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EFFECTIVENESS IN COMBINING MORINGA OLEIFERA PHYTOCOAGULANT AND NATURAL FILTER MEDIA TO IMPROVE GROUND WATER QUALITY

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ABSTRACT

This paper presents the performance of combination system in processing coagulation using Moringa oleifera seeds and filtration of a one and two natural media to improve ground water quality. The natural media used was rice husk charcoal and sand. The ground water was characterized in third (III) to fourth IV class water classifications. Adding 100 mg/L Moringa oleifera seeds with two natural media filtration of rice husk charcoal followed by sand (K_2T_2) provably resulted on the best removal all parameters. This combination process provided turbidity removal efficiency of 84%, BOD removal of 89.02%, Manganese removal of 100%, electrical conductivity removal of 89.77%, and total coliform removal of 99.02%. However, this combination increased pH to 7.42 or 24.12% and decreased DO by 11.4 mg/L or 28.75%. Despite these, pH and DO met first (I) class water classification. Regrettably, decrease in DO caused by adding Moringa oleifera seed was due to technology limitation. As future potential, this research requires technology combinations which are able to maintain DO content in ground water.

Keywords: *Moringa oleifera*, coagulant, ground water, filtration, rice husk charcoal.

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1. INTRODUCTION

Water is a basic need for economic, social and environmental lives integration as well as an inevitable instrument for sustainable development. Nearly 75% of the body weight is made up of water. In developing countries, the water resource availability is increasingly limited. At present, 75% of world population lives in developing countries. Hence, approximately 1.2 million people are lack of drinking water and every year more than 6 million children die of diarrhea [1, 2]. It proves that the importance of safe drinking water for health still becomes challenge.

Groundwater is one of drinking water sources. Groundwater is taken by drilling holes in the ground and this water is usually saturated with rock chemicals at different depths [2, 3]. Chemical substances contained in the groundwater are likely from natural or anthropogenic sources such as nitrates from fertilizers and bacteriological contamination from sewage. This contamination tends to be worse in the sandy areas and shallow water tables. Nowadays, the majority of groundwater is polluted by both domestic and industrial wastewater. Water pollution contributes negatively to environment and human health [4].

Currently, there is no adequate low-cost technology that can be used to remove contaminants usually found in groundwater. Commonly, water treatment for drinking water uses metal salts coagulation followed by flocculation particle aggregation and separation through sedimentation and filtration [5]. Aluminium and iron salts are mostly used as coagulant reagents. Using these coagulants derives to several disadvantages including the excess sludge production during the process [6]. The chemical changes in water are caused by the reaction between OH and alkalinity in water; besides, it requires high costs due to the limited material as it is an imported one [7]. Using chemical coagulants can cause various diseases such as Alzheimer which is triggered by high aluminum content in residuals of treated water [1]. Therefore, low cost technology in processing groundwater for safe drinking water especially in the developing countries depends on the use of environmentally safe coagulants and filtration media.

Natural coagulant or better known as phyto-coagulant is an environmentally safe coagulant. The advantage of using *Moringa oleifera* as coagulant is due to its environmentally friendly (not dangerous), low cost, less volume of sludge production, and no pH effect on water [1, 8]. In addition, *Moringa oleifera* is easily found in Indonesia, as it is one of the native vegetations. Using *Moringa oleifera* in physical-chemical drinking water treatment can reduce total hardness, bacteria, and fungi [9]. 100 mg/L *Moringa oleifera* is able to reduce 95% of water turbidity and 77% of coliform [10]. Another reason, using *Moringa oleifera* in pre-treatment of slow sand filters is able to reduce *E. coli* by 99.4% [11]. 100 mg/L *Moringa oleifera* is able to reduce 97.9% water turbidity in the wastewater of textile industry compared to PAC (by 89.6%). The same concentration allowed reducing conductivity by 10.8%; removing metal Mn, Cd, and Cr until almost undetectable; and decreasing *E. coli* by 80% [12].

