Simplified Method for Groundwater Treatment Using Dilution and Ceramic Filter

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Abstract. Groundwater is one of the natural resources that is not susceptible to pollutants. However, increasing activities of municipal, industrial, agricultural or extreme land use activities have resulted in groundwater contamination as occurred at the Research Centre for Soft Soil Malaysia (RECESS), Universiti Tun Hussein Onn Malaysia (UTHM). Thus, aims of this study is to treat groundwater by using rainwater and simple ceramic filter as a treatment agent. The treatment uses rain water dilution, ceramic filters and combined method of dilute and filtering as an alternate treatment which are simple and more practical compared to modern or chemical methods. The water went through dilution treatment processes able to get rid of 57% reduction compared to initial condition. Meanwhile, the water that passes through the filtering process successfully get rid of as much as 86% groundwater parameters where only chloride does not pass the standard. Favorable results for the combination methods of dilution and filtration methods that can successfully eliminate 100% parameters that donot pass the standards of the Ministry of Health and the Interim National Drinking Water Quality Standard such as those found in groundwater in RECESS, UTHM especially sulfate and chloride. As a result, it allows the raw water that will use clean drinking water and safe. It also proves that the method used in this study is very effective in improving the quality of groundwater.

Keywords: Groundwater treatment, dilution, filtration.

1. Introduction

The use of groundwater in remote areas and estates were not fully explored and utilized. the groundwater quality study are scares and the result is still not widespread. Arguably, there is still no party that conducted the study and obtain detailed data on the sources of groundwater [1]. Although the research and technology to treat groundwater is existed, but it still cannot improve the quality of groundwater and reduce the concentration of pollutants entirely. Raw water from various sources typically contain various contaminants and inappropriate for domestic and industrial use. Water treatment process is necessary to treat raw water to a level that can be used for certain purposes[2].

Study area was chosen as the location for this study caused by limited groundwater used in the area. Water wells are used for daily usage purpose in RECESS. However, the cleanliness and water quality of the well is not at a good level. Based on previous studies [3], several parameters were tested to determine the level of quality in groundwater in the study area. There are some parameters...
that should not be treated as already meet the standards set by the Ministry of Health [4] unless sulphate, chloride and turbidity need to be treated they have very high value in groundwater.

The presence of contaminants in the area is not caused by human activity which give a direct impact on groundwater or disposal of garbage and waste that can increase the concentration of contaminants in the groundwater. A result of the analysis finds that this area is a flat area and is located near to sea about 20 km. Thus, this area found a layer of soil sediments and fossils formed due to tidal effects for centuries. Acidity levels are also influenced by the existence of a patches saltwater identified exists and trapped in the clay layer which the movement to drain are limited [3]. Indirectly, it had some impact on the presence of undesirable concentrations.

When groundwater is contaminated, it is difficult to return to the level of clean water quality due to condition of its location far below the earth's surface. Therefore, in order to control and reduce the percentage of parameters that do not meet the standard requirements for water users in Research Centre for Soft Soil Malaysia (RECESS), UTHM. This study has selected certain parameters to be analyzed without disturbing the stability of other parameters using the method of dilution and ceramic filters. The selected parameters were pH, dissolved oxygen (DO), turbidity, manganese, chloride, sulphate and fluoride. Both of these methods has been tested for its effectiveness in reducing the percentage concentration of pollutants to groundwater.

This study aims to identify the effectiveness of the dilution of rainwater process to raw groundwater, to treat raw water using ceramic filter and to ensure the effectiveness of the combination of dilution and filtration ceramic process. This experimental study was set up by using the dilution and filtration methods to groundwater samples which were taken from well at RECESS.

2. Materials

2.1 Filtration materials
Raw water was treat flows down through ceramic media, filter model were consists of activated carbon, silica sand, LECA and stone mineral and then remain as a drinking water.

2.2 Ceramic media
Before water gone through the filter model, raw water were filtered first at the upper tank with ceramic media which is medium cell to provides biological filtration for raw water process. The ceramic filter media is a man-made material and will not alter the pH balance and increase the surface area available for bacteria colonisation enhancing biological filtration. Ceramic media filtration is the use of porous ceramic (fired clay) to filter microbes or other contaminants from drinking water. Pore size can be made small enough to remove virtually all bacteria and protozoa by size exclusive, down to 0.2μm, in the range referred to as microfiltration[5].

