Geo-chemical and Mineralogy Assessments with Groundwater Recharge Well System (REWES) for Water Circulation

S. Musa, N. A. Zakaria, and T.L. Lau, *Member, IAENG*

***Abstract*— The water quality index is not stable for long time constraints because variable forms of contamination affect by groundwater movements. During recharge and discharge circulation in the ground, the original water quality is disturbed by the surface water injected into the ground system. This paper aims to identify the purity of water contaminations in the ground layer (clay mineral) during abstraction method. Using geo-chemical (XRF) and mineralogy (XRD) analysis, the groundwater quality gives the best result on dilution actions more than 12% decreases compared with purity indexes. Schedulable pumping for withdrawal groundwater flushing for water distribution also gave positive in quality index in order to natural or mineral water intake. The recharge coefficient found in the range of 0.05 to 0.19 for the study area. The circulation system with control function more quality-effective to pure the groundwater ecology system with lower cost-treatment for water distribution purpose. Therefore, evaluating the water quality for duo actions in this study must consider the safety level for the ground system and water demand records.**

***Index Terms*—Recharge water, discharge groundwater, water quality, clay mineral, water circulation**

I. Introduction

THIS study presents based on the pumping and recovery/refill activities of pumps (well capacities) and the availability of aquifers at on-site locations. Some solutions were evaluated in terms of the effect of the natural formation of clay minerals on the quality of groundwater when it is naturally treated within the layers of the aquifer. Another evaluation parameter was the usefulness in meeting water demand at a certain time.

The factors of study influence by area problems. Given the increase in the number of buildings and pavements, the green area causes too much stress on the remaining drainage area, which can cause several instances of flooding in rural or urban areas especially Parit Raja (Musa et. al, 2009),(Zhou, 2007). But, Parit Raja faced drainage system problems, where at the end of 2006, a flood occurred at the area due to the poor drainage system in order to channel it properly. One of the consequences of population increase is high water demand. Unfortunately, the municipal government is not able to provide sufficient levels of water quantity and quality for surface water intake. Therefore, this study focuses to benefit support for community and ecology system to circular the groundwater with lower cost-treatment and quality-effective for water demand opportunity. Using simple concept in naturally without maintenances, discharge and recharge was applied in a well. Discharge well is water is pumped out from ground, and recharge wells, where water flows under gravity to the ground system.

Mostly studies needs to monitoring for long term case to stabilized records. A study by Pettyjohn (1982) found that relationship becomes apparent when the areal extent of groundwater contamination with time is examined for at least three years. His study assumed that the first two wells represent the groundwater quality at depths of about nine feet and 23 feet, respectively. Between those levels, the composite well has a higher concentration and higher mineralogy than both the deep and shallow wells. However, chloride concentration fluctuates, occasionally manifesting at the shallowest depths, at the greatest depth, or somewhere in the middle of the aquifer. The concentration spreads to different areas because of the groundwater flow and fluctuations.

Gerhart (1986) focused on the effects of groundwater recharge on nitrate concentration in Pennsylvania in short-term studies that took place over two to seven days. Direct recharge of stormwater to the ground caused nitrate concentration to fluctuate, because the amount of stormwater runoff diluted and dissolved the nitrates during or after the storm. Changes in nitrate concentration caused by direct recharge during a storm occurred more rapidly compared with gradual recharge which mostly takes several weeks or more after the storm has ended.

Nightingale and Bianchi (1977) also observed another parameter in groundwater quality turbidity on recharge activities. Their study observed aquifers used for domestic or public supply purposes. An analysis of the recharge time of different aquifers showed that the salinity contamination decreased with time and after a storm event compared with turbidity concentration. Sometimes, the groundwater quality was affected by suspended materials from spreading

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recharge basin or by water table effects. Turbidity is also aesthetically objectionable, and some treatment studies observed the effects of the infiltration galleries, the gypsum used, and macrospore structure, among others. However, not all studies had good impacts or were economical to water supply and distributors.

Groundwater and aquifer had relationship for water demand supported were increases time by time. An assessment of the requirements of the boundaries and the body of water must also focus on water quality and quantity. A study by Mohamed and Ghazali (2009) on selected wells in Malaysia, including Kelantan, Melaka, and Terenggganu, was able to determine different use-to-yield ratios at different locations. Groundwater quality is always found to be acidic, contain chloride, and have an additional concentration of iron and manganese that is higher than the allowable limit. Groundwater usage in other locations within Malaysia must be evaluated.