Combining coagulation and filtration provides excellent removal rates [8, 13]. By combining these technologies, it reduces color, natural organic matter (NOM), microorganism, clay, etc [14]. Furthermore, it is able to use up almost 30% coagulant compared to conventional process (flocculation-coagulation and high rate sedimentation) [15]. In filtration process, using natural media is cost effective. Natural materials used as filter are sand, gravel, charcoal, coconut fiber, and burnt rice husks [8]. The success in using *Moringa oleifera* has been widely studied as a primary treatment for water treatment including wastewater. Likewise, the success in using natural media (single and combination) in the filtration unit of wastewater treatment has broadly been studied as well. This study aims to combine the two types of processing units to process various contaminants in groundwater to be safe drinking water.

2. MATERIALS & EXPERIMENTAL PROCEDURES

2.1. Sample collection and characterization

Groundwater samples were taken from a well in Surabaya. All analyses methods referred to APHA standards (APHA, 1998). Turbidity measurement was conducted using portable turbidity meter (HANNA Instrument). pH was measured using pH meter (Myron L ARH1). Electrical conductivity was measured using portable conductometer (Myron L ARH1). Dissolved Oxygen (DO) was measured using DO meter, while Biological Oxygen Demand (BOD) was analyzed on the fifth day after sample was incubated in the temperature of 20ºC ± 1ºC and found its oxygen need. Heavy metals were analyzed using Atomic Adsorption Spectrophotometer (Perkin Elmer). The existence of coliform bacteria was analyzed using multiple-tube fermentation and stated in the Most Probably Number (MPN).

2.2. Oil extraction and stock solution preparation of *Moringa oleifera*

Dried seed kernel was finely ground using mortar and pestle becoming powder sized 600 µm. It was followed by removing oil by mixing the seed powder with ethanol and stirring using magnetic stirrer for 45 minutes. Next, residuals were separated from supernatant by centrifuging at 4000 rpm for 10 minute to get the residual solid and the supernatant. The residual solid was then dried at room temperature for 24 h. Dried *Moringa oleifera* seed kernel powder was added with tap water to get 75 mg/L, 100 mg/L, and 125 mg/L of solutions. Dried seed kernel of Moringa oleifera was dissolved using magnetic stirrer for 15 minutes for perfect solution. This solution was filtered using 47 mm glass microfiber filter to separate the residual from solution [9, 10, 16, 17].

2.3. Producing an activated rice husk charcoal

Rice husk (RH) was firstly cleaned from dirt and dried on the temperature of 105ºC for 2 hours. Dried RH was then finely ground to particle sized. Chemical activation was performed in the RH powder using 0.16 NaOH. Activated RH was filtered and dried on the temperature of 120ºC for 4 hours. Carbonization of dried activated RH was done on the temperature of 650ºC for 2 hours [18].

2.4. Rice husk charcoal filter

Activated rice husk charcoal was sieved to get 1.54 mm size. This natural media was added into 700 mm depth on transparent pipe with 20 mm diameter and 850 mm length (T_1). To differentiate it with others, the unit was filled with natural media, sand, in the 350 depth of activated husk charcoal (T_2). Importantly, filter tube must be firstly cleaned.

2.5. Pretreatment groundwater by coagulation process

Coagulation process was done using conventional jar-test apparatus consisting of 6 labelled beakers filled with 500 mL of water samples. Stock solution concentration was added into each breaker and operated from the initial speed of 150 rpm for 4 minutes. Speed was lowered into 40 rpm for 20 minutes. Stirring process was stopped, then sedimented for ±1 hour. Supernatant from settled groundwater was filtered using filter paper Whatman No.1 to determine the optimum dose of coagulant. As result, the optimum dose was 100 mg/L.

2.6. Experimental procedure

Before conducting test, running test performance rice husk charcoal filter was firstly carried out. Running test rice husk charcoal filter was done at the determined optimum dose on the coagulation process. Running test was conducted using optimum dose at the coagulation process ranging from the lowest limit as 75 mg/L (K_1) to the highest limit as 125 mg/L (K_3). Supernatant from flocculation-coagulation tank was sedimented for ±1 hour. Subsequently, supernatant was flown with constant debit of 5 l/d into rice husk charcoal single media filter (T_1) and dual media filter of combined rice husk charcoal and sand (T_2) using peristaltic pump [17]. Samples were taken to be analyzed for its turbidity, pH, electrical conductivity, heavy metal (Mn, Cd, and Cr), DO, BOD and total coliform using APHA standard. These procedures are showed in Figure 1.

