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Nitrate and Iron Removal Using Triple Filter at Household Scale

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***Abstract*—Groundwater utilized for domestic purposes in Yogyakarta, Indonesia often contains nitrites, nitrates, and Iron compounds. Excessive levels of nitrate and Iron in water might pose a health risk. Therefore, it is necessary to take measures to remove them. This study aims to examine the efficacy of household-sized triple filters in reducing nitrite, nitrate, and Iron. The experiment was conducted by maintaining a constant flow of water for 70 minutes. Samples were collected at 10-minute intervals before and after filtration, respectively. Samples were then analyzed for nitrite, nitrate, and Total Iron. The Wilcoxon signed-rank test results demonstrate the significant efficacy of triple filtration in eliminating nitrate and Iron from water ($p < 0.05$). The results also show that nitrite removal by triple filtration is not significant. Nevertheless, the level of nitrite is fairly low and is within the limits set for drinking water quality. Hence, the implementation of household-scale triple filter is a promising approach that may be suggested to effectively reduce the levels of nitrate and Iron in groundwater, which is used as a source of clean water for domestic purposes and drinking.**

***Keywords*—Iron removal, nitrate removal, household filter**

I. INTRODUCTION

Nitrate contamination is a topic of major health and environmental concern, globally, in most of groundwater aquifers [1]. Widespread nitrate contamination in groundwater in the area of Yogyakarta is prevalent [2]; the concentration in wells in Sleman area, Daerah Istimewa Yogyakarta ranged from around 1 mg/L to 18 mg/L, and household filtration devices has been recommended to reduce the amount of it [3].

Factors which influenced drinking water qualities includes physical, chemical, and microbiological properties; nitrate content should not exceed 50 mg/L for clean water supply and less than 10 mg/L for drinking water as stated in the Ministry of Health Regulations (PERMENKES RI) [4]. Refill drinking water with filtration method from groundwater has also been tested with the concentrations of nitrate and nitrite compounds contained in five samples of refill drinking water which all met the requirements in the KEPMENKES RI No. 492/MENKES/PER/IV/2010 [5]. A combination of aeration and filtration process with silica sand, zeolite, and activated carbon can effectively reduce Iron and Manganese content from water [6]. Maximum efficiency was reached by zeolite quartz filter when added by $KMnO_4$ compared to when it was added by $Ca(ClO)_2$ [7]. Nanofiltration was used after pretreatment of activated carbon filters and for nitrate removal, yet the result was less than expected for nitrate removal, sulphate, and chloride [8]. There are advantages and disadvantages process performance and cost for treatment technologies such as reverse osmosis (RO), ion exchangers, biological denitrification, and electrodialysis for nitrate reduction, yet biological treatment is more efficient and cheaper [9]. Reverse Osmosis (RO) water did not meet the standard for nitrite (0.05 and 2.72 mg/L), and one of the samples did not meet the nitrate standard for drinking water (over 50 mg/L); concentrations in well water was safe for clean water, 0.05 to 0.09 mg/L for nitrite and 8.22 to 36.58 mg/L for nitrate [10]. Removal of Iron, Manganese, and ammonia from groundwater was achieved by single step filtration [11].

A hybrid system could be a promising technology for achieving simultaneous removal of NO_3^- and NH_4^+ ions from aqueous solution which uses HCl-treated zero-valent iron (Fe^0) combined with different adsorbents (sepiolite, filtralite, and GAC) as hybrid systems [12]. Ferric chloride exhibits greater removal efficiency than that of alum, with direct chemical reactions and adsorption mechanism [13]. Adsorption could be the most promising nitrate removal technique from water. Adsorption method absorb pollutant and therefore free from the limitations of biological denitrification which has problem with disposal of waste to the environment, and the limitation of Reverse Osmosis (RO) which have the risk of nitrate formation (potential incomplete denitrification) [14]. Rice husk biochar is a good sorbent for nitrate and ammonium, but not for phosphate [15]. Iron in groundwater can be removed almost all by using oxidizing filter [16].

The objective of this study is to evaluate the efficacy of filtration at a household level using triple filters in eliminating nitrites, nitrates, and Iron from groundwater that is used for everyday domestic purposes. The triple filter comprises a series of arrangement using two charcoal-sand filters and one polypropylene filter as one whole system of filtration.

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II. MATERIAL AND METHODS

A. The Filter Devices

The research of household filter in Minomartani, Sleman, Yogyakarta Special Region, Indonesia used triple filtration devices to reduce both nitrate and Iron content in groundwater as shown in Fig. 1 and Fig. 2. The first filter, F1 is installed after the pumping of raw groundwater, using charcoal-sand filter. Afterwards, water is routed to the water tank (WT), then filtered through F2 (another charcoal-sand filter) and F3 (polypropylene biofilter).