2.3 Filter model
A filter model was used where this model can be found at the market. This model consists of four layers which is, a first layer containing activated carbon, the second layer is silica sand, followed by a third layer which is LECA (Lightweight Expended Clay Aggregate) and the bottom layer is a mineral stone. This system model with a diameter of 8 cm and a height of 10.6 cm, 6.4 cm for the first stage, second stage, third and fourth stage is 1.4 cm. The ratio between the layers is 2: 1: 1: 1 as shown in Figure 1. It functions as a filter water flows down through these layers.
Figure 1. Water filter to reduce the percentage of unwanted parameters in the water.

2.4 Activated carbon
Activated carbon, also known as Granular Activate Carbon (GAC) is the most standard media for treating water containing chemicals and impurities (coal). Activated carbon can be created in a variety of different physical forms. Large surface area gives good absorption ability and is commonly used in the raw water intake, and gravity filters. GAC has long been applied to reduce the impurities found in water. It is widely introduced in the absorption and ability to suppress the materials and chemical solution were contained in the water because carbon has a strong attraction to absorb pollutants. The process water using GAC should be applied in the treatment process after using other media such as sand in the pre-treatment process to protect the carbon from contaminated before it reach time. Impurities and chemicals can cause color, taste and bad odors in the air [6]. Macro generated in this process is the active chemical that absorbs organic and other chemicals. This GAC media is commonly used from wood carcoal < 10mm diameter in size.

2.5 Silica sand
Sand is a material that has a variety of shapes, sizes and densities of approximately uniform, so it is widely used as filter media in most water treatment plants across the country. Silica sand used is composed of fine sand with a diameter between 0.60 mm and 1.18 mm. It was chosen because of its inert and durable. It is the unique nature of the removal of acidic substances and eliminates unpleasant taste in water [2].

During the filtering process is executed, the flow of running water will force the sand layer expands and yanks separate sand particles that move and interact with each other among the particles. This action has caused impurities trapped and cleaner water can be released.

2.6 LECA
LECA (Lightweight Expended Clay Aggregate) is a lightweight ceramic with honeycomb which produced by core natural clay for a temperature 1100-1200°C in a rotary kiln. Pellets are rounded and fall from kiln in a grade of approximately 0-32 mm with an average dry bulk density of about 350 kg/m³. This material has been sieved at several different grades that can be adjusted in various conditions.

This clay is considered as very good aggregate for use in various applications with the advantages of lightweight, high permeability, high durability and excellent sound and thermal insulation properties. It is also an environmental friendly product where consists mainly of clay which occurs naturally, not susceptible to chemical attack, decay or frost and have long lifespan. Clay pellets are also widely used in water filtration systems because of its high surface area [7]. Clays have a relatively large surface area and surface forces are important in determining the composition of the clay pieces during sedimentation [8]. Clay produces pure purification process in addition to adding calcium mineral content in the water. It also helps the production of calcium ion which enhances the taste of water.
2.7 Stone mineral
Mineral rock is type of granite rock were used in diameter between 10 to 15 mm where this material is often used in the refining process with sand. Irregular shape is very suitable for the preparation of natural porosity for water drainage. It is from the type of granite taken from the quarry. These stones will liberate minerals and oxygen as well as coordinating pH in the water to reduce the alkalinity of water that can help balance the pH in the body and makes the water more palatable. Before the filtration process conducted, these stones must be cleaned first to remove all elements of impurities like dust and silt so as not to affect the results obtained.

3. Methods
This study consists of two methods used as a treatment of groundwater quality. Figure 2 was shown the steps of methods used which are dilution, filtration and lastly combination of dilution and filtration process.

3.1 Dilution Method
For dilution process, raw rainwater was used as experimental medium of groundwater wells in RECESS. Water samples from well-mixed with rainwater by using certain ratio of 1:2 (1 litre = groundwater samples and 2 litre = rainwater), 1:4 (1 litre = groundwater samples and 4 litre = rainwater) and 1:8 (1 litre = groundwater samples and 8 litre = rainwater). Before the rainwater mixed with raw groundwater samples, parameters that contained in rainwater were tested. The content of reduction in the parameters were measured on day 1, day 2 and day 3 to obtain the percentage of water parameters before and after experiments. Then, the percentage of parameters was compared to raw drinking water quality standards for groundwater outlined by the Ministry of Health [4].

![Figure 2. Flow of groundwater treatments.](image-url)
3.2 Filtration Method

Beside filtration methods, this study was used a ceramic filter set were consists of ceramic media and filter model (Activated carbon, GAC, Silica sand and LECA). Experiments was conducted directly and indirectly sampling were taken from wells. Then, samples were directly flows into filter set and tested for each parameter. For indirect, samples were pumped into tank and store being let to deposited for three days and flows into filter set later. The reduction reading of parameters were measured on day 1, day 2 and day 3 to obtain the percentage of water quality improvement. Percentage of experimental parameters was compared with raw drinking water quality standards for groundwater outlined by Ministry of Health [4].