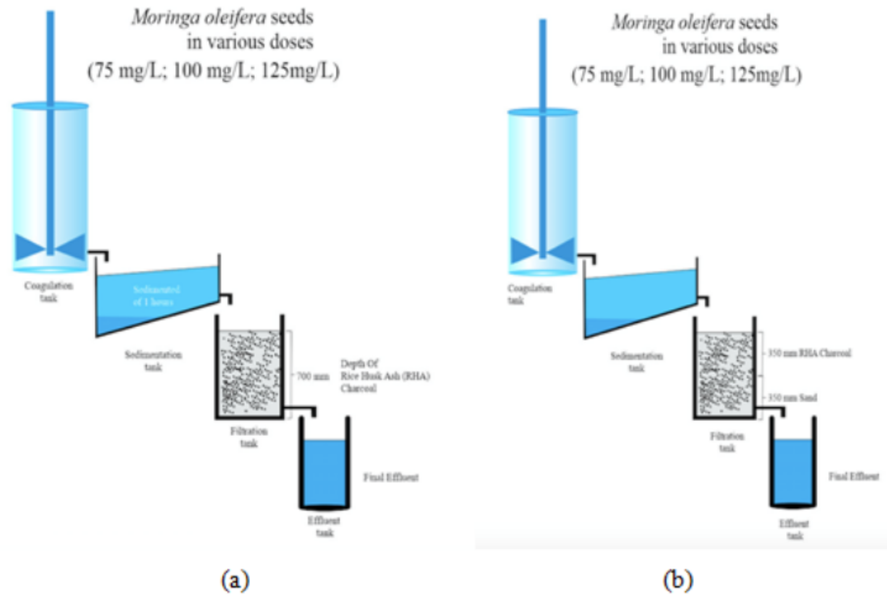

Figure 1 Schematic diagram of laboratory coagulation combine with filtration (a) single media filter (rice husk ash charcoal); (b) dual media filter (rice husk ash charcoal and sand)

2.7. Statistical analysis

Data were analyzed using one-way analysis of variance (ANOVA) to determine the difference of groups in groundwater treatment. To find the significance of independent variables and interaction between independent variables and repeated factors, Duncan's multiple range tests was performed. The significance was showed by $P < 0.05$.

3. RESULT AND DISCUSSION

3.1. Chemical-physical characteristics of the initial groundwater

Table 1 shows that in the initial groundwater characteristics, the only parameter meeting standard set (more than class I) was Dissolved Oxygen (DO). DO level in water was used as an indication of the potential and occurrence of pollution. Thus, it created a key test in water pollution control activities and wastewater treatment control. The DO on groundwater was 8.6 mg/L (> 6 mg/L) meaning that it met the standard set by WHO (>8 mg/L), as lower levels indicated the existence of microbial contamination or corrosion [19].

Table 1 Comparison of groundwater characteristics with water classifications and quality standards

Parameter	Units	Groundwaterquality (before treatment)	Water classifications and quality standards*			
			Grade I	Grade II	Grade III	Grade IV
Turbidity	mg/L	122.69	50	50	400	400
pH		5.6	6-9	6-9	6-9	5-9
Conductivity	µm	1,235.6	-	-	-	-
Mn	mg/L	1.23	1	-	-	-
Cd	mg/L	-	0.01	0.01	0.01	0.01
Cr	mg/L	-	0.05	0.05	0.05	0.01
DO	mg/L	8.6	6	4	3	0
BOD	mg/L	8.2	2	3	6	12
Total coliform	MPN/100 mL	1,325	1,000	5,000	10,000	10,000

*Guidelines of water quality and its classification based on Indonesian Government Regulation No.82/2001 about water quality treatment and water pollution control (Source : the state secretary of the Republic of Indonesia, Secretary of the Republic of Indonesia 2001).