Manukan Island, Sabah was determined to have higher levels of manganese, calcium, and chloride than the drinkable standard. Magnesium and calcium are main cations usually found in natural waters, but a normal concentration was found in many cases for other study areas. There are also some geochemical effects in this area due to contamination from seawater and existing fractures.

Konikow et al. (2001) conducted a chemical analysis of samples of the column effluent from the brackish and fresh water flushes. The results indicated that base exchange occurred between sodium ions at the clay surface and calcium and magnesium ions in the freshwater. The concentration of calcium and the magnesium in fresh water was too low to prevent clay dispersion.

A case in Iran was studied by Dobaradaran et al. (2009), who found that water quality also affects water depth. They found that electrical conductivity and total dissolved solids increased with depth, but others like total coliform and fecal coliform did not exhibit the same response. The geological aspect was exhibited some responses to water quality index and contaminants. Area selection and planning were crucial to locating the supply and distribution well for any location.

A mineralogical aspect, Tan et al. (2000) conducted a subsurface investigation at Klang Clay, Malaysia, and their work characterized this location as having the engineering properties of soft, silty clay. In their study, the site generally consisted of very soft to firm silty clay up to a depth of 25 m to 30 m with intermediate sandy layers. The study also found that the quartzite that appears 40 m deep was completely weathered.

Almost the same deposit dominated by quartz and aluminum oxide, in a sequence of gray to dark gray colors, that was found at Johor, Malaysia was also observed at the study site. Hassan et al. (2009) studied the geochemical state and found that the lower dark gray to the black sediment area is rich in mica and organic matter. The hematite and sulfur trioxide encountered was limited at this point. The behavior of alluvial soil is influenced by depositional processes, erosion, re-deposition, and consolidation. It is also affected by groundwater level fluctuation. The Al_2O_3 and SiO_2 placed into the solution during labile grain dissolution were the probable sources of well-ordered kaolinite precipitation in the pore spaces within kaolin. However, clay mica is the other major source of potassium (kaolinite) and aluminum, particularly in the fine-grained sediments. Sodium (Na_2O) and calcium (CaO) showed an antipathic relation with arsenic (As).

The rest of the compositions encountered below 4% by parent depositions in minimum were carbon dioxide, magnesian, potassium oxide, siderate, sodium oxide, titanium oxide, and chloride at some point. These combinations in clay soil naturally affect groundwater resources and the recharge system. According to Shamshuddin and Markas (2008), hematite generates positive charge, whereas kaolinite (potassium oxide) generates negative charge in the soil. The kaolinite, limited to just below 2%, only affected variable charge to variable pH. Thus, the negative charge of kaolinite developed a potential for an alkaline condition. In other words, the pH value for groundwater is high in natural conditions that are safe for water distribution purposes.

Semi-quantitative estimation of minerals using this method showed the proportion of quartz and kaolinite in the soil studied was in the order of that at the Johor site. Shamsuddin and Markus (2008) also found that the area at Segamat, Sungai Mas, and Kuantan are dominated by kaolinite with organic matter. Therefore, kaolinite contributes in increasing the pH values to alkaline condition for clay minerals in Johor and surrounding states.

II. Methods and Concepts

A. *Well in Duo-Concepts*

The Recharge Well System (REWES) concept was implemented on site based on deep clay formation with low infiltration rate. The selected location at Parit Raja, Johor Malaysia was built in physical model for duo functions during wet and dry problems. Groundwater was tested for water quality aspects during discharge and recharge activities to determine the effectiveness of the concepts used. However, tested on samples for every layers was analyzed on XRF (X-Ray Fluorescence) and XRD (X-Ray Diffraction) solutions to evaluate the mineralogy in deep layers. Combination of water quality and mineralogy gave some positive responds to water demand indexes and stabilize the system naturally.

