C-GT-019: Development of Underground Water Treatment System at Pusat Bimbingan Insan Kg Kabog, Kunak, Sabah

Wan Mohd Faizal Wan Ishak[1], Mohammad Adam Bin Azman[2], Muhamad Aliff Bin Ramli[3]

[1]Pusat Penyelidikan & Pengurusan Sumber Alam (CERRM)
Universiti Malaysia Pahang, Leburaya Tun Razak,
26300, Gambang, Kuantan, Pahang Darul Makmur
Corresponding author: *Wanfaizal72@gmail.com*

Abstract

Malaysia is a country with rich water resources including its surface water such as river, reservoir, lake, sea and ground water. In general, Malaysia has an abundance of water either on surface or underground. However, the supply of clean water is decreasing while demand is growing parallel to the population increment. Hence, an alternative has been chosen and implemented to assist the people of Pusat Bimbingan Insan Kg Kabog, Kunak, Sabah to deal with this demand. This project was divided into two stages, the preliminary stage where the system is designed based on the early parameter and the construction stage where the system is built and the equalization tank, sedimentation, open bed media and filtration system are installed. The water samples are taken from both influence and effluence to be analysed. The samples are analysed using ICPMS for Potassium (K), Sodium (Na), Calcium (Ca), Magnesium (Mg), Iron (Fe), Manganese (Mn), Sulphate (SO_4), Bicarbonate (CO_3) and Chloride (Cl). The result showed that all the water parameter tested is in accordance with the drinking water standards and safe to be consumed. In additionally it also removes the odour and taste of underground water which often exists. Therefore, the use of underground water in daily life can be an alternative to replace the current source of water used in Malaysia, whereby the area required for this system is adequate to be installed in schools, agricultural and industrial sectors in Malaysia.

Keywords: *Underground Water, Drinking Water Standard, Underground Water System, Filtration System*

1. Introduction

In general, Malaysia has an abundance of water sources including surface water and underground water. However, the supply of clean water is decreasing while demand is growing parallel to the increase of total population (Falkenmark, 1994). Lack of clean water will also affect public health. For example, due to lack of clean water for drinking can cause dehydration (lack of water in the body) as well as causing diseases outbreak like cholera due to contaminated drinking water. Shortages of clean water also affect land resources where soil will become barren. Contaminated water consequently affects the quality of land and thereby affecting subsequent agricultural activities, affecting food supply and economic growth. The underground water treatment system is an idea to solve the problem faced by the community for their domestic uses and also the development of farmer's area residences and community. The design of water treatment system is developed to solve the problem faced by the community in that area. Several stages of the system will mainly treat the high iron content in water and stabilize the pH to suit drinking water standard and farmer's need for irrigation.

However, underground water is also exposed to contamination from various source of pollution such as industrial pollutants, agricultural, leaching and leakage from underground storages tank (USTs). (Esfandiar, Nasernejad, et al, 2014). Even though underground water has undergone a natural filtration process through rock and sand, the underground water has dissolved minerals, salt and ions when passing through the earth crusts. Clean water is essential for survival, a basic human right and it is important for the health of well-being (Hossain, *et al.*, 2014). To get safe water, all contamination that is hazardous to human, animal livestock and agricultural activities must be eliminated.

There are minerals contained in underground water that is dangerous to human health if they are consumed intentionally or unintentionally exceeding our body limit such as manganese. Drinking excessive manganese is dangerous to brain tissue and affects the central nervous systems. (Esfandiar, Nasernejad, & a, 2014). Iron, however, effects more on agricultural and industrial activities compared to human health, where Iron exceeding 0.1 ppm may cause clogging of drip irrigation emitters and above 0.3 ppm may lead to iron rust stains and discoloration on foliage plants in overhead irrigation applications. If iron exceeds 4 ppm it will become toxic to plant tissues (Zinati & Shuai, 2005) and (Joshua, *et al.*, 2014).

Generally, various treatment methods for removing heavy metals from groundwater have been developed such as ion-exchange, adsorption, reverse osmosis, chemical precipitation, ultrafiltration and oxidation, but most of the conventional methods are expensive, not user-friendly and using external chemicals such as polymer and alum. The use of activated carbon (AC) is widely used in water treatment in order to remove odour and taste of ground water. To increase its effectiveness, some pre-treatment steps must be carried out. The pre-treatment also function to secure the life expectancy of the filter.