Similar to DO, the total coliform (TC) at the initial characteristic was 1,325 MPN/100 mL. This was slightly higher than the water classification requirement for class I (1,000 MPN/100 mL). It caused groundwater classified into class II water use. Although passable, the coliform content in groundwater required attention because according to WHO the most dangerous thing related to drinking water is sewage contamination human and animal excreta [19]. The high coliform content in groundwater was caused by poor sanitation, while the presence of microbes in the wastewater came from biological treatment of wastewater treatment [12]. Similar to TC, Manganese (Mn) in the initial groundwater characteristics was 1.23 mg/L which was slightly higher than the water classification for class I (1 mg/L). However, it needs to be carefully observed as Mn is one of groundwater contaminants. High Mn level can cause aesthetic and health problems. Adding with dissolved iron, Mn (II) can flocculate and form sediments in distribution lines. If the flow in the distribution lines increases, the sediment can become re-suspended and result in black or brown water. In which possibly occurred, if the Mn concentration in water was as low as 0.2 mg/L [20].

For pH parameters, biochemical oxygen demand (BOD), turbidity indicated the classification of groundwater to class III or IV. pH showed the level of acidity and alkaline of body of water. However, it assisted to simply determine the quality of water characteristics. A pH of < 4 has an acidic taste while high pH (pH > 8.5) has an alkaline taste. The pH cannot be used for various purposes without prior processing [21]. In the initial characteristics analysis, the pH was 5.6 or in the range of 5-9 (class IV water classification). Similar to pH, BOD was of 8.2 mgO_2/L (> 6 mgO_2/L) and classified groundwater into class IV.

BOD is a method to determine the amount of dissolved oxygen needed by aerobic organisms in a body of water to disintegrate organic material in a water sample at certain temperature over specific period of times [22]. An indication of pollution on groundwater is BOD increase. Typical BOD is 150-300 mgO_2/L for raw sewage, 200-600 mgO_2/L for storm water at the residential area, and 20-30 mgO_2/L for treated sewage. Unpolluted natural water is characterized by BOD < 5 mgO_2/L or a BOD level between 1 and 2 mgO_2/L indicates clean water; 3.0 to 5.0 mgO_2/L indicates moderately clean water; and BOD > 5 mgO_2/L

indicates nearly polluted source. BOD levels of ≥ 100 mgO_2/L means that the water supply is considered as very polluted with organic waste [23]. The results showed a BOD content of 8.2 mgO_2/L (> 5 mgO_2/L) meaning that it was nearly polluted source which was probably caused by inapt garbage disposal, river defecation, Industrial waste disposal method (directly discharging effluents unto land, stream and sanitation sewers) [19].

The turbidity in the initial characteristics was 122.69 mg/L meaning that it considered as class III and IV water classification standards of 400 mg/L. Turbidity is the amount of granules in undated in the water which is caused by clay, mud sediment, organic and non-organic materials consisting of fine granules, soluble organic color mix, plankton and microorganism [24]. High turbidity is probably due to the rain season, especially during heavy rain and a storm, as it becomes very high due to rapid soil surface soil erosion [25].

Two parameters having higher values than the standard set were Electrical conductivity (EC). Electric conductivity is the capacity of water transmitting electricity. EC becomes important parameter to assess the total concentration of soluble salts in the body of water, as it was used to measure the hazards crop since it reflected the TDS in groundwater [25]. The EC in the initial characteristics of ground water was far above standard set (or 1,235.6 µm). Although there is no standard set for EC, high level of conductivity in water is not permitted in drinking water [25]. The high EC was probably caused by intrusion seawater and tidal effects [21, 26]. Although the majority of the initial groundwater remained in class III and IV of the water classification, but as a source of drinking water, it needs to be properly treated to maintain human health and minimize problems occurred for humans.

3.2. Ground water characteristics after treatment

Combining coagulation and filtration, the groundwater effluent significantly changed. As supported by Suhartini et al. (2013), Hashim et al. (2018) and Wilson and Andrews (2011) adding *Moringa oleifera* seed as a pre-treatment was very effective to reduce color and turbidity [8, 27, 28]. Besides, the combined treatment was seemingly more effective than either treatment individually [28]. In this process, *Moringa oleifera* seed acted as a coagulant that produced cationic proteins which were distributed to the solution and interact with negative charged particles causing dispersed turbidity; thus, it improved the removal efficiency in wastewater [29].