B. *Discharge Study*

The study site was designed to solve inundation problem and to capture and collect surface water runoff. Based on the setup, recharging the well system was a refreshing point, following on-site conditions and the abovementioned problems. An actual RW (Recharge Well) pump was installed on-site to determine the feasibility of using this method to determine the correlation between flooding and water supply problems. Pumping using the RW reverses the natural hydraulic gradient such that the surrounding groundwater is induced to flow into the lower layer. This simple analysis was carried out to interpret basic simulation tests. The quantity studied in this case concentrated on groundwater flow at surface conditions and shallow sub-layers. However, their study was conceptualized to solve the problem on the water table height problem.

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C. Recharge Study

Pumping activities performed in the area indicated that the layers had several parameters that could be reasonably used as parts of the drainage system. Test results on the well determined that the transmissivity (T) and storativity (S) of the RW were 3.121 m^2/day and 0.1, respectively, as estimated before. Other parameters, such as storage capacity and hydraulic conductivity (K), were found to be in the ranges of 0.866 m^2/day to 2.56 m^2/day and 0.0001 m/day to 0.086 m/day, respectively. This aquifer was composed of fine sand with varying percentages of clay. The sandy layer, with a thickness of 10 m to 12 m, was predominant. As such, the quantity of recharge and the rate of horizontal and vertical movements through the aquifer can be highly variable with these combined methods.

Prior to the pumping test evaluation, the system is required to relate the capacity and capability of the aquifer with the mechanical installation aspect. Table 1 shows that the withdrawal availability can be increased by improving the discharge flow rate. The system responded effectively to the increase in the available capacities of single pumping or injection well with pumps that have suitable power. Therefore, the capacity of the pump is related to the storage capacity in capturing the injection of surface water for storage and for the recovery of the system with differential storage capabilities.

Table 1 Capability discharge and recharge in the system based on pump types

Parameters	Average	
	RW_{1hp}	OW_{2hp}
Flow rate, Q (m^3/day)	45	104
Storage capacity, Sc (m^2/day)	1.11	2.54

III. ANALYSIS ON OLD WELL (OW)

The old well (OW) in the study area was also basic tested to determine the concentrations of nitrate, nitrite, phosphorous, and manganese. For the total solids analysis, the conventional method of water sampling for limited concentration for recharge effects was used. The sample was tested before and after rainfall, as shown in Figure 1. The results are compared according to quality water distribution.

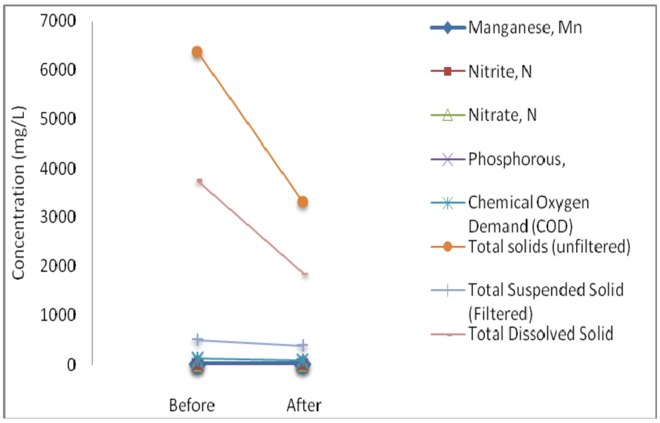

Fig. 1 Result of groundwater quality test at OW (before and after recharge)

After diluting with rainwater, the groundwater showed improved quality but still does not pass the standard for water supply source, except for its nitrate and nitrite concentrations. This phenomenon is because the recharge volume directly added to the well via without percolation does not follow the appropriate method for safe recharge. However, the application of recharging through the dilution method improved the concentration to more than 12% to 50% of safe quality treated water. A medium with packed gravel can reach the interflow more significantly compared with a sand medium. However, a mixture of sand and gravel medium can be used for natural treatment; it can serve as remover in groundwater movement. Thus, the additional method was applied to inhibit the direct contamination of surface water into the ground as designed in the REWES model for this case. This model can improve conditions for water quality control and water demand requirements.

IV. HYDRO-CHEMICAL ON REWES

According to REWES model application, the assessment of groundwater quality was carried out based on available data. The concentrations of these parameters were compared to those specified in the drinking water standard (NDWQS) to identify groundwater exploration in the area under investigation. A few of the parameters studied are listed in Table 2. Some parameters were passed as drinking standard for both seasons, and one parameter was used for a single season. The groundwater samples were limited in this case due to the number of groundwater wells in the study area. Geochemical data show that the groundwater in the study area is categorized as neutral, as indicated by the pH value range of 5.85 to 6.6.

