Sustainable solar energy capability studies by using S2H model in treating groundwater supply

S Musa[1,a], **M F Anuar**[1,b] , **M M Shahabuddin**[1,c], **M B Ridzuan**[1,d], **R M S** Radin Mohamed[1,e] and **M A Madun**[1,f]
[1]Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia.

E-mail: [a]sabariah@uthm.edu.my, [b]fadlee_94@yahoo.com, [c]m.muzzammil6852@gmail.com, [d]mdbahar@uthm.edu.my, [e]maya@uthm.edu.my, [f]aziman@uthm.edu.my

Abstract. Groundwater extracted in Research Centre for Soft Soil Malaysia (RECESS) contains a number of pollutants that exceed the safe level for consumption. A Solar-Hydro (S2H) model which is a practical prototype has been introduced to treat the groundwater sustainably by solar energy process (evaporation method). Selected parameters was tested which are sulphate, nitrate, chloride, fluoride, pH and dissolved oxygen. The water quality result shows that all parameters have achieved 100% of the drinking water quality standard issued by the Ministry of Health Malaysia. Evaporation method was proven that this solar energy can be applied in sustainably treating groundwater quality with up to 90% effectiveness. On the other hand, the quantitative analysis has shown that the production of clean water is below than 2% according to time constraints and design factors. Thus, this study can be generate clean and fresh water from groundwater by using a simplified model and it has huge potential to be implemented by the local communities with a larger scale and affordable design.

1. Introduction
The groundwater sample for this research was taken from RECESS. It was pumped and stored in a container before it can undergo the evaporation treatment and laboratory testing. From the previous study, groundwater in RECESS has been categorized as low quality water [1]. For that particular reason, this study was conducted to prove that evaporation method is able to improve the groundwater quality and fulfil the National Drinking Water Quality Standard (NSDWQ) issued by Ministry of Health Malaysia. The method suggested was more economical, practical, environmental friendly and hopefully it can attract the people of Parit Raja to use groundwater as an alternative source.

Groundwater is one of the natural resources that is not susceptible to pollutants. However, according to Musa et al. [2], the modernization and growing population have resulted in groundwater contamination. A proper treatment must be conducted before the groundwater could be consumed or used in daily basis.

Water shortage has forced many countries to use their groundwater resource which has been estimated to be 3000 times cleaner than surface water [3]. Even though Malaysia has plenty of fresh water supplies today, but it does not ensure an everlasting water supplies. According to the

Department of Statistics Malaysia, in 2010 the country's raw water is still heavily reliant on the dam and river water. Table 1 shows the Malaysia raw water sources.

Groundwater is only used by minority of the population who mostly live in the state of Kelantan Darul Naim. In addition, Kelantan have managed to extract as much as 150 million litres of groundwater within a day. This amount is the highest compared to other states in Malaysia. In Kota Bharu, groundwater is the main water source that meets the water needs of the people there. In Johor, groundwater usage has not been practiced by water reticulation company or any individual. The number of users of treated water supplied by Syarikat Air Johor (SAJ) registered a total of 92.753 connection pipe and the utilization rate was 107.84 million litres of water until April 2002.

Furthermore, gaining access to a reliable source of electricity is one of the most important milestones in modern community development because it can resolve many issues commonly faced by the population in rural area. Therefore this paper will also investigate how energy can make a difference in the extraction of clean water, which is a major challenge for rural communities in developing countries and regions [4].

A clean and safe groundwater is possible to be as an alternative source of water supply to the growing population of Malaysia [5]. Normally, groundwater is naturally contaminated due to the nature of surrounding soil [3]. Groundwater is hardly contaminated by foreign pollutants. However, the increase in exploration activities and new land use is causing groundwater pollution is no longer a foreign matter [6].Groundwater obtained from RECESS well was very low in quality [7]. The soil condition which contains fluoride, nitrate, chloride and low dissolved oxygen with acidic pH value has affected the groundwater quality in that area.

Table 1. Malaysia raw water sources.

State	**Litre Ton/Day**			
	River	**Dam**	**Groundwater**	**Total**
Johor	1002	566	0	1568
Kedah	1277	15	0	1292
Kelantan	226	0	150	376
Labuan	39	12	0.3	51.3
Melaka	298	214	0	512
N. Sembilan	466	374	0	840
Pulau Pinang	1011	78	0	1089
Pahang	1035	0	28	1063
Perak	884	447	0	1331
Perlis	106	44	5	155
Sabah	707	272	19	998
Sarawak	940	109	0.4	1049.4
Selangor	4014	144	0	4158
Terengganu	614	0	0	614
MALAYSIA	12619	2275	202.7	15096.7

2. Methods and materials

This section reviews on the procedures and laboratory test that were conducted in the evaporation treatment of groundwater in RECESS. The groundwater was treated by using prototype of S2H or natural evaporation process. This study was conducted by using groundwater extracted from wells was located in the RECESS area. The groundwater sample was pumped and stored in a container before undergo any treatment.