Table 2 shows that the turbidity removal efficiency increased by adding 75 mg/L and 100 mg/L *Moringa oleifera* seed and combining with single media (rice husk charcoal) filtration namely K_1T_1 and K_2T_1 as well as combined media (rice husk charcoal and sand) namely K_1T_2 and K_2T_2. In single media filtration (rice husk charcoal), 75 mg/L of K_1T_1 had efficiency of 57.62% or 52 mg/L, while 100 mg/L of K_2T_1 had efficiency of 67.4% or 40 mg/L. Likewise on the combined media filtration (rice husk charcoal and sand), 75 mg/L of K_1T_2 had removal efficiency of 75.55% or 30 mg/L and 100 mg/L of K_2T_2 had removal efficiency of 84.62% or 8 mg/L. The best combination for turbidity removal was by adding 100 mg/L *Moringa oleifera* seed with filtration using rice husk charcoal and sand (K_2T_2). By adding more dose (125 mg/L) of *Moringa oleifera* seed on single media filtration (rice husk charcoal) (K_3T_1) and combined media (rice husk charcoal-sand) (K_3T_2), the turbidity removal efficiency was 51.91% or increase by 59 mg/L and 76.36% or the turbidity increased to 29 mg/L. This decreased by 15.49% compared to the addition of 100 mg/L *Moringa oleifera* seed on the single media filtration and 8.25% on combined media filtration. One-way ANOVA analysis shows that variations in doses of *Moringa oleifera* seed and natural filter media significantly affected turbidity ($p > 0.05$).

All combination treatments produced effluent categorized to class I water classification. This study disagreed to previous study which mentioned that increasing dose of *Moringa oleifera* seed provided better performance [8]. The decrease in the efficiency by adding the *Moringa oleifera* seed doses was caused by the exceeded optimum dose of the coagulant. Hence, it caused turbidity to increase, as all colloids were denaturalized and precipitated. If the optimum coagulant condition was exceeded, excessive coagulants would not interact with the opposite content of colloidal particles [12]. In this study, combining two filtration media (rice husk charcoal and sand) in turbidity removal showed better results than previous study which used 150 mg/L of *Moringa oleifera* seed with two steps clarifier (coconut fiber-sand) to process tapioca starch wastewater [8].

The degree of acidity (pH) is one of important factors in coagulation process. Prior studies found that the optimum pH obtained by using *Moringa oleifera* as a coagulant was around 6 to 8. When the pH exceeded this range, it caused floc formation failure, so it produced poor water quality. At optimum pH, amino acids ionized and produced carboxylate ions and protons; proton charge attracted electrons to create neutral groups and then produce floc. The optimum pH was different on each coagulant type [12]. In T_1 and T_2 treatment, adding *Moringa oleifera* seed resulted on a slightly less effect to increase pH.

In T_1 and T_2 treatment, the highest dose of *Moringa oleifera* seed combination had the highest pH by adding 125 mg/L *Moringa oleifera* seed and filtration of single media rice husk charcoal (K_3T_1) by adding 125 mg/L *Moringa oleifera* seed and combined filtration of rice rice husk charcoal and sand (K_3T_2). Likewise, adding the least dose in all filtration conditions (K_1T_1 and K_1T_2) resulted on the least pH. The average pH increase on various doses of *Moringa oleifera* seed in single media filtration was by 12%; while in combined media filtration was by 25%. However, this combination provided a pH effluent met standard set by the government for class I water classification (pH 6-9). Hamza et al. (2016)found that the protein component in *Moringa oleifera* seed released hydroxyl groups (OH^-) in which when contacted with water, it caused pH increase[30]. This was supported by statistical analysis where there were significant differences in adding difference doses of *Moringa oleifera* seed at single media and combined media filtration conditions ($p < 0.05$). This study was similar to previous studies which found that increasing *Moringa oleifera* seed doses resulted on pH increase [31,32].

