Filter Series Model for Processing Well Water into Drinking Water in the Milala Residential Area, Central House of Pancurbatu District

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Abstract

Many methods of processing well water have been previously studied, but there has been no research aimed at reducing the physical, chemical, and microbiological parameters so that the treated water can be directly consumed. This research aims to determine the appropriate thickness of the series filter media and its ability to process well water into drinking water. This type of research is quasi-experimental with a pre-test post-test design. In the initial stage before the intervention, an examination of the physical parameters (turbidity, color, Total Dissolved Solids/TDS), chemical parameters (iron, manganese, hardness), and microbiological parameters (E. coli bacteria) in well water samples was conducted. In the second stage, changes in water parameters were assessed after treatment using the Parallel Filter Model. The research results show a percentage reduction in turbidity of well water in the Milala Housing Complex in the Pancurbatu Subdistrict, reaching 90.9% - 100%. The percentage reduction in iron (Fe) content of well water in the Milala Housing Complex is 81.9% - 96.2%. The percentage reduction in manganese (Mn) content of well water is 76.9% - 100%. The percentage reduction in water hardness in the Milala Housing Complex is 58.3% - 97.6%, and the reduction in the presence of E. coli in well water occurred in three out of five locations that initially tested positive for E. coli. The series filter is capable of reducing turbidity, iron (Fe), manganese (Mn), the presence of E. coli, and water hardness in well water.

Keywords : Drinking water, filter seri, well water treatment

INTRODUCTION

Water is the most important and indispensable compound for the survival and growth of all living organisms on earth, but it is also used in food production, economic development, transportation, and recreation (Bilewu et al., 2022; Gebresilasie et al., 2021). Water supply can be met by utilizing water sources available in nature, namely rainwater, surface water, river water and groundwater (Purnama, 2020). Dug wells are one of the commonly found means of providing clean water, as their construction and maintenance are easy to undertake. Approximately 43 million households in the United States obtain their water from private wells (Agency & Wells, 2023). However, the water quality from dug wells often poses numerous issues. A water quality assessment of a dug well in Sidokumpul Village revealed color levels at 56 TCU, total hardness at 998 mg/l, Manganese (Mn) at 5.26 mg/l, Sulfate (SO_4) at 980 mg/l, water pH at 6.33, and organic matter ($KMnO_4$) at 14.85 mg/l (Munfiah, 2013), all of which exceed the standards set by the Ministry of Health Regulation No. 492/ Menkes/Per/IV/2010, also in Kampung Ujung, Labuan Bajo, do not meet quality standards. A total of five parameters that do not meet the criteria i.e. TDS, DO, nitrate, nitrite, and E. coli.

It shows the pollution of shallow water in the Kampung Ujung area. This research concluded that the quality of the to dug wells in the Kampung Ujung Labuan Bajo area is not appropriate for use as rawmaterial for drinking water (Wolo et al., 2020).

Research on treating dug well water with high iron and manganese content has been conducted extensively, including methods such as sand filtration (Aba et al., 2019). The use of charcoal and carbon media filters made from candlenut shells (Adeko & Ermayendri, 2019). Electrocoagulation combined with carbon filters, resulting in improvements in physical parameters (turbidity, color, TDS) and reduction in iron. However, the pH increased from 7.15 to 8.33, and microbiological quality (E.coli and coliform) remained above the permissible limits (Masthura & Jumiati, 2017). Another method involving combination of zeolite filter media and activated carbon was effective in reducing iron and manganese levels in well water Fe and Mn levels before treatment were 1.20 mg/l and 0.90 mg/l, Fe and Mn levels after treatment with zeolite filter media became 0.16 mg/l and 0.14 mg/l (Trianah & Sani, 2023). The natural chemical composition of well water varies with region, underlying geologic formation, and type of aquifer. In addition, anthropogenic contamination is dependent on nearby land uses, surface geology and soil type, industry practices, and the diligence of those storing, using, and disposing of potential contaminants (Woolf et al., 2023).