In Malaysia, the clean water issue is still in critical condition, either shortages of clean water to be distributed amongst Malaysia population or the quality of the clean water distributed to the user. Safe water is one of the civil rights, Villages located at the outskirt of the treated water circulation is the main reason why this system is developed. This project was divided into two stages where the preliminary stage is designing stage based on early parameter measured and second stages is the construction of the system. In this paper, influent and effluent samples were taken to study the effectiveness of the system and to compare with Ministry of Health's (KKM) standards for Sodium (Na), Magnesium (Mg), Calcium (Ca), Iron (Fe), Sulphate (SO_4), Chloride (Cl) and Bicarbonate (CO_3).

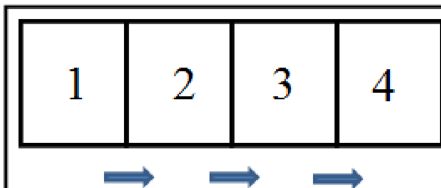
2. Material and Method

2.1 Study Area

The study area is located at Pusat Pembangunan Minda Insan (PPMI), Kg Kabog, Kunak, Sabah. PPMI is a school managed by Pertubuhan Himpunan Lepasan Institusi Pengajian Malaysia (Haluan) with the collaboration of Ministry of Rural and Regional Development (KLLW) and Implementation Coordination Unit of Prime Minister's Department (ICU). Most of the student's ethnic are Bajau Laut. This ethnic have been neglected of the civil rights such as electricity, education and safe water supply. In 2014, there were 264 students studying in PPMI and 10 teachers teaching in this school.

2.2 Pre-Treatment System

A pre-treatment process consists of one unit of the concrete tank with dimensions of 8.5m long and 2.3m wide. The pre-treatment tank is divided into 4 different partitions where each partition carries its own special task as shown in Figure 1. The equalization tank is made for aeration process where all the mineral, salt and ions contain in ground water go through an oxidation process. This process will change the mineral, salt and ions from diluted form to undiluted form and become residue and sludge. After the process of aeration, the residue and sludge's will flow through clarification tank where all the residue and sludge will settle and coagulate down to tank slab. The clarified water will continue to be filtered at open bed media consisting aggregates, river graded sand and activated carbon. The bottom of the open bed media is equipped with a self-made strainer. The self-made strainers are constructed from 2" unplasticized polyvinylchloride (uPVC) screen pipe and uPVC connector as shown in Figure 2. The filtered water will go to the last partition of the tank where the tank act as first storage tank before it is filtered by the multimedia filtration system. The water level in the tank is controlled by controlled level switch connected to a submersible pump control panel as shown in Figure 2. In the case of low water level in the storage tank one, the submersible pump will automatically pump the underground water to the pre-treatment tank until the water level in the storage tank reaches maximum level.



Tank No	Name/Function
1	Equalization/Aeration
2	Clarification
3	Open Bed Media
4	Storage one

Figure 1: Tank details

Figure 2: Self-made strainer using 4 inch uPVC screen pipe, uPVC pipe and uPVC connector

2.3 Multimedia Filter System

Two set of multimedia filtrations system is used in this project to treat the underground water. Figure 3 represent the flow diagram of the filtration system. The filter unit is made from fiber reinforced plastic (FRP) vessel with a 30-inch diameter and a 72-inch height. The upper and bottom mouth of the FRP vessel are 2 inches wide. The filter media consist of anthracite layer, river graded sand, activated carbon (AC) and Iron Treat. The characteristic of each layer is summarized in Table 1. The bottom of the FRP vessel is layered with river graded sand 1 until the FRP vessel strainer is covered, the second layer was fill with river graded sand 2, the third layer was topped with river graded sand 3, the fourth layer was the iron treat (*metalease*), the fifth layer was AC and the top layer is finished with anthracite.

Table 1: Physical property of filter media

No	Media\Property	Particle Size (mm)	Bulk Density (g/cm^3)	Surface Area (m^2/g)
1.	Anthracite	1.2 ± 0.05	0.72–0.74	-
2.	Activated Carbon	0.6-2.36	0.47-0.50	1100
3.	Iron Treat (Metalease)	1.19-2.36	1.826	-
4.	River Graded Sand 1	2.4-4.8	-	-
5.	River Graded Sand 2	1.2-2.4	-	-
6.	River Graded Sand 3	0.3-0.8	-	-

Multimedia filtration system is supported with two multistage pumps and one unit of controlled level switch that is connected to the control panel as shown in Figure 3. The filtration of the pre-treated water will start when the storage tank two reach a low level and stopped when the water reaches a high level of the tank. The high and low level can be modified by adjusting the control level switch. Figure 4 shows the flow diagram of Multimedia Filtration System.