Mineral solubility greatly varies in different geographical regions causing to diverse electrical conductivity. The different EC in groundwater is strongly influenced by the depth of tube well and the distance to the sea [26]. The EC decrease is strongly influenced by the EC at the initial condition. At low EC, there is high EC decrease and it was in contrary on the high EC. The EC on the initial characteristics of groundwater was 1235.6 µm. This was within the EC range standard set by WHO for drinking water (0 - 3,000 µm) [33]. Adding *Moringa oleifera* seed resulted in EC decrease for the combination treatment of K_1T_1, K_2T_1, K_1T_2, and K_2T_2. In K_1T_1 the efficiency decreased as 76.22% or 293.8 µm; K_2T_1 the efficiency increased as 82.45% or 216.9 µm; K_1T_2 the efficiency decreased as 86.99% or 160.7 µm; and K_1T_2 the efficiency increased as 89.77% or 126.4 µm. Furthermore, different conditions occurred by adding 125 mg/L *Moringa oleifera* seed with single (T_1) and combined media (T_2) filtration, namely in K_3T_1 and K_3T_2. The result showed EC increase which led to the efficiency decreased as 81.77% or 225.2 µm on K_3T_1 and 88.63% or 140.5 µm on K_3T_2. One-way ANOVA analysis showed that the dose variations of *Moringa oleifera* seed significantly affected EC ($p> 0.05$). However, the natural filter media did not significantly affect EC on groundwater ($p> 0.05$). The EC removal in all treatment variations was caused by the dispersion of minerals ions and organic matter forms a flock which precipitated and separated from the solution [12]. The increase in conductivity by adding 125 mg/L *Moringa oleifera* seed was due to exceeding of optimum dose of *Moringa oleifera* seed. Excessively adding Moringa oleifera seed dose caused unbound ions that exist in the water. Moreover, by the reaction of water and acid or alkaline metals or the dissociation of inorganic compounds, itcausedthe water capable to conduct very large electric current [33].

Table 2 shows that combining *Moringa oleifera* seed with natural media was able to remove Manganese content up to 100% or from 1.23 mg/L to undetectable in groundwater. This study was similar to previous study which found that adding *Moringa oleifera* seed in the domestic wastewater treatment removed Mn content by 70% [34]. One-way ANOVA analysis showed the dose variations of *Moringa oleifera* seed which significantly affected on Mn ($p > 0.05$). However, the natural filter media had no significant effect on the Mn removal in the groundwater ($p > 0.05$).

Manganese (Mn) is possibly found in natural water in the most concentrated and soluble form as Mn (II) and in the oxidized and insoluble form as MnO_2. When manganese ions are not oxidized during the water treatment process and exist in the public potable water distribution system, they are gradually oxidized, form insoluble MnO_2 and generate various water qualities, such as water color, metallic taste, odor, turbidity, corrosively, hardness, and discoloration of laundry and plumbing fixture [35]. To prevent the possible health hazard as a result of chronic exposure to manganese, WHO set a standard of 0.4 mg/L of manganese content for drinking water as a health-based guideline [20]. A coated sand of iron oxide containing sufficient manganese is the second best option for a reasonably high adsorption capacity and a substitute by-product of the water treatment plants [20].

Manganese removal process was caused by heavy metals bonding in the floc formed by coagulants. Adding coagulants, removal materials, basically transpired through the changes in the material properties which can be precipitated from not easily deposited (coagulation-flocculation); either with or without oxidation-reduction reactions; and for the result of oxidation reaction. Heavy metal content removal was also likely due to Moringa's amphoteric proteins bonded to the oppositely charged metal-binding compounds causing metal to precipitate. The alkaline conditions produced by adding *Moringa oleifera* also allowed positive charged metal to precipitate as insoluble metal hydroxides due to the release of OH^- groups of *Moringa oleifera* [12]. This was supported by previous study which found that without adding any coagulant, heavy metal precipitation was carried out using lime solutions to form hydroxide. Precipitated metal became more stable when pH water was > 10.5. Nevertheless, it was certainly difficult in processing groundwater because it required additional processes to produce a higher pH [36].

The initial DO content in ground water was 16 mg/L. This study indicated that adding *Moringa oleifera* seed as a coagulant decreased the content of dissolved oxygen (DO) at all doses (75 mg/ L (K_1), 100 mg/L (K_2) and 125 mg/L (K_3)) and filtration media (T_1, and T_2). In K_1T_1, DO decreased by 4.38% or 15.3 mg/L; K_2T_1 was decreased by 15% or 13.6 mg/L; and K_3T_1 was decreased by 23.75% or 12.2 mg/L. In K_1T_2 DO decreased by 25.63% or 11.9 mg/L; K_2T_2 was decreased by 28.75% or 11.4 mg/L; and K_3T_2 was decreased by 30.00% or 11.2 mg/L. One-way ANOVA analysis showed that the dose variations of *Moringa oleifera* seed and natural filter media did not significantly affect DO in groundwater ($p > 0.05$). Although DO decreased, but it was considered above the effluent of standard set for class I water classification. Decreased oxygen content is caused by an increase in the need for oxygen to oxidize *Moringa oleifera* which is an organic material [12]. This study was in line with previous study which found that *Moringa oleifera* seed had important role in removing DO [4].