3.3 Dilution and Filtration

It is the combination of dilution using rainwater and then filtration methods. Samples were taken from the ratio of effective rainwater from dilution method before. Then, the process was conducted by dilution and then filtration processes. The observation were measured on day 1, day 2, and day 3 to obtain the percentage of changes of values. The percentage values were compared to raw drinking water quality standards for groundwater outlined by the Ministry of Health [4] and National Standard For Drinking Water Quality [9].

4. Results and discussion

4.1 Dilution and filtration methods

After dilution and filtration methods was analyzed to determine the water quality reduction of turbidity, manganese, fluoride, chloride and sulfate, the results of average comparison of those parameters are as shown in Table 1.

| Table 1. Water quality measurement for dilution and filtration methods respectively. |
| --- |
| **pH** |
| Sample | Average (KKM) | Remarks |
| Control | 6.97 | 6.5 - 9.0 | √ |
| Dilution | 1:2 | 7.25 | |
| | 1:4 | 7.19 | |
| | 1:8 | 7.1 | |
| Ceramic filter | Direct | 7.56 | √ |
| | Indirect | 7.73 | |
| **Turbidity** |
| Sample | Average (KKM) | Remarks |
| Control | 3.23 | < 5 NTU (Class I) | √ |
| Dilution | 1:2 | 1.49 | |
| | 1:4 | 1.66 | |
| | 1:8 | 1.75 | |
| Ceramic filter | Direct | 1.28 | √ |
| | Indirect | 1.15 | |
Table 1. Water quality measurement for dilution and filtration methods respectively.

| Sample   | Average | (KKM)     | Remarks |
|----------|---------|-----------|---------|
| Control  | 6.8     |           |         |
| Dilution | 1:2     | 7.82      | 8-10 mg/L | ✓       |
|          | 1:4     | 7.87      |         |
|          | 1:8     | 7.89      |         |
| Ceramic filter | Direct | 8.09      |          | ✓       |
|          | Indirect | 8.88     |         |

| Sample   | Average | (KKM)     | Remarks |
|----------|---------|-----------|---------|
| Control  | 0.047   | ≤ 0.1 mg/L | ✓       |
| Dilution | 1:2     | 0.042     |         |
|          | 1:4     | 0.041     |         |
|          | 1:8     | 0.032     |         |
| Ceramic filter | Direct | 0.017     |          | ✓       |
|          | Indirect | 0.008    |         |

| Sample   | Average | (KKM)     | Remarks |
|----------|---------|-----------|---------|
| Control  | 9.07    |          |         |
| Dilution | 1:2     | 3.6      | 0.5-0.7 mg/L (Class II) | x |
|          | 1:4     | 2.25     |         |
|          | 1:8     | 1.16     |         |
| Ceramic filter | Direct | 0.29     |          | ✓       |
|          | Indirect | 0.15    |         |

| Sample   | Average | (KKM)     | Remarks |
|----------|---------|-----------|---------|
| Control  | 1450.47 |          |         |
| Dilution | 1:2     | 315.61    | 250 mg/L | x |
|          | 1:4     | 239.05    |         |
|          | 1:8     | 102.46    |         |
| Ceramic filter | Direct | 95.09     |          | ✓       |
|          | Indirect | 65.07    |         |

| Sample   | Average | (KKM)     | Remarks |
|----------|---------|-----------|---------|
| Control  | 1518.49 |          |         |
| Dilution | 1:2     | 1853.8    | 250 mg/L | x |
|          | 1:4     | 1585.3    |         |
|          | 1:8     | 1377      |         |
| Ceramic filter | Direct | 1094.5    |          | x       |
|          | Indirect | 649.22   |         |
Dilution and filtration treatments were purified the groundwater pH values. Based on these processes, the pH values of groundwater is to neutral after the treatment although, the raw groundwater is almost neutral and fresh. Then, this two processess can increase water to become more neutral until pH 7.65 as shown in Figure 3. This process flocculates the acidic water to be more neutral and natural by reaction of dilution and ceramic filtration actions.

The turbidity and manganese reduction have more effective reactions to treat groundwater quality by dilution and filtration methods until reaches the standard of groundwater and drinking water. Turbidity reduction of the groundwater can be seen from 3.23 NTU for control samples treatment to 1.63 NTU for dilution method and 1.22 NTU for filtration. Both treatments were able to reduce the turbidity although groundwater before treatment is still below the standards. After compared with the standard [4], it found that groundwater was used both treatments was better in class 1 with a minimum values. Groundwater samples before treatment showed a decrease of 1.60 and 2.01 for dilution and filtration methods respectively. These case cause by groundwater always clean from debris and any particular and also natural filtered by soil layer in the ground.