The dilution concentration during wet season was produced under the drinking standard through recharge action or dilution of water surface concentration. The recharging method can naturally release groundwater contamination in the system. The evaluation of groundwater contamination was exchanged with time. Not all the stable values for all parameters and time periods were shown. Therefore, monitoring water quality needs to be studied in detail for water supply applications and water recycles used for the limited aquifer (Figure 2).

Fig. 2 Freshness groundwater in quality at REWES model

The study evaluation on REWES with proper installation for water quality and quantity aspects showed better results under standard water quality index for minority concentrations. Other parameters did not show higher values to meet the required level. They can be treated by case and by using a suitable method without spending too much money. Some physical aspects can be normally diluted by flushing more times, pumping, or arranging withdrawal schedules. Meanwhile, concentrations in chemical aspects can be treated with specific laboratory methods to achieve suitable level requirements. Future actions are needed for this purpose.

Table 2 Water quality evaluations at both seasons for two pumped wells in the study area

	DRY		WET		Standard
Parameters	RW	OW	RW	OW	NDWQS
Temperature (°C)	28.31	28.32	27.3	27.32	27-31
pH	6.61	6.36	6.17	5.85	5.5-9
Turbidity (NTU)	8.6	11.23	185.9	157.4	0-5
Conductivity (mS/cm)	8.05	7.38	0.002	0.03	0 - 1000
Salinity (ppt)	4.15	3.78	0	0.01	0.5-2
Chlorine (ug/L)	5.33	16.43	9	19.95	250
DO (mg/L)	9.88	9.77	3.44	5.85	3.0-7.0
Zinc (mg/L)	0.01	0.01	0.34	0.062	0 - 3
Cadmium (mg/L)	0.07	0.05	6.4	0.01	0.003
Mangnese (mg/L)	0.01	0.01	10	8.5	0 - 0.1
Iron (mg/L)	3.5	3.3	0.01	2.58	0 - 1
Lead (ug/L)	0.1	0.2	0.082	0.09	0.01
Copper (mg/L)	2.52	2.59	0.01	0.01	1
Nitrate (mg/L	0.05	0.03	6.4	9.1	0 - 10
COD (mg/L)	302	160	44.9	43.5	0 - 10
BOD (mg/L)	142	58.4	30.21	29.94	0 -1
Nitrogen Ammonia (mg/L)	0.147	0.15	7.8	6.05	0 - 1.5
TSS(mg/L)	204	208	181	245	8 - 100

V. Clay Mineral Effects

A. Geo-Chemical Conditions

Groundwater and their mineral contents cannot be separated because both are important in relating each other's compositions in the mineralogical aspect. Top to bottom samples were used to analyze specific conditions for geochemical and mineralogical characterizations. Two methods used were analyses made to characterize the relationship among soil samples to one another and to determine their respective compositions, especially in clay minerals aspect.

The soil samples were collected at depths of 1.5 m to 48 m (Figure 3) by drilling. For the purpose of analyzing elements and minerals, the samples were dried, crushed, and powdered using the crusher at the UTHM (Universiti Tun Hussein Onn Malaysia) laboratory. The powdered samples were then compressed and molded for scanning of chemical and mineralogy distributions.

Geochemical analysis was conducted on the chemical elements through the X-ray fluorescence (XRF) scanning method. To identify the secondary minerals in the soil, the X-ray diffraction (XRD) method was carried out by layers through the XRF composition outputs.

Fig. 3 Samples at the bottom level in the natural site

B. XRF- Geo-chemical Characterization

The bulk composition of the sediment compressed powder samples was determined using the XRF Bruker model S4 Pioneer spectrometer at the laboratory. A binding material (boric acid) was used to hold the compressed powder on the quality tablet (Figure 4). Tablets for every layer were scanned for their geochemical characteristics, quartz and aluminum oxide dominated every tested layer.

Fig. 4 Tablet produced for XRF analysis

Deeper analysis through XRF found that the geochemical condition at the site is influenced by carbon dioxide, quartz, aluminum oxide, hematite, sulfur trioxide, magnesium oxide, potassium oxide, calcium oxide, sodium oxide, titanium oxide, chloride, manganese oxide, calcium, manganese, and sulfur. However, available values for calcium, manganese, and sulfur were not detected, indicating that these are not significant to water quality effects.