The initial BOD analysis on groundwater of 8.2 mg/L (> 5 mg/L) indicated that the groundwater was located near the pollution source. This indicated that there was potential for organic matter pollution. Adding *Moringa oleifera* seed possibly decreased BOD in various treatments K_1T_1, K_2T_2, K_1T_2, and K_2T_2. In K_1T_1, the removal efficiency was decreased by 25.61% or 6.1 mg/L; and in K_2T_1 the removal efficiency was increased by 76.83% or 1.9 mg/L. However, 125 mg/L of *Moringa oleifera* seed dose (K_3) with single media filtration (T_1) or K_3T_1 caused the removal efficiency decreasing to 71.95% with or 2.3 mg/L. Similarly, by adding 75 mg/L (K_1) and 100 mg/L (K_2) of *Moringa oleifera* seed with combined media (T_2) resulted on BOD removal efficiency of 73.17% or 2.2 mg/L (K_1T_2), and it increased to 89.02% or 0.9 mg/L (K_2T_2). Similarly, adding 125 mg/L of *Moringa oleifera* seed (K_3) with combined media filtration (T_2) also decreased the BOD removal efficiency of 76.83% or 1.9 mg/L (K_3T_2). One-way ANOVA analysis showed that dose variations of *Moringa oleifera* seed did not significantly affect BOD on ground water ($p > 0.05$). Yet, the natural sequence of media filters (rice husk charcoal and sand) in the filtration unit significantly affected BOD values ($p < 0.05$).

The difference was in the combination of single media filtration (K_2T_1) resulting in BOD close to class II water classification. Whereas the combination of combined media filtration (rice husk charcoal and sand) (K_2T_2) produced BOD close to class I water classification. However, this condition occurred at optimum dose. When the *Moringa oleifera* seed was exceeded, organic matter in the groundwater increased. The BOD removal by *Moringa oleifera* seed proved that *Moringa oleifera* seed has a suitable as a coagulant in binding organic particles in the groundwater. Nevertheless, the filtration unit had important roles in removing the organic content in the water as well [37]. In addition, using natural media sequences increased the BOD removal [38], supported by previous study which found that different organic material combinations in multi soil layers (soil-charcoal powder-zeolite) were able to exclude BOD up to 99% [39]. This study proved that a combination of coagulation and combined media filtration had removal efficient on organic matter.

Diseases in the tropics are approximately 80% caused by poor water conditions and characterized by the coliform bacteria. Although in the initial analysis on groundwater of 1,325 MPN/100 mL were categorized in class II water classification, it should be carefully observed. When water contaminated by coliform bacteria is consumed without any prior process, it will trigger the spreading of waterborne disease [40].

Adding *Moringa oleifera* seed resulted in total coliform decrease in the treatment variations (K_1T_1, K_2T_1, K_3T_1, K_1T_2, K_2T_2 and K_3T_2). In K_1T_1 total coliform removal efficiency decreased by 97.28% or 36 MPN/100 mL; K_2T_1 total coliform removal efficiency decreased by 98.8% or 16 MPN/100 mL; and K_3T_1 total coliform removal efficiency decreased by 98.87% or 15 MPN/100 mL. Total coliform removal efficiency increased in combined media filtration as K_1T_2 was 99.02% or 13 MPN/100 mL; and K_2T_2 was 99.32% or 9 MPN/100 mL. Anyhow, adding 125 mg/L of *Moringa oleifera* seed (K_3) with combined media filtration (T_2) did not increase in removal efficiency (K_3T_2) from K_2T_2 as 99.32% or 9 MPN/100 mL.One way ANOVA analysis showed that total coliform removal was significantly affected by the dose of *Moringa oleifera* seed and the natural media sequence ($p < 0.05$).