The Multimedia Filtration System is controlled by the face piping system. The face piping systems have been designed as shown in Figure 5. The valve sequence must be set correctly in order to execute the correct function of the system. The functions of face piping system include filtrating, rinsing and backwashing. Table 2 summarized the valve sequence for 3 function of face piping system.

Table 2: Face piping valve sequent according to its function

No	Function	Valve Sequent
1.	Filtered/Service	V2 + V5
2.	Backwash	V1 + V3
3.	Rinse	V2 + V4

Only the selected valve as shown in Table 2 should be open for water to flow according to the filter system function while the rest must be closed.

3. Result and Discussion

3.1 Pre-treatment (Roughing Filter)

Application of roughing filtration has a long history since the middle ages where numerous castles and forts were constructed with the roughing filter used to treat surface water and supply to the consumer. (Nkwonta & Ochieng, 2009). Several studies have revealed that roughing filtration to be an effective and reliable method for removing suspended solid, turbidity and coliform bacteria's. (Nkwonta & Ochieng, 2009). There are two type of roughing filtration, Horizontal Flow Roughing Filtration and Vertical Flow Roughing Filtration. In this project, the vertical flow has been choose base on limitation such as space and it can provide a simple self-cleaning mechanism. (Patil, Kulkarni, & Kore, 2012). The basic roughing filter design parameter consists of Media types, filter media sizes, filtration rate and filter length. Type of media that commonly used are any clean, insoluble and mechanical resistant. Previous studies have showed that the filter media size effect on particle removal efficiency in the roughing filter. Several studies have revealed that good removal occurs when low filtration rates are applied because of low filtration rates are critical to retaining particles that are gravitational deposited to the surface of the media. Previous studied also proved that better cumulative removal efficiencies are typically correlated with longer filter lengths. (Onyeka, 2010), (Nkwonta & Ochieng, 2009) and (Patil, Kulkarni, & Kore, 2012).

The advantages of roughing filtration as pretreatment process compares to conventional method are conventional are demanding in chemical use, energy input and mechanical parts as well as skilled manpower that are unavailable in the study area. Conventional method also demanding high operating costs compare to roughing filter.

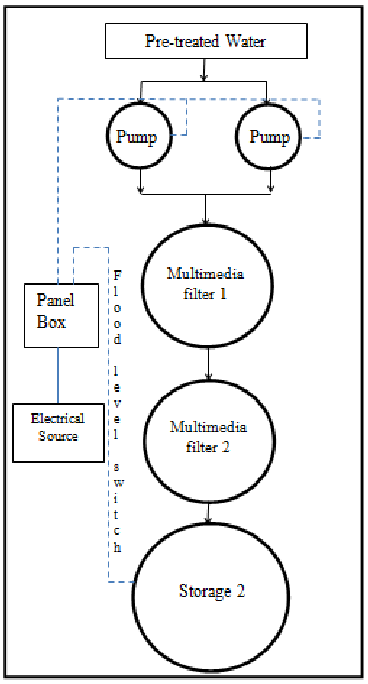


Figure 3 Flow Diagram of Multimedia Filter System

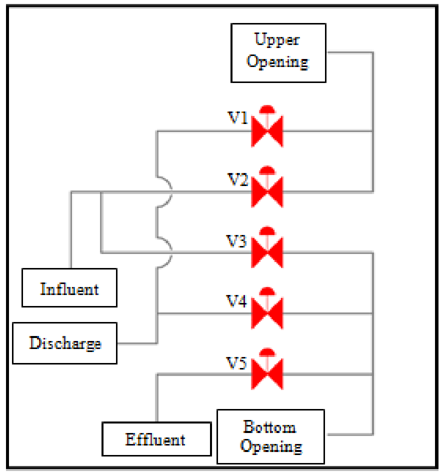


Figure 4: Face Piping System

3.2 Filtration Result

The samples were taken from the raw underground water and treated water to be brought back to Universiti Malaysia Pahang (UMP) for Laboratory Testing. The tests were conducted by UMP Central Laboratory for five parameters. The parameters and procedures are summarized in Table 3. The samples were analyses using Inductively Coupled Plasma Mass Spectrometry (ICPMS).