Groundwater samples were taken from RECESS for times on three different days. Each sample was gone through evaporation treatment on three different days. The samples were treated as soon as it was taken from the storage container. On the day of treatment, each sample was placed in the prototype for the evaporation process to take place naturally. The prototype was taken to a field and left under the sun from 9.00am until 5.00pm. The evaporated water was collected and ready for laboratory tests. This evaporation process depends entirely on the heat of the sun without any additional energy from any sources. If it rains on the day of treatment, samples will be taken and tested on different days.

2.1. S2H Prototype

A prototype named S2H model was designed prior to the groundwater treatment. This functional prototype was used to generate clean water by treating groundwater through natural evaporation process with supporting of main solar energy at day time. The structure of the prototype was built using black perspex material (2mm thickness) to ensure that heat can be absorbed and trapped as shown in figure 1. The prototype was built with 1 square feet exposure area. The surface area was large enough to let the water evaporate naturally with significant rates.

Figure 1. S2H model is generating clean water for 8 hours per day.

2.2. Water quality perspective

Groundwater quality test was carried out before and after evaporation treatment. Sulphate, chloride, nitrate, and fluoride was used Ion Chromatography machine while pH meter and DO meter were used to determine pH value and dissolved oxygen level respectively. Three samples of raw groundwater have gone through laboratory test as a control values to determine the changes of parameters involved. Another laboratory test was also conducted after the sample has undergone evaporation treatment. In this study, six parameters were taken into account in order to determine the level of groundwater quality which has been treated. These parameters were sulphate, chloride, nitrate, fluoride, dissolved oxygen and pH value was analyzed and compared to water drinking standard.

2.3. Water quantity considerations

Groundwater quantity was conducted to obtain the optimum number of samples. The samples used were varied which start with 1, 1.5, 2.0 and 2.5 litres. All four samples were tested on four different days at same conditions. In addition, the external temperature was recorded using a thermometer to identify the relationship between the weather and the quantity of water generated. The amount of

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water generated was recorded in periodically for every 4 hours of treatment processes a day. Water generated in the prototype were measured and monitored in order to determine the losses values.

3. Results

This section was described the results obtained from the groundwater treatment based on the engineering needs. The analysis of this S2H model was divided into two parts; qualitative and quantitative analysis. Qualitative analysis involves groundwater quality before and after the treatment which were carried out in accordance with National Drinking Water Quality Standard (NSDWQ). The analysis of S2H model in treating the groundwater was shown the effectiveness for all parameters respectively.

The quantitative analysis focused on the quantity of clean water generated from the treatment process based on environmental condition and time. An optimum values by the amount of water generated resulting from any number of samples was identified successfully.

3.1. Qualitative analysis

According to table 2, the pH value of the sample A, B and C were slightly lower than the value 7. These values mean that the groundwater in RECESS was acidic. However, the pH value obtained was within the range allowed standard. Dissolved oxygen levels also within the safe ranges issued by the Ministry of Health had issued. The average oxygen concentration for all three samples was 6.31 mg / l, while the allowable range MOH is between 8.0 mg / L to 10.0 mg / l. However, both parameter pH and DO was produced better quality because groundwater reacts on air (oxygen) can be improved these samples more natural and oxidize.

In addition, the chlorides for all three samples have exceeded the limits. The average value of chloride samples A, B and C was 2330.73 mg / l which gives a difference of 2080.73 mg / l with the value issued by standard. This situation shows that the groundwater was absolutely not safe to drink without undergoing any treatment. Furthermore, the fluoride also cannot meet the standards published by the Ministry of Health. All of the samples were tested have shown very positive results on the quality or treated groundwater. Most of the parameters have been changed as expected as shown in table 2 and figure 2 respectively. The effectiveness S2H model by solar energy process was reduced more than 76% for chloride, fluoride and sulphate to groundwater quality without any chemical dosage because reactions from solar was generated by heating temperature and evaporates water sample as treated water naturally.