The decrease of total coliform in groundwater was caused by the alkaline condition formation causing bacteria to stop growing and die. Adding *Moringa oleifera* seed produced positive charge that acted as a magnet and was predominantly negative charged particles such as clay, silk and other toxic materials [12]. As seen in Table 2, this study showed that groundwater treatment using a combination of coagulation and filtration both single and combined media possibly removed the total coliform content as required for class I water classification. These findings were in line with previous study where found that *Moringa oleifera* seed reduced the microorganisms growth in groundwater [4].

The coagulation process was possibly reducing bacteria that attached to solid particles up to 90-99%, in which bacteria were aggregated together with the floc and removed from the water. Adding *Moringa oleifera* seed not only caused bacteria in an inactive state (dormant state) but also killed them [12]. The use of biomass derived silica in filtration increased the coliform removal efficiency [41]. The microorganism removal mechanism from water through porous media occurred in two ways, straining and adsorption. The process of straining was determined by the material and the bacterial cells. Larger cells were effectively removed by filtration, whereas smaller cells infiltrated deeper into the material [37].

Table 2 Performance indicator for ground water sample

Parameters	Ground water quality (before treatment)	Unit	Effluent quality (after treatment)					
			K_1T_1	K_2T_1	K_3T_1	K_1T_2	K_2T_2	K_3T_2
Turbidity	122.69	mg/L	52	40	59	30	8	29
pH	5.6		6.2	6.4	6.5	6.9	7.38	7.54
Conductivity	1,235.60	µm	293.8	216.9	225.2	160.7	126.4	140.5
Metal Mn	1.23	mg/L	-	-	-	-	-	-
Metal Cd	-	mg/L	-	-	-	-	-	-
Metal Cr	-	mg/L	-	-	-	-	-	-
DO	16	mg/L	15.3	13.6	12.2	11.9	11.4	11.2
BOD	8.2	mg/L	6.1	1.9	2.3	2.2	0.9	1.9
Total coliform	1,325	MPN/ 100 mL	36	16	15	13	9	9

*K_1 = coagulation using Moringa oleifera seed at a dose of 75 mg/L;
K_2 = coagulation using Moringa oleifera seed at a dose of 100 mg/L;
K_3 = coagulation using Moringa oleifera seed at a dose of 125 mg/L;
T_1 = Filtration using rice husk ash charcoal media;
T_2 = Filtration using rice husk ash charcoal and sand media.

The results shown are the average value of duplication of 3 samples. Data were analyzed using one-way ANOVA with significant levels P <0.05.

3.3. Determining the best combination of groundwater treatment

Determining the best combination of treatment was based on the results of performance parameters on the fulfilment of effluent standards set by the government. From previous studies, it was finally concluded that the combination of coagulation process with 100 mg/L of *Moringa oleifera* seed and combined natural filtration of rice husk and sand resulted on the best removal for all parameters in groundwater. This combination provided the best removal efficiency including turbidity removal of 84%, BOD removal of 89.02%, Manganese removal of 100%, electrical conductivity removal of 89.77%, and total coliform removal of 99.02%. In this combination, pHs increased to 7.42 or 24.12% and DO decreased by 28.75% or 11.4 mg/L. Although there was pH increase, it considered as in neutral conditions that supported the coagulation process and met class I water classification. Similarly, the DO decrease considered to meet the class I water classification standard.

Variation process showed that using combined filter natural media had better removal efficiency for the groundwater treatment. Placing sand after rice husk charcoal was the best way, as sand has smaller size, larger pores fraction, and higher specific areas, and it reflected a greater potency in reducing organic material [8]. Media with greater porosity should be placed in the first stage followed by larger pore fraction to provide better results. It is due to the sufficient oxygen transfer on filter media with high porosity. While the media filter with a larger fraction of pores provided sufficient areas for microorganisms to grow which cause higher removal of organic content [42].

4. CONCLUSIONS

In conclusion, groundwater treatment using a combination of coagulation process with *Moringa oleifera* seed and filtration with natural media (single and combined media) under the configuration tested was provably effective to reduce turbidity, electrical conductivity, Manganese, BOD and total coliform, yet it increased pH and DO. However, increasing pH and DO was within the range of effluent standards set by the government. Using two media arrangement in the filtration unit increased removal efficiency. This process was able to improve the groundwater quality from class III and IV classifications to class I. The limitations of this technology resulted on DO decrease (due to adding *Moringa oleifera* seeds). There is a need to combine more technologies in order to maintain DO content in groundwater.

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