Table 3: Chemical Test and Method

No	Parameter	Method
1.	Sodium (Na)	CENLAB/WI/CHEM-TM/008
2.	Magnesium (Mg)	CENLAB/WI/CHEM-TM/008
3.	Calcium (Ca)	CENLAB/WI/CHEM-TM/008
4.	Iron (Fe)	CENLAB/WI/CHEM-TM/008
5.	Sulphate (SO_4)	In-House Method
6.	Chloride (Cl)	In-House Method
7.	Bicarbonate (CO_3)	In-House Method

At the equalization tank, the underground water goes through aeration process. The aeration process has oxidized some chemical properties in underground water such as Iron and Magnesium. This process resulted in the iron from the soluble form in underground water to become insoluble that exist in residue and sediment. Some of the oxidation processes that takes part in the equalization tank are shown in Equation 1 (Alicilar, Meric, Akkurt, & Sendil, 2008).

The stoichiometry for the overall oxidation of Fe^{2+} ions by O_2 is given:

$$O2\ (aq) + 4Fe^{2+} + 6H20 \leftrightarrow 4FeOOH(s) + 8H^{+} \quad (1)$$

However, the form of iron in water depends on its pH, acidic compound, ions solution and oxygenation will be greatly accelerated in the presence of a surface. (Ahmet, Goksel, Fatih, & Olcay, 2008). The residue will settle and coagulate down to the bottom of clarification tank and the balance will be treated in the open bed media and multimedia filter.

Table 4 shows the result of the analysis of raw underground water. From the analysis, sodium was not detected which mean it is less than 0.5 ppm, magnesium concentration is 12.42 ppm, calcium concentration is 22.54 ppm, iron concentration is 0.44 ppm, sulphate concentration in raw underground water is 6 ppm, chloride concentration is 10 ppm and bicarbonate is 30 ppm. From the analysis, magnesium and calcium are dominant in the underground water. It shows that the underground water diluted some of magnesium and calcium during infiltration process passing through the soil and rock in the earth crust. (Esfandiar, Narges, Bahram, & Ebadi, 2014).

Table 4: Chemical test result of selected parameter for raw ground water

No	Parameter	Result (ppm)
1.	Sodium (Na)	Less than 0.5
2.	Magnesium (Mg)	12.42
3.	Calcium (Ca)	22.54
4.	Iron (Fe)	0.44
5.	Sulphate (SO_4)	6
6.	Chloride (Cl)	10
7.	Bicarbonate (CO_3)	30

Table 5 shows the result of treated underground water after completing all the treatment process. From the analysis, sodium was not detected which mean it is less than 0.5 ppm, magnesium concentration also less than 0.5 ppm, calcium concentration is 2.48 ppm, Iron concentration is 0.06 ppm, sulphate concentration is 5 ppm, chloride concentration is 10 ppm and Bicarbonate is 7 ppm. Most of the parameter show reductions after treatment process only two parameters do not change after the treatment which is chloride and sodium.

Table 5: Chemical test result of selected parameter for selected water

No	Parameter	Result (ppm)
1.	Sodium (Na)	Less than 0.5
2.	Magnesium (Mg)	Less than 0.5
3.	Calcium (Ca)	2.48
4.	Iron (Fe)	0.06
5.	Sulphate (SO_4)	5
6.	Chloride	10
7.	Bicarbonate	7

The comparisons have been made between raw water and treated water and the reduction of selected parameter is calculated by using Equation 2, where Co is the initial concentration of parameter in ppm and Ce is the final or treated concentration of selected parameter in ppm.

$$\text{Parameter (\%)} = ((Co - Ce) / Co) \times 100 \quad (2)$$

Table 6 shows the reduction that was made by this treatment system in the form of percentages. The results of reduction show that sodium and chloride do not have any reduction in the treatment process, while Mg, Ca and Fe respectably removed for 95.57%, 88.99% and 86.36%. 16.67% sulphates have been removed from underground water from its original concentration and 76.67% bicarbonate have been removed from original concentration.

Table 6: Reduction after treatment

No	Parameter	Reduction (%)
1.	Sodium (Na)	0
2.	Magnesium (Mg)	95.97
3.	Calcium (Ca)	88.99
4.	Iron (Fe)	86.36
5.	Sulphate (SO_4)	16.67
6.	Chloride	0
7.	Bicarbonate	76.67

The parameters are also compared to the drinking water standard issued by Ministry of Health Malaysia (KKM). (Malaysia, 2010) Not all selected parameter are included in drinking water standard issued by KKM. Table 7 shows only the selected parameters that are included in drinking water standard. Only 5 from selected parameter are listed in drinking water standard which is sodium, magnesium, iron, sulphate and chloride. From the analysis that has been done, all the selected parameters are within the limitation of drinking water standard. The comparison is summarized in Table 7.

