Chloride and Sulphate Removal by Using N-GET System with Additional Filters

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Abstract. Groundwater is an alternative source of water for human consumption. Groundwater at Research Centre of Soft Soil (RECESS), Universiti Tun Hussein Onn Malaysia (UTHM) is one of the water sources that available to be used. Unfortunately, it has a high content of chloride and sulphate concentration in which originated from the mineral content in the ground. This research was conducted to identify the effectiveness of the Nature Groundwater Eco-Treatment (N-GET) system that has been designed at RECESS in removing sulphate and chloride concentration as well as pH and turbidity parameter. N-GET system is a natural treatment process without mixing any substances intended to improve the quality of groundwater can give benefits to users. N-GET system in this study uses two treatment tanks in the treatment of groundwater which are aeration tanks, sedimentation tanks, and three sets of filters which were activated carbon filter, Do-It-Yourself (DIY) filter, and ceramic filter. The chloride and sulphate parameters were tested with 12 numbers of the sample while pH and turbidity were tested with 63 numbers of the sample. Using combination with sedimentation and aeration, ceramic filtration were performing better by reducing the pH of the samples by 3.9% towards neutrality and removed 32.6% of sulphate, 13.1% turbidity, and 33.0% of chloride concentration from RECESS groundwater in comparison to an activated carbon filter, Do-It-Yourself (DIY) filter. Then, the effectiveness of each filter based on design flow and types of particle size in the filter. Therefore, the capability of each filter able to remove the specific contaminant as designed need.

1. Introduction
The contaminant within the water sources is also causing bad taste of drinking water, disturb healthy drinking diet, and affect daily cleaning activities. For that reason, the focus of water treatment is usually addressed strictly on the characteristic of water sources and the process of removal of a contaminant. However, the conventional measures that capable to treat a wide range of contaminants effectively from waters such as reverse osmosis, deionization, and distillation are extremely cost-consuming [1] and the disinfection process usually involved the usage of chemical.

Among the water resources, groundwater is more inexpensive to treat as compared to other sources of raw water such as rivers, lakes, and sea because it has less contaminant and good natural quality [2]. Since ancient times, groundwater has been acquired through the digging of wells and natural springs. It was consumed with limited knowledge of what is contained within the water resources. At present,
it is known that the substances that may present in the groundwater are parasites (such as Cryptosporidium) [3], bacteria, minerals including toxic metals (such as Lead, Copper), and anions (such as chloride and sulphate), and it is becoming more worsen with the presences of anthropogenic chemicals. In typical, the quality problem of groundwater is related to high hardness, high salinity, and elevated concentration of some minerals [2] depending on the location of extraction. The contaminants that existed within the extracted groundwater can be harmful, hence must be measured against the parameter of water quality standards and treated to be in safety compliance, others are removed to improve the smell, taste, and appearance of the water. Therefore, it could be said that groundwater treatment is a process to treat the raw groundwater by removing the harmful contaminant such as microbes, chemicals, and excess minerals to produces safe water for human consumption and industrial use. There are numerous studies were conducted in dealing with one or several specific contaminants. It is because the water treatment system includes several parts of the process and groundwater is normally treated with the same principle.

Groundwater is known to contain minerals, salts, chemicals, and microbes, which causing health and quality problems as contaminants. These problems are certain with the present dangerous microbes [3], excess harness, and salinity [2] in the groundwater. The process of boiling water can kill the pathogen in the water, however, might not remove another type of contaminants. As such, it is crucial to treat the groundwater for safe consumption in the present days more than ever since the industrial and urban activities already known to contribute to add variation and level of a contaminant in aquifer stream.

In regards, it is not safe to drink water just by observing it, whether it has a clear, watery appearance, or not; not even a natural spring. Regarding drinking purposes, all sources must be tested before determining the applicable treatment. However, the world's biggest threat to groundwater quality is not dangerous chemicals or industrial effluent but salinization. Chloride and sulphate are two groundwater quality parameters that contribute to the salinity of the water. Coastal intrusion, flood, and anthropogenic activities may be polluting groundwater sources and contributing to the elevated value of these two parameters.

Effective treatment is also a major issue in providing safe raw and drinking water to people especially in rural places of developing countries where there is limited development for water treatment technology. Safe water is essential for the continuity of human life and should be made available for everyone. Therefore simple but effective natural treatment is needed to solve this problem. Therefore, this study would intend to conduct a state-of-art review on the parameter of contaminants at RECESS, UTHM by literature and laboratory testing to determine the effectiveness of sedimentation, aeration, and filtration treatment for removal of chloride and sulphate that measured against a set of the standard by Ministry of Health Malaysia [4]. Sulphate and chloride are two contaminant parameters that should be removed to improve the water's smell, taste, and appearance for safe raw and drinking water. The previous study of groundwater at RECESS was conducted on small scale but an effective household scale is needed for sustainable usage.