Table 2. The percentage of groundwater improvement by S2H model

Parameter	Effectiveness (%)			NSDWQ	Statement
	A	B	C		
pH	4	8.4	7.2	5.5-9.0	Fulfill Standard
DO, (mg/l)	11.5	20.2	4.3	8.0-10.0	Fulfill Standard
Chloride (mg/l)	90	90	89	250	Fulfill Standard
Fluoride (mg/l)	100	82	76	0.5-0.7	Fulfill Standard
Sulphate (mg/l)	81	80	76	250	Fulfill Standard
Nitrate (mg/l)	50	10	13	10	Fulfill Standard

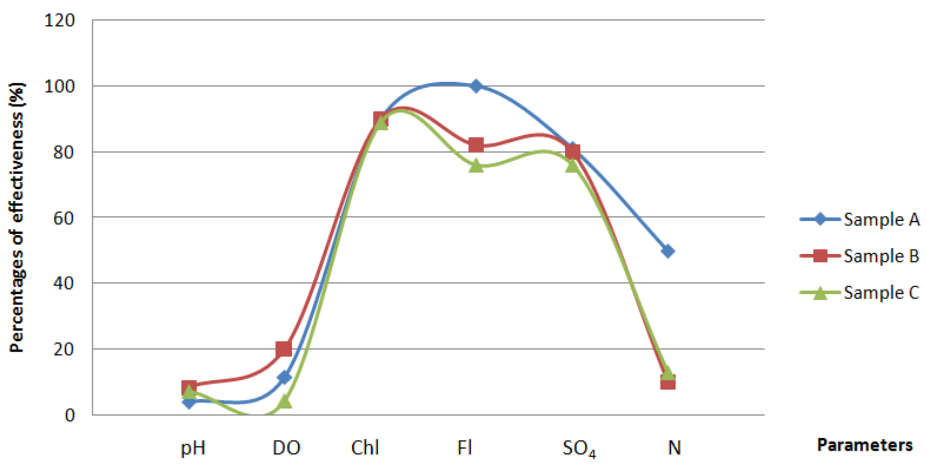

Figure 2. The effectiveness of removal from each parameter.

However, the content of nitrate has shown unexpected results. Referring to figure 3, the nitrate has increased in all three samples. Sample A has the addition of nitrate most significantly by 49.47% increase. This increase stems from the content of the treated water contains ammonia which reacts with oxygen to produce nitrite. Due to the process of condensation and evaporation occurs at room exposed to oxygen, so the concentration of water have increased nitrate naturally on the surface of the treated water.

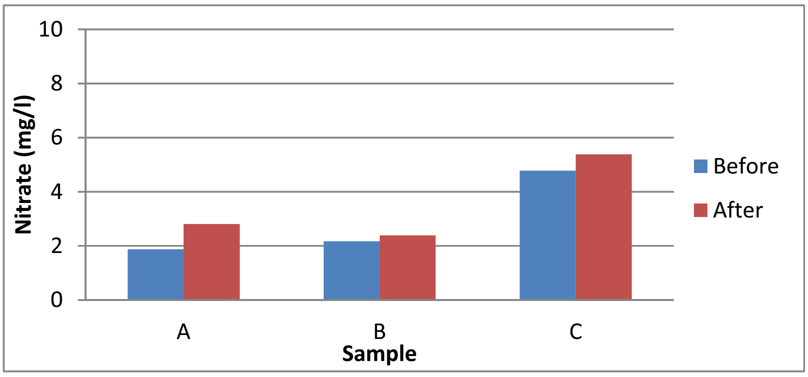

Figure 3. Nitrate quality changes at differences samples at differences of amount.

3.2. Quantitative analysis

In this study, the generated clean water from the treatment were recorded and analyzed. In addition, the amounts of water loss throughout the treatment process were identified. This is necessary to determine the efficiency of the prototype in generating treated groundwater. The amount of evaporated water was recorded every 4 hours starting at 9 am and ends at 5 pm. The treatment process was conducted 4 times with different amount of samples to determine the optimal amount of water evaporated.

Figure 4 shows the volume of water evaporated after the end of treatment. The samples used are varied, namely 1.0, 1.5, 2.0 and 2.5 litres. The smallest samples of 1.0 litre generate the highest number of clean water. The largest samples of 2.5-liter produces the lowest amount of clean water when compared with other samples. The amount of water evaporated outlook despite a surface area of 1 square foot was used for all samples. The optimal number of water samples obtained was 1.20 litres.

This amount should be used to get the evaporated water with the optimal rate on surface area of 1 square foot.