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C. X- ray Diffractometer (XRD) Studies

The presence of the above minerals was further tested by XRD. Unoriented powder XRD of the heavy mineral fraction was done at the laboratory to identify the crystalline phase in the sediment and to determine the mineralogical composition of the raw material components as well as the qualitative and quantitative phase analysis of multiphase mixtures. An X-ray diffractometer Bruker D8 Advance was used for this analysis.

Mineralogical analysis by XRD revealed the dominance of quartz, muscovite, kaolinite, and pyrite. The presence of authigenic pyrite in the dark gray sediment indicates active reduction in the aquifer. The kaolinite (potassium) and aluminum in the sediment came mostly from muscovite $[KAl_2(AlSi_3O_{10})(F,OH)_2]$ and potassium feldspars ($KAlSi_3O_8$). Quartz and kaolinite distributions are inversely proportional. The variation in the amount of quartz may be related to the clay content of the sediments. However, lower quartz content is compensated by the overall increase in the amount of mica, hematite, and siderite.

Bottom level relationship on chemical and mineralogy had high of percentage of quartz for both of analyses. There are commonly identified that the purity of the deep level occupied most of mineral have not yet effected by poor water quality. The freshness and natural groundwater also studied by Kirov and Truc (2012) that soil layer also have not effected by seawater yet although the study area nearby Red River delta. For this case, surely it never affected for any instruction matter because it filtered by fined deep clay layer. Others concentration also naturally exists with good conditions with minor appearances in sample (Figure 5).

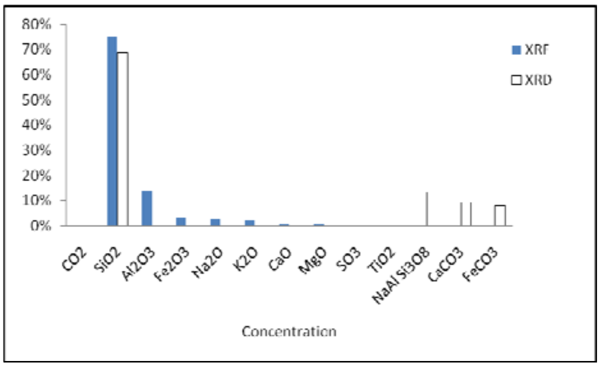

Fig. 5 Concentration for both analysis in XRF and XRD sampling for bottom level

VI. CONCLUSION

The concept of pumping and recharge was used to capture more than 12% of the water drains effectively via dilution and withdrawal. Combining discharge and recharge studies would yield quantitative and qualitative relationships for each sample to qualify the characteristics of groundwater. For the quantity aspect, the most important component of groundwater recharge is the infiltration of rainwater. Rainwater can infiltrate the ground before it is saturated. The recharge coefficient was in the range of 0.05 to 0.19 for the study area. For higher rates of recovery, the water obtained will consist of a mixture of groundwater and recharge water.

This geological and mineralogy study established the relationship between pure groundwater and contamination quality control work during discharge or recharge actions. Groundwater quality was influenced by infiltration from the surface or from rainfall.

Clay minerals reacted by balancing the composition of the clay zone during natural conditions for cyclic uses. Groundwater demand always increased with time. By letting water pass through the ground, its quality will change, and its geo-hydraulic characteristics will improve its capacity through fracture and planning. These positive changes to hydrological care can affect human activities and the natural phenomena of the water system. The mineralogy of the clay fraction in the study area was dominated by quartz, kaolinite, muscovite, aluminium oxide, and hematite. Negative or positive charges contribute to the pore and purity of the soil minerals with balanced pH variables. Geochemical studies are related to the mineralogical aspect of the natural treatment of groundwater systems.

The clay type of soil effects of water quality and quantity influences the characteristics of contaminations. Therefore, the cross-disciplinary acts able to solve any negative effects under the ground by circulation system. Studies indicated that the said aquifer can yield water according to the level of quality of groundwater usage (potable or non-potable). However, the groundwater needs to be simple treated if it will be used for domestic or commercial purposes.

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