B. Sampling, Removal Efficiency, and Statistical Analysis

The experiment was carried out by running the filter continuously for 70 minutes. Sampling was performed at 0, 10, 20, 30, 40, 50, 60, and 70 minutes for raw water samples (before filtration) and water samples after filtration. The Wilcoxon signed-rank test statistical analysis was used to determine the differences between pairs of samples before and after filtration. The level of significance threshold used was 0.05. Removal efficiency of the filtration was calculated with universal formula for nitrite, nitrate, and Iron as one whole system of filtration (inlet of F1 and outlet of F3) in this research.

$$\text{Removal Efficiency} = \frac{(\text{Inlet concentration} - \text{Outlet concentration})}{\text{Inlet concentration}} \text{ x } 100\% \quad (1)$$

Ranges from 0 to 100%

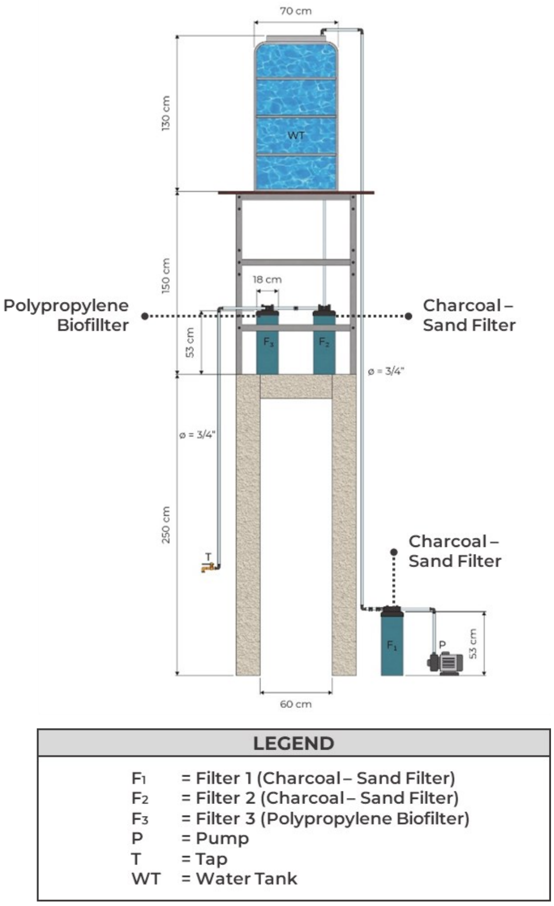

Fig. 1. Household Scale Triple Filter Arrangement

Fig. 2. The Filter Devices

C. Nitrite, Nitrate, Iron Laboratory Analysis

Nitrite (NO_2-N) from raw groundwater and the water after the filtration process was analyzed with HACH DR 2010 Spectrophotometer for concentration range of 0.002 mg/L to 0.300 mg/L NO_2-N with NitriVer 3 reagent powder pillows, 10 mL, while nitrate (NO_3-N) was analyzed in the laboratory using HACH DR 2010 Spectrophotometer for concentration range of 0.00 mg/L to 30.0 mg/L NO_3-N with NitraVer 5 Nitrate Reagent PP. The total Iron (Fe) content was tested using HACH DR 2010 Spectrophotometer for a range of 0.02 mg/L to 3.00 mg/L with Total Iron testing reagent FerroVer Iron reagent.

The upper limit for nitrite, nitrate, and Iron content in drinking water for everyday use is defined by the Indonesian regulations [17, 18] that is maximum of 1 mg/L for nitrite (NO_2-N), 10 mg/L for nitrate (NO_3-N), and 1 mg/L for Total Iron content.

III. RESULTS AND DISCUSSON

The results of water quality prior to and after filtration are shown in Fig. 3, Fig. 4 and Fig. 5. It can be seen that the reduction of nitrite concentration is best at 40 minutes after filtration, while the reduction of nitrate is best at 70 minutes after filtration, and for Fe is best at 60 minutes after filtration:

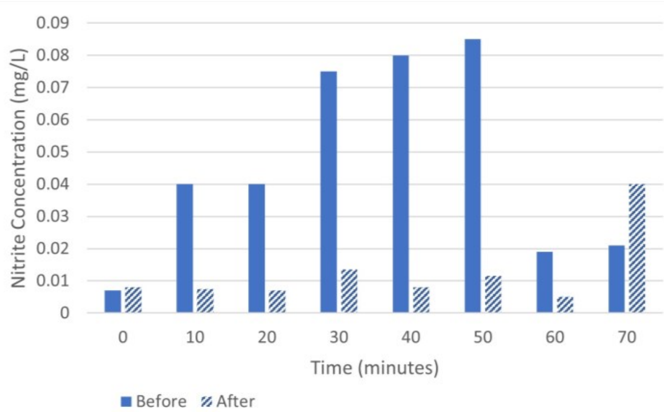

Fig 3. Nitrite Concentration Before and After Filtration

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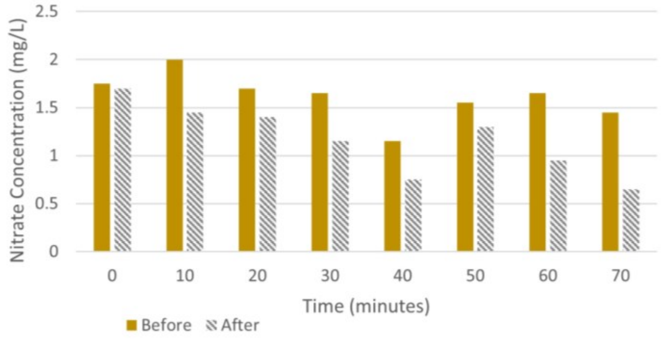

Fig. 4. Nitrate Concentration Before and After Filtration

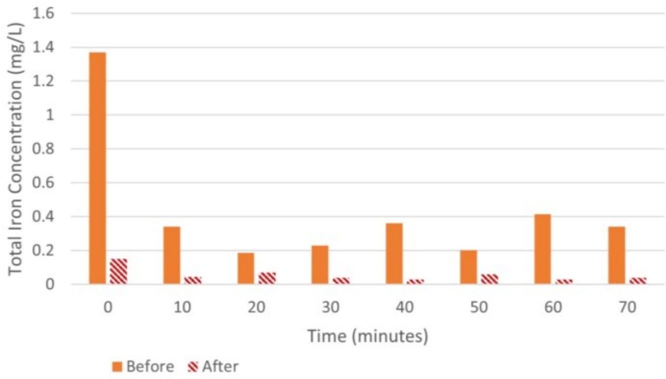

Fig. 5. Iron (Fe) Concentration Before and After Filtration

The removal efficiencies of nitrite (NO_2-N), nitrate (NO_3-N), and Iron (Fe) using the triple-household-filter are shown in Table 1.

Table 1. Nitrite, Nitrate, and Iron Removal Efficiency

	Removal Efficiency		
Time (minutes)	Nitrite (%)	Nitrate (%)	Fe (%)
0	0[a]	2.9	89
10	81.3	27.5	86.8
20	82.5	17.6	62.6
30	82	30.3	82.6
40	90	34.8	91.7
50	86.5	16.1	70
60	73.7	42.4	92.8
70	0[a]	55.2	88.2

[a.] Removal efficiencies are written 0 (zero) for nitrite at 0 minutes and at 70 minutes after filtration since there were increments at the outlet

In this research, the removal efficiency of Iron is highest at 60 minutes after filtration (92.8%), while nitrite is highest at 40 minutes after filtration (90%), and nitrate at 70 minutes after filtration (55,2%) with an ascending trend of removal efficiency for nitrate. The alternative solutions for better adsorption of nitrate in groundwater are using wood pellets as biofilter filling material [19], agricultural byproducts, reed, and rice stalks which can be used as an alternative carbon source for biological denitrification process [20]. Modified pumice can also increase the removal efficiency and nitrate uptake compared to natural pumice [21].

Table 2. Statistical Result Using the Related Wilcoxon Signed Test

	Nitrite	Nitrate	Fe
Total N	16	16	16
Asymptotic Sig (2-sided test)	0.312	0.014	<0.001
Significance level	0.05	0.05	0.05

The statistical analysis is shown in Table 2. Using the related-samples Wilcoxon signed rank test at $p < 0.05$, it can be seen that the nitrite content (NO_2-N) has no significance in difference for prior to and after filtration process, yet the nitrite content is still in a safe concentration in this research of below 1 mg/L; while the nitrate (NO_3-N) and Iron (Fe) content significantly differ for before filtration compared to after filtration, using the triple household filter. Therefore, the triple filter at household scale can be recommended to be implemented to remove nitrate and Iron content from water.

IV. CONCLUSIONS

The triple filtration method has been significantly reducing nitrate and Iron content from the raw groundwater in this research. Adsorption method using triple household filter of double biochar-sand filter and a polypropylene biofilter is therefore a promising method that can be recommended for nitrate and Iron removal from groundwater used as clean and drinking water supply.

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