7.46	5.91	7.10	5.73	4.25	7.56	2.53	0.55	0.04
		Air-into water	4.87	7.54	5.85	6.69	6.19	3.71	0.07	0.00	0.35	0.02
	D	Water-into air	5.55	7.63	6.40	6.98	9.17	6.32	0.00	0.00	0.17	0.06
		Air-into water	5.39	7.43	5.84	6.20	10.27	4.96	1.56	0.00	0.39	0.03

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