Table 7: Comparison with drinking water standard

No	Parameter	Limitation (mg/L)	Concentration of treated water (mg/L)

1.	Sodium	200	Less than 0.5
2.	Magnesium	150	Less than 0.5
3.	Iron	0.3	0.06
4.	Sulphate	250	5
5.	Chloride	250	10

Base on the comparison that has been made, all the parameters concentration have been reduced to more than 80% of the limitation of the standard. Sodium and magnesium, compared to the standard, it has been reducing to 99.75% of the limit. Iron is 80% below the limit of the drinking water standard. Sulphate is 98% below the limit of the drinking water standard. While, Chloride is 96% below the limitation of the drinking water standard. Figure 7 shows the pre-treatment tank and the signage of this KTP project, while figure 8 shows the multimedia filtration system installed at the target area.

3.3 Project Impact

During the development of underground water treatment system, many local communities involved including teachers, student and local society. This gives a chance for them to learn and practice the knowledge of the construction of tubewell and installing the water treatment system. Figure 5 and 6 show the local community together with project team working together in order to complete this project.

Figure 5: Local communities helping construct the tube well

Figure 6: Knowledge sharing between project member and local communities

After completed construct the tube well and install the water treatment system, a short course has been conducted in order to educate the local community about the important of clean water. This short course also teaches the local community to maintained and handle the treatment system. A manual have given to the local community in hard copy and soft copy as guidance to them in order to maintain the treatment system.

In an aspect of teaching and learning process, this project has ensured that the school facilities can be built the insufficient basis for the creation of conducive condition for the learning process by given the viability of clean water to be used. The viability of clean and safe water also help in controlling the spread of water-borne disease indirectly secured the student health.

4. Conclusion

The result shows that all the tested water parameters are in accordance with the drinking water standard and safe to drink. It also removes the odour, colour and taste of underground water which often exists. The local communities, teachers and student can get a viability of clean water and this project gives one of important basis needed in building a conducive condition for learning process which is clean water. The knowledge of constructing tube well and installing of water treatment system also can be use by local communities to do water exploration in other places and can be expanded as one of income sources by creating a local business. Therefore, the user of underground water in daily life can be an alternative to replace the current source of water used in Malaysia where the area required for the system is adequate to be installed in the school, an agricultural and industrial sector in Malaysia.

Figure 7: Pre-Treatment tank

Figure 8: Multimedia filter

References

Ahmet, A., Goksel, M., Fatih, A., & Olcay, S. (2008). Air Oxidation of Ferrous Iron in Water. *J. Int. Environmental Application & Science*, 409-414.

Esfandiar, Narges, Bahram, N., & Ebadi, a. T. (2014). Removal of Mn(II) from groundwater by sugarcane bagasse and activated carbon (a comparative study): Application of response surface methodology (RSM). *Journal of Industrial and Engineering Chemistry*, 3726–3736.

Falkenmark, M. (1994). The Dangerous Spiral: Near-Future Risk for water-related eco-conflicts. *Proceeding of the ICRC Symposium "Water and War: Symposium on Water in Armed Conflicts* (p. 16). Montreux, Switzerland: Inernational Commitee of the Red Cross.

Hossain, M., Bhattacharya, P., Frape, S. K., Jacks, G., Islam, M. M., Rahman, M. M., et al. (2014). Sediment color tool for targeting arsenic-safe aquifers for the installation of shallow drinking water tubewells. *Science of the Total Environment*, 615–625.

Joshua, E., Mitchell, D., Norris, D., Musgrave, A., Yiasoumi, W., Evans, L., et al. (2014, August 12). Farm water quality and treatment. *Primefact 1337, first edition agriculture NSW Water Unit*, pp. 2-4.

Ministry of Health, M. (2010, January 11). *kmam.moh.gov.my*. Retrieved December 28, 2015, from Drinking Water Quality Surveillance Programme: http://kmam.moh.gov.my/public-user/drinking-water-quality-standard.html

Nkwonta, O., & Ochieng, G. (2009). Roughing Filter For Water Pre-Treatment Technology in Developing Countries: A Review. *International Journal of Physical Science* , 455-463.

Onyeka, N. (2010). A Comparison of Horizontal Roughing Filter and Vertical Roughing Filter in Wastewater Treatment using Gravel as a Filter Media. *International Journal of the Physical Science*, 1240-1247.

Patil, V., Kulkarni, G., & Kore, V. (2012). Performance of Horizontal Roughing Filters for Wastewater: A review. *International Research Journal of Environmet Science*, 53-55.

Zinati, G., & Shuai, X. (2005, December 1). *Management of Iron in Irrigation Water*. Retrieved september 15, 2015, from rutgers university web sites: https://njaes.rutgers.edu/pubs/fs516/