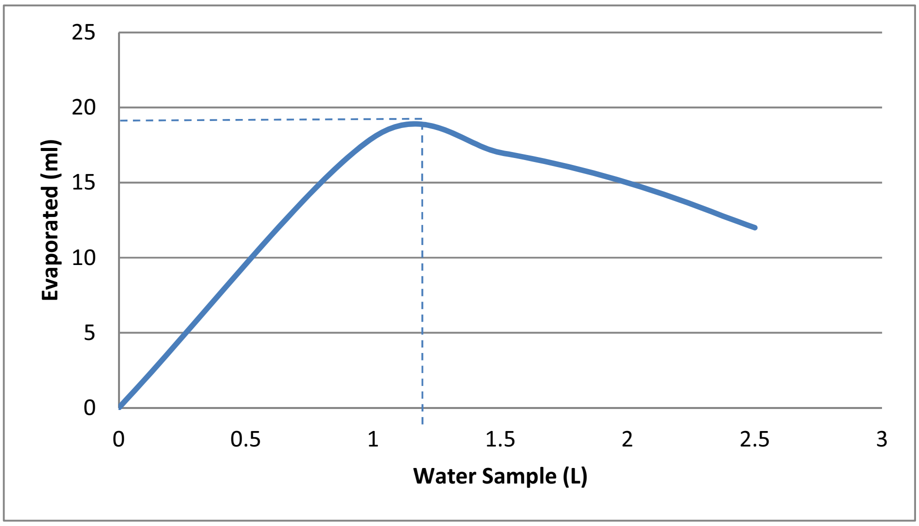

Figure 4. Optimization value for water generated in 1 ft^2 surface area.

3.3. Water losses

Not all the evaporated can be collected. A small portion of the evaporated water will be lost in the air through small holes or cavities. Table 3 shows the percentage of water lost in the air according to the number of samples used. Small sample size loses more water than a large number of samples.

This problem occurs due to insufficient prototype seals to prevent water evaporated from escaping into the air. There are several factors prototype is not watertight. In addition, the material selected to build the prototype cannot resist heat for a long time and it will change its behaviour throughout the times.

Table 3. Losses was occurs during testing samples.

Volume Sample (L)	Evaporated Water (ml)	stored water (ml)	Water Losses(ml)	Percentage of water losses (%)
1.0	18	872	110	11.0
1.5	17	1326	157	10.47
2.0	15	1834	151	7.55
2.5	12	2345	143	5.72

4. Conclusion
The groundwater was successfully treated by using S2H model and evaporation method. Nitrate is the only parameter that shows negative changes due to the reaction of existing ammonia in the treated water with oxygen. However, it still remains in the acceptable ranges as before. The rest of the parameters manage to show positive changes and they are able to fulfilled the requirements by the Ministry of Health Malaysia. Apart from that, the S2H model can only generate less than 2% of clean water. The model was too small and could not generate a decent amount of clean water. The possible solution is to develop the prototype in a larger scale and a proper assembling technique.

5. References
[1] Musa S, Ariff N A, Kadir M N A and Denan F 2015 Simplified Method for Groundwater Treatment Using Dilution and Ceramic Filter *IOP Conference Series: Materials Science and Engineering* **136** 12074.
[2] Musa S, Denan F, Hamdan R and Radin Mohamed R M S 2015 Natural Groundwater Eco-Treatment (N-GET) for Water Supply at Johor Malaysia *Journal of Advanced Research in Fluid Mechanics* **9(1)** 19–27
[3] Mohamed I 2004 Kajian kualiti air tanah di jajahan pasir puteh, kelantan *Theses Master of Science Universiti Putra Malaysia.*
[4] Fong D 2014 Sustainable Energy Solutions for Rural Areas and Application for Groundwater Extraction *Global Energy Network Institute (GENI)*
[5] Abdul Kadir A, Othman N and Mohd Azmi N A 2012 Potential of Using ROSA Centifolia to Remove Iron and Manganese in Groundwater Treatment *International Journal of Sustainable Construction Engineering and Technology* **3(2**) 70–82.
[6] Musa S, Zakaria N A and Lau L T 2013 Kaedah Lestari Bio-Serapan Dalam Merawat Air Bumi Menggunakan Bahan Organik *Proceeding of Seminar Kebangsaan Aplikasi Sains dan Matematik 2013* 29–30.
[7] Musa S, Hamdan R, Ahmad N A, Denan F and Ariff N A 2015 Groundwater Eco-Distribution System for the Combination of SAT and Therapy-electrolysis Methods *Applied Mechanics Material* **774** 1340–1344.

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