Given the various treatment methods researched previously, there has not been a study specifically aimed at reducing physical, chemical, and microbiological parameters to make the treated water directly potable. Therefore, the researchers are interested in conducting a study using a Serial Filter Model consisting of six processing units: sand-chlorine, ferolite, resin, zeolite, activated charcoal, and a membrane unit to treat well water for drinking purposes.

Based on observations by the researchers and partners, well water in Milala Housing, Rumah Tengah Simpang Gardu, Pancurbatu District, Deliserdang Regency, North Sumatra Province, and Sukarejo Village, Wedi District, Klaten Regency, Central Java Province, appears turbid, very yellow, with an oily and odorous upper layer. Despite these issues, the local community continues to use this water. School uniforms, which are white in color, show yellow stains and black spots. Such water conditions are deemed unsuitable for use. This study is conducted in two different locations to examine whether areas with similar characteristics of well water can be treated using the same filtration model. The ultimate goal is for the serial filtration model to be applicable throughout Indonesia. This research aims to determine the appropriate thickness of the serial filter media and its ability to treat well water for drinking purposes. The study is necessary as, until now, no prototype of a dug well water treatment unit capable of reducing physical, chemical, and microbiological parameters has been found, allowing for direct consumption of the treated water.

METHODS

This type of research is a quasi-experimental study with a pre-test post-test design. In the initial stage, before the intervention, an examination of the physical parameters (turbidity, color, Total Dissolved Solids/TDS), chemical parameters (iron, manganese, hardness), and microbiological parameter (Escherichia coli bacteria) of the dug well water samples is conducted. In the second stage, changes in water parameters are determined after treatment using the Parallel Filter Model.

The research is conducted in Milala Housing, Rumah Tengah Simpang Gardu, Pancurbatu District, Deliserdang Regency, North Sumatra Province, at five households with dug wells exhibiting highly turbid, yellow-colored, and odorous water with an oily upper layer. Due to the water conditions, there are many rust deposits around the bathroom. The analysis of the physical parameters of well water is done in the field, while chemical and microbiological analyses are conducted in the laboratories of the Environmental Health Department at Poltekkes Medan and Poltekkes Yogyakarta. Data collection procedures in this study involve treating the dug well water using the Serial Filtration Model.

RESULTS

The levels of turbidity, TDS (Total Dissolved Solids), Iron, Manganese, Hardness, and E. coli bacteria in dug well water before and after treatment using the serial filter model at five research locations in Milala Housing, Rumah Tengah Simpang Gardu, Pancurbatu District, Deliserdang Regency, North Sumatra Province.

From Table 1 above, it can be observed that the lowest turbidity value of well water is 16 NTU for well 4, while the highest turbidity value is 302 NTU for well 5. However, after treatment, the turbidity levels have fallen below the drinking water quality standard, specifically less than 5 NTU. Total Dissolved Solids (TDS) levels in the well water of the community in Milala Housing, Rumah Tengah Simpang Gardu, Pancurbatu District, Deliserdang Regency, North Sumatra Province, both before and after treatment using the serial filter model, still meet the drinking water quality standards, which is < 500 mg/l. Iron (Fe) level after treatment with the serial filter model in four locations meet the standard, while only one location does not meet the standard due to its concentration being 0.68 mg/l. After treatment with the serial filter model, the levels of Manganese (Mn) in all five locations meet the standard requirements. Hardness levels after treatment with the serial filter model at all five locations meet the water quality standards. From the table above, it can be observed that after treatment with the serial filter model, three dug well waters no longer contain E.coli bacteria.