Both manganese concentrations before and after treatments was shows below the standards (<0.1 mg/l). Removal through dilution method is not so obvious that just as much as 0.038 mg/l from 0.047 mg/l. While the removal of a fairly significant effect for treatment of indirect filtration was found 0.013mg/l from 0.047 mg/l because the manganese from indirect samples was settled and helpful with sedimentation within 3 days process. The comparisons of resulted parameter was shown in Figure 3 to Figure 4.

Figure 5 shows that the treatment of rainwater dilution and ceramic filtration toward changes in the level of removal of fluoride in groundwater quite stimulating results. However, the removal of fluoride in groundwater (rain water dilution) can be seen from 9.07 mg/l to 1.16 mg/l. It can be concluded that although the fluoride decreased, but the value is still exceeding the standards. This is because the content of rainwater in these experiments was not enough to reduce the parameter fluoride in groundwater. Beside, sample filtration method shows that rate of fluoride content in groundwater is better values. Ceramic filtration treatment was shown quite a big difference because the data obtained is lower than the standard groundwater (0.5-0.7mg/l). This result indicates that samples of water that has gone through a ceramic filter medium, no further treatment is required to reduce the fluoride content in the water of the earth.

Dissolved oxygen values for groundwater through rainwater dilution do not exceed the standards of the Ministry of Health, as shown in Figure 5. This result indicates that the dilution rainwater treatment was not effective in increasing the concentration of dissolved oxygen in the water. While the ceramic filtration treatment method was more effective because it can increase the concentration of dissolved oxygen in the water which is 8.49mg/l.
However, sulphate removal for dilution is not successfully comply with the standards under the standard [4] which is (250 mg/l) which is 219.04 mg/l as shown in Figure 6. Vice versa for ceramic filtration treatment in which the removal of successful compliance under the standard [4] (250 mg/l). Dilution process showed no positive impact on the reduction of the chloride. Despite the decline of the filtering process, but the chloride is still not under the standards.

4.2 Combination of dilution and filtration method
The best result for the combination of dilution and filtration process also was analyzed to groundwater samples in order to obtain the level of groundwater quality in higher and safer. Treatment using rain water dilution (1:8) and filtration using ceramic filter medium were combined in this study. Table 2 clearly shows the experimental results that the water quality has improved and can be eliminated for all parameters and successfully meet the standards set by the merger method of dilution and filtration. The analysis also proved that the groundwater is safe to drink directly after the it compared with the Ministry of Health [4] and the Interim National Water Quality Standard [9]. Combination of this method is more effective because the ceramic filter has been cleaned more water which was diluted with rainwater where rainwater dilution already helped to improve water quality.

Table 2. Results of the analysis combination of dilution and filtration treatments.

| Parameters       | Samples                  | Standard from MOH and INWQS | Remarks          |
|------------------|--------------------------|------------------------------|------------------|
|                  | Controller                   | Dilution + Filtration       |                  |
| pH               | 6.97                      | 7.03                         | 6.5-9.0 (class II) | Pass standard   |
| Turbidity (NTU)  | 3.23                      | 0.95                         | < 5 NTU (class I) | Pass standard   |
| Dissolve oxygen (DO) (mg/l) | 6.80 | 8.05 | 8-10 mg/l       | Pass standard   |
| Manganese (mg/l) | 0.047                     | 0.001                        | < 0.1 mg/l       | Pass standard   |
| Fluoride (mg/l)  | 9.07                      | 0.18                         | 0.5-0.7 mg/l (class II) | Pass standard |
| Sulphate (mg/l)  | 1450.47                   | 53.13                        | 250 mg/l         | Pass standard   |
| Chloride (mg/l)  | 1518.49                   | 245.09                       | 250 mg/l         | Pass standard   |

Figure 5. Average comparison of parameters DO and fluoride.

Figure 6. Average comparison of parameters sulfate and chloride.
5. Conclusion
These treatments were demonstrated to identify the increasing of level of groundwater quality for entire parameters in this study. First method by using rainwater was known as dilution method shown that pH, manganese, turbidity and sulphate beyond the standard which was 57% achievement. Whereas, the second method for filtering using ceramic filter medium, the only chloride parameter that does not surpass the standard with 86%. However, third method for the combination of dilution and filtration treatments altogether was shown 100% effectively pass the standard during these treatments. Overall, this study was achieved through the three methods of treatments application. The effectiveness of treatment in this study has been shown to improve the quality of groundwater before the water supplied and distributed for use in RECESS, UTHM. This application method are also very economical, user friendly and easy to apply to all users.

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