As such, this study is conducted to reduce chloride and sulphate, the two contaminants parameter in which were detected in the groundwater extracted from the well at the RECESS area. In this connection, this study was conducted to explore the methodology, issues, and conduct process in avenues for non-chemical treatment which are simple sedimentation, aeration, and additional filter media which are locally available and inexpensive using natural processes for sulphate and chloride reduction in groundwater.

2. Methods

This study consists of a state-of-art review on previous parameter testing from RECESS well and a review on water treatment practices in the search for the process of removing chloride and sulphate. In the brief for the study workflow, five stages of fieldwork were conducted by using the natural treatment process of the N-GET system with focussed on sedimentation, aeration, and filtration as the process to treat the groundwater study [5]. Groundwater sample was taken and labelled at each stage of treatment. In particular to water quality improvement and removal of the chloride and sulphate from
groundwater, each treatment sample was laboratory tested to determine the percentage of removal from each stage and at the end of the treatment process.

At the first stage of the fieldwork, pumping activity was conducted to extract the groundwater to sedimentation tank for simple sedimentation process in which are the second stages of work. The third stage is the aeration process by using the water-to-air method with an air-compressor pump and air diffuser. The groundwater samples were taken before the sedimentation process and at six (6) hours interval of the process for forty-eight (48) hours. Similarly, samples were also taken at an interval of six (6) hours for forty-eight (48) hours in the aeration process. At the fourth stage is the filtration process, three settings for the water filtration process was prepared in which are the Do-It-Yourself (DIY) filter, ceramic filter, and activated carbon (AC) filter. Do-It-Yourself (DIY) filter setting of the groundwater filtration process was made using combinations of sand, gravel, cockle shells (*anadara granosa*), and sponge.

The process of filtration would be conducted simultaneously, monitored, and sampled after 24 hours of aeration process at six (6) hours intervals for twenty-four (24) hours. To determine the water quality compliance and improvement percentage of turbidity and pH, the samples collected at each scheduled interval were analyzed using, HACH 2100AN Turbidity meter and HACH Sension3 pH Meter respectively. In particular to the removal of chloride and sulphate parameter from RECESS groundwater by the natural treatment process, six (6) samples that comprised of control, forty-eight (48) hours sedimentation, forty-eight (48) hours aeration, DIY filtration at 48 hours aeration, ceramic filtration at 48 hours aeration and activated carbon filtration at 48 hours sample were analyzed using Metrohm Ion Chromatography (IC) machine to determine the value of parameters removed in the samples. Then the value of the parameter of each sample was compared and interpreted to determine the objectives of the study.

2.1 Sampling and Location

Raw samples of groundwater were retrieved by sampling from the storage tank during the pumping process from the groundwater or pumped well. The well is located at Research Centre for Soft Soil (RECESS) as shown in Figure 1 in Parit Raja, Batu Pahat. The RECESS is located in front of Jalan Kluang – Batu Pahat main road besides Universiti Tun Hussein Onn Malaysia, Johor.

![Figure 1. Groundwater well in RECESS, UTHM [5]](image)

N-GET system is a natural treatment a facility that already available at RECESS, UTHM was studied by Musa et al.,[5-6]. The N-GET system comprises of sedimentation tank, aeration tank, filtration tank, storage tank, and distribution tank. Previously, aeration treatment placed before the sedimentation treatment with specific treatment duration of twenty-four (24) hours; however, this
study was made different for the order treatment process and prolonged the treatment duration to forty-eight (48) hours according to the following treatment process plan as shown in Table 1 and Figure 2.

| Process order | Treatment                          | Duration (hr) | Notes                                                                 |
|---------------|------------------------------------|---------------|----------------------------------------------------------------------|
| Treatment 1   | Sedimentation                      | 48            |                                                                     |
| Treatment 2   | Aeration                           | 48            |                                                                     |
| Treatment 3   | Filtration                         | Filtered immediately after 24 hours | aeration treatment and repeated                                    |
|               | 1. DIY (Filter tank)              |               |                                                                      |
|               | 2. Ceramic -candle filter          | at 6 hours interval until 48 hours |                                                                     |
|               | 3. Activated carbon -candle filter| of aeration treatment.            |                                                                     |

![Figure 2. Revised N-GET system in RECESS, UTHM [5]](image)

2.2 Filters Media Characteristics

The material of the filter was tested by using X-ray Fluorescence (XRF) instrument. Using the XRF test, the characteristics material used at filter media can be measured except for gravel and activated carbon. The Table 2 show the characteristic of materials that used filter media.

Based on the test, it was known that the main composition in cockle shells was calcium oxide (CaO) and the main component of the sand used as silicon dioxide (SiO$_2$). On the other hand, as a complementary to the characteristics provided by the ceramic filter's manufacturer, the XRF testing was also conducted on the ceramic filter and it was known that the main composition of the ceramic was silicon dioxide (SiO$_2$).
Table 2. Media characteristics for filters

| Parameter | DIY Filter | Candle Filter |
|-----------|------------|---------------|
|            | Cockle shell | Sand | Ceramic |
| CaO       | 69.4        | -    | 3.68    |
| SiO₂      | 1.43        | 60.2 | 70.1    |
| MgO       | -           | -    | 4.35    |
| Al₂O₃     | 0.49        | 8.8  | 4.26    |
| Fe₂O₃     | 0.37        | 0.64 | 1.02    |
| C         | 1           | 1    | 1       |
| Na₂O      | 0.39        | -    | 0.26    |
| MnO       | -           | -    | -       |
| SO₃       | -           | -    | -       |
| SrO       | 0.22        | -    | -       |
| TiO₂      | -           | 0.81 | 0.29    |
| K₂O       | -           | 0.39 | 0.55    |
| ZrO₂      | -           | 2.03 | -       |

Figure 3. DIY filters in actual scale

Candle filter is a ready-made design by Kemflo as shown in Figure 4 and dimension as shown in Figure 5. The purpose of candle filter in this system was also to determine the percentage of contaminant parameters from groundwater at RECESS especially chloride and sulphate removal from ceramic filter and activated carbon cartridge. The porosity of activated carbon filter cartridge was 5 micron meter while the porosity for ceramic filter cartridge was 0.1 micron meter.
Figure 4. Ceramic and activated carbon filled in this casing - candle filter (Kemflo water filter)

Figure 5. Ceramic or activated carbon-candle filter fitting in the system

Kemflo water filter is the high flow housing for whole-house filtration. It is normally installed at the outlet of the rooftop water tower or tap water inlet. Therefore, this water filter was determined suitable and chosen as an additional part of this study on natural treatment systems.

3. Result
This main objective study was to investigate the improvement of water quality parameter of chloride and sulphate by using N-GET system. It was concluded that sedimentation and aeration treatments were able to reduce the chloride and sulphate from RECESS groundwater samples.
3.1 Chloride Analysis
Chlorides are widely distributed in nature as salts of sodium (NaCl), potassium (KCl), and calcium (CaCl2) [9]. According to the National Standard for Drinking Water Quality by the Ministry of Health Malaysia, the recommended raw water quality parameter of chloride is 250 mg/liter [4]. Table 3 shows the chloride result of the untreated control sample and treated groundwater sample. The Process 2 and Process 3 samples from the N-GET system were taken for chloride parameter testing using Ion Chromatography (IC) Machine. The result from the IC testing for untreated and treated RECESS groundwater samples using N-GET system sample [7].

In the notification, the result was showing the chloride removal from each stage of the treatment and cumulative result as the treatment progresses. As mention earlier, the preceding treatment of the filtration process was sedimentation and aeration treatment, and the separated activated carbon, ceramic and DIY filtration process was not preceding each other. The result showing the cumulative pattern line and removal value at each stage as shown in Figure 6. As the result showed, ceramic filtration was the best-functioned filter.

| Sample               | Mean conc. (mg/l) | Std Dev. of mean conc. (mg/l) | Cl. from preceding treatment removed (mg/l) | Preceding Cl. percentage removal (%) | Control sample conc. (mg/l) | Control percentage removal (%) |
|----------------------|-------------------|-------------------------------|--------------------------------------------|--------------------------------------|-----------------------------|--------------------------------|
| Control (untreated)  | 2506.41           | 95.49                         | 0                                          | 0                                    | 0                           | 0                              |
| 48 hrs - Sedimentation | 2335.28           | 49.55                         | 171.14                                     | 6.8                                  | 171.14                      | 6.8                            |
| 48 hrs - Aeration    | 2182.28           | 18.45                         | 153.2                                      | 6.6                                  | 324.33                      | 12.9                           |
| Activated carbon filter | 2149.13           | 9.12                          | 32.95                                      | 1.5                                  | 357.28                      | 14.3                           |
| DIY filter           | 2018.9            | 2.8                           | 163.18                                     | 7.5                                  | 487.51                      | 19.5                           |
| Ceramic filter       | 1678.2            | 8.68                          | 503.88                                     | 23.1                                 | 828.21                      | 33                             |

In comparison, the combination of sedimentation, aeration, and ceramic filtration treatment was able to remove 33.0 % of chloride concentration from RECESS groundwater, followed by the combination of sedimentation, aeration, and DIY filtration with 19.5 % chloride removal and 14.3 % of chloride removal by the combination of sedimentation, aeration, and activated carbon filtration. However, by standards, all the samples tested were not passed the standard value stated in National Standard for Drinking Water Quality [4,8] in which the concentration should be equal to or lower than 250 mg/l. However, it can be concluded that the filtration treatment used in the N-GET system was able to reduce the chloride concentration value of RECESS groundwater to a more desirable quality. Finally, it was also concluded that the most effective filtration treatment was ceramic filtration with 33.0 % of chloride concentration removal from RECESS groundwater.
3.2 Sulphate Analysis
Sulphate is a naturally occurring substance that contains sulphur and oxygen atoms and its concentrations in water are the results of natural weathering of minerals, atmospheric deposition, and anthropogenic discharges [9-10]. It is present in various mineral salts that are found in soil. Sulphate forms salts with a variety of elements including barium, calcium, magnesium, potassium, and sodium. According to the National Standard for Drinking Water Quality [4], the recommended raw water quality and drinking water quality standard for the parameter of sulphate is 250 mg/litre [4]. In another hand, according to National Water Quality Standard for Malaysia, the parameter of chloride for water supply 11A class is also 250 mg/l [8]. Aside from chloride, the Process 2 and process 3 samples from the N-GET system were also taken for parameter testing using Ion Chromatography (IC) Machine. The result was as shown in Table 4.

| Sample                  | Mean sulphate conc. (mg/l) | Std Dev. of mean conc. (mg/l) | Sulphate from preceding treatment removed (mg/l) | Preceding Sulphate Percentage removal (%) | Control sample conc. (mg/l) | Control sample percentage (%) |
|-------------------------|---------------------------|-------------------------------|-----------------------------------------------|------------------------------------------|-----------------------------|---------------------------------|
| Control (untreated)     | 200.41                    | 2.13                          | 0                                             | 0                                        | 0                           | 0                               |
| 48 hrs - Sedimentation  | 180.21                    | 1.49                          | 20.2                                          | 10.1                                     | 20.2                        | 10.1                            |
| 48 hrs - Aeration       | 156.06                    | 1.45                          | 24.15                                         | 13.4                                     | 44.35                       | 22.1                            |
| Activated carbon filter | 154.93                    | 0.26                          | 1.13                                          | 0.7                                      | 45.48                       | 22.7                            |
| DIY filter              | 138.94                    | 0.82                          | 17.12                                         | 11                                       | 61.47                       | 30.7                            |
| Ceramic filter          | 135.09                    | 1.4                           | 20.97                                         | 13.4                                     | 65.33                       | 32.6                            |
Figure 7. Sulphate removal for each stage of N-GET system

Based on the result in Table 4 and Figure 7, the mean sulphate concentration parameter detected in control samples was 200.413 mg/l. Therefore, by analysis, it was determined that chloride removed in sedimentation treatment of this study was 20.2 mg/l or 10.1% at the end of 48 hours sedimentation time. Similar to chloride, the result of sulphate concentration reading on the samples indicated that the sulphate was settled at the bottom of the tank due to downward gravity thus reducing the sulphate concentration for the aeration treatment. However, groundwater treatment must be design based on local groundwater quality needed to archives the simplest step and economical design.

4. Conclusion

In a conclusion, using a combination with sedimentation, ceramic filtration was the most effective in removing chloride and sulphate concentration from RECESS groundwater in compared to activated carbon, and DIY filter. The percentage of removal between this study were not so far different [11] but N-GET were capable to removed 33% of chloride and 32.6% of sulphate from high initial concentration of RECESS groundwater. In comparison to the standard, although the treatment filters in this study was unable to remove 100 percent the chloride parameter according to Drinking Water Quality [4], by scale projection on the percentage removal of the filters, it was suggested that 3 series of ceramic or DIY filter would be able to remove chloride and sulphate concentration of RECESS groundwater to comply with the quality standards of drinking water supply by the Ministry of Health (KKM). Overall, this study had indicated improvement towards the natural water treatment process by additional filter without using chemicals treatment.

5. References

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**Acknowledgments**

This research was conducted and supported by Universiti Sains Malaysia and Universiti Tun Hussein Onn Malaysia. Funding was provided by Higher Ministry Education (Exploratory Research Grant Scheme vot E039) and Research Centre for Soft Soil (RECESS) for good facilities.