Table 1 The Turbidity Level, Total Dissolved Solids (TDS) Level, Iron (Fe) Level, Manganese (Mn) Level, Hardness Level, and Presence of E. coli Bacteria of Well Water in the Community of Milala Housing, Rumah Tengah Simpang Gardu, Pancurbatu District, Deliserdang Regency, North Sumatra Province)

Well water	Before filter	After filter	The Maximum Permissible Level	The percentage (%) reduction
Turbidity level				
1	61	0.29	5 (NTU)	99.5
2	93	0.10	5 (NTU)	99.9
3	63	0.00	5 (NTU)	100
4	16	1.46	5 (NTU)	90.9
5	302	1.19	5 (NTU)	99.6
Total Dissolved Solids (mg/l)				
1	430	419	500 (mg/L)	
2	230	277	500 (mg/L)	
3	244	259	500 (mg/L)	
4	227	289	500 (mg/L)	
5	244	217	500 (mg/L)	
Iron (Fe) level				
1	4.36	0.3	0.3 (mg/L)	93.1
2	3.97	0.15	0.3 (mg/L)	96.2
3	4.50	0.3	0.3 (mg/L)	92.3
4	3.76	0.68	0.3 (mg/L)	81.9
5	3.19	0.21	0.3 (mg/L)	93.4
Manganese (Mn) Levels				
1	6.8	0.4	0.4 (mg/L)	94.1
2	2.9	0.0	0.4 (mg/L)	100
3	7.0	0.4	0.4 (mg/L)	94.3
4	2.8	0.3	0.4 (mg/L)	89.3
5	1.3	0.3	0.4 (mg/L)	76.9
Hardness Level				
1	850	53.4	500 (mg/L)	93.7
2	712	35.6	500 (mg/L)	95.0
3	170.8	71.2	500 (mg/L)	58.3
4	729.8	17.8	500 (mg/L)	97.6
5	712	53.4	500 (mg/L)	92.5
Presence of E. coli Bacteria				
1	+	-	0/100 ml	
2	+	-	0/100 ml	
3	+	+	0/100 ml	
4	+	-	0/100 ml	
5	+	+	0/100 ml	

DISCUSSION

The rainwater that reaches the Earth's surface will seep into the soil layers and eventually become groundwater. Before reaching the layer where groundwater is present, rainwater will penetrate several soil layers and cause the water to contain certain concentrations of mineral substances. These minerals include calcium, magnesium, and heavy metals such as iron (Husaini et al., 2020).

Filtration, or screening, is a process to remove suspended solid particles, measured by turbidity, from water through a porous medium. Filtration through a porous medium occurs by hindering particles from entering the pore spaces, leading to the collection and stacking of these particles on the surface of the medium grains. The accumulation of particles adhering to the medium grains results in clear and cleaner water. Water filtration can eliminate bacteria, color, turbidity, and metal content such as iron (Cescon & Jiang, 2020). Ridha et al (Ridha et al., 2023) explained in their research that filtration using Combination of Filter Media Types can reduce water turbidity from 90 NTU to 6.9 NTU. The initial concentration of iron (Fe) at 2.6 mg/l was reduced to 0.2 mg/l. In addition to reducing turbidity, the filter is also capable of lowering the manganese (Mn) level from 0.48 mg/l to 0.08 mg/l (Timpua, 2011).

This research also utilizes the filtration method, namely the serial filter consisting of six housing tubes containing the following media: activated sand mixed with chlorine, ferroline, resin, zeolite, activated carbon, and a cartridge/membrane. Based on the results of the conducted research, it is known that the serial filter is capable of treating well water with high levels of turbidity, iron, manganese, hardness, and containing high levels of E. Coli bacteria, making it suitable for drinking. The reduction in turbidity of well water in the research location or in Milala Housing, Rumah Tengah Simpang Gardu, Pancurbatu District, can reach 90.9% to 100%. The reduction in manganese levels ranges from 76.9% to 100%. The ability of the serial filter to reduce hardness levels at the research location is between 58.3% and 97.6%. Regarding the reduction in the presence of E. coli bacteria in the five wells at the research location, the bacteria were eliminated in three locations (no E. coli found or 0 E. coli). However, the results for TDS levels are less satisfactory because the research findings indicate that TDS levels decrease but sometimes increase.

The ability of the serial filter to reduce turbidity, iron, manganese, hardness, and E. coli bacteria is attributed to the highly compatible media utilized, which consists of active sand media combined with chlorine, ferrolite, resin, zeolite, activated carbon, and a membrane. The functions of these media are as follows:

Activated Sand and Chlorine

The content within sand includes minerals, one of which is quartz containing Silica (SiO2), hence it is often referred to as silica sand. This sand has a hardness of 7 on the Mohs scale, a specific gravity of 2.65, a melting point of 1715°C, a hexagonal crystal shape, and thermal conductivity of 12-100°C. Silica sand is highly effective in filtering mud and other impurities in water. (Mugiyantoro, 2017) Meanwhile, the addition of chlorine serves to oxidize iron in the water and to eliminate germs or bacteria. (Adefisoye & Olaniran, 2022). The oxidation reaction between iron and chlorine is as follows:

$$2Fe^{2+} + Cl_2 + 6H_2O \longrightarrow 2Fe(OH)_3 + 2Cl^- + 6H^+$$

From the above reaction, it can be inferred that 0.64 mg/l of chlorine is required to oxidize every 1 mg/l of iron (Azzahrah, 2014).

The addition of chlorine to water aims to disinfect the water from unwanted bacteria (Suhartawan et al., 2023). Chlorine reacting in water produces hypochlorous acid and hypochlorite anion. Hypochlorous acid will penetrate the bacterial cell membrane and destroy it. At pH 7.5, the chlorine residue will be balanced. A lower pH will result in more hypochlorous acid than hypochlorite anion. Chlorine can be obtained from Cl2 gas or from NaOCl and Ca(OCl)2 salts. Chloramines are formed due to the reaction between ammonia (NH3), both organic and inorganic, and amino acids in water, which is referred to as chlorine residue capable of binding with iron. In this study, the thickness of the mixed media of activated sand and chlorine used is 16 cm.

Resin

The resin media used in this study has a diameter of 0.6-0.8 mm, packed in a housing tube with a media volume of 615 grams and a height of 16 cm. The flow rate through the housing tube is set at 1 liter per minute. The decrease in Manganese levels occurs due to the ion exchange process that takes place when water comes into contact with the resin. The resin accepts positive ions and releases other ions into the water in an equivalent amount. Manganese in water is dissolved in the form of the Mn2+ cation. Monovalent cations, such as Na+ or H+, are selectively released from the resin. The ion exchange reaction between the resin and Manganese is as follows:

$$R{-}Na_2 + Mn(HCO_3)_2 \longrightarrow R{-}Mn + 2Na(HCO3)$$

In the above reaction, it is evident that the resin exchanges Na+ ions from the solution and releases the Na+ ions it possesses into the solution. When the resin has exchanged all its Na+ ions, the ion exchange reaction comes to a halt. At that point, the resin is said to be exhausted and must be regenerated with a solution containing Na+ ions, such as NaCl.

Typically, ion exchangers can work optimally for concentrations ranging from 1 to 5 mg/l. If the Manganese content in the water is excessively high, clogging may occur. Therefore, in water with a very high Manganese content, pre-treatment is required before flowing it through the ion exchange unit. If the pollutant levels in the water are too high, the resin will saturate quickly and need to be regenerated or replaced more frequently (Haryono, 2020).

Zeolite

Zeolite is a hydrated alumino-silicate compound with sodium, potassium, and barium cations. Zeolite carries a negative charge, allowing it to bind to cations. Often referred to as a molecular mesh, zeolite has molecular-sized pores that enable it to filter molecules of a specific size (Ismawati, 2018). In water filtration processes, zeolite can eliminate bacteria and bind metal content present in water (Azzahrah, 2014). As stated by Li et al. and Jiang et al., zeolite is a crystalline microporous material composed of three-dimensional open-framework aluminosilicate tetrahedra, forming a network of pores and cavities, making it suitable for use as an adsorbent or ion exchanger (Li, 2017).

Natural zeolite-based composites are alternative as cost-effective adsorbents for metal ions sorption. The simultaneous use of adsorption capacity of zeolite and other inorganic adsorbents such as metal oxides, carbonaceous materials, and hydroxyapatite in the zeolite/inorganic material composites could introduce them as effective adsorbents for wastewater treatment. (Roshanfekr Rad & Anbia, 2021). The zeolite-based composites have also been used for the adsorption of emerging contaminants such as pharmaceutical wastes as one the largest groups of emerging contaminants (Z.-L. Cheng et al., 2018; Smiljanić et al., 2020, 2021; Sturini et al., 2020)

Research on the use of zeolite as an adsorbent has been conducted, revealing its ability to adsorb copper (II), chromium (III), and iron (III) ions from industrial graphic wastewater, with zeolite's adsorption capacity ranking as Fe > Cr > Cu (Zanin et al., 2017). Motsi et al. also conducted research using zeolite as a potential adsorbent to reduce Fe (III), Cu (II), Mn (II), and Zn (II) ions from acid mine water. Zeolite was able to reduce 95.4% of iron, 96.0% of copper, and 85.1% of chromium at 25.0 °C and pH 4.0 (Motsi, 2009). In an experiment Cheng et al (2018) investigating the Beta zeolite's ability to adsorb rhodamine B from an aqueous solution, zeolite achieved an adsorption of 27.97 mg/g when the SiO2/Al2O3 ratio was 18.4. The reaction that occurs in zeolite during the ion exchange process with Fe involves the exchange of the formed Fe precipitate with cations from Group IA and IIA metal elements (Alkali and Alkaline Earth) such as Na+, K+, Ca2+, and Mg2+ (Oesman & Sugito, 2017):

$$Na^+ + Fe^{3+} \rightarrow Zeolite.Fe^{3+} + Na^+$$

Zeolite is commonly used for various applications, especially to enhance the effectiveness and efficiency of industrial processes. Due to its relatively low cost and high thermal stability, zeolite has broad potential applications in separation processes and as a catalyst (Loiola, 2012). In this study, the thickness of the zeolite media used is 16 cm.

Activated Carbon

Activated carbon in the water filtration process operates through adsorption, meaning that when a substance or object passes through activated carbon, the materials contained in it will be absorbed. In the water filtration process, activated carbon filters out odors, clarifies, and filters out metals contained in the water. Additionally, it functions to: Absorb chlorine, create a fresh taste in the water, absorb salts, minerals, and inorganic compounds. In this study, the thickness of the media used is 16 cm.

Membrane Catrix

The ability of membranes to reduce turbidity levels depends on the selectivity and permeability characteristics of the membrane. Polysulfone membranes exhibit a very high level of selectivity in reducing turbidity levels. In experiments conducted to reduce the turbidity of peat water with an average turbidity of 41.77 Pt-Co, after treatment using polysulfone membranes, the turbidity parameter decreased to an average of 6.50 Pt-Co (achieving an efficiency of 90.76%).

In addition to reducing the turbidity of water, membranes are also capable of decreasing the TDS (Total Dissolved Solids) content. In a study by Degremont in 1999, membranes were used to reduce the TDS of peat water and Musi River water, which initially had an average TDS content of 438.9 mg/l. After treatment, a reduction in TDS content was achieved, averaging 153 mg/l. Ultrafiltration membranes were also able to reduce the organic content in water by 88.9%. To reduce iron (Fe) levels, polysulfone membranes have low selectivity because iron (Fe) particles easily clog membrane pores, causing fouling on the membrane surface. However, for reducing manganese (Mn) content, the membrane's ability is greater compared to reducing iron (Fe) levels. This is because manganese metal particles have a larger size than ultrafiltration membranes, causing manganese to be retained on the membrane surface, resulting in high rejection rates.

A comparison of the serial filter's ability to treat well water in the community in Milala Housing, Rumah Tengah Simpang Gardu, Pancurbatu District, with that in Poerwodadi Village, Wedi District, Klaten Regency, regarding turbidity, iron, manganese, and hardness parameters, showed greater effectiveness in Milala Housing. This is evident in Table 4.23. The percentage reduction in turbidity of well water in Milala Housing reaches 90.9% - 100%, while in Poerwodadi Village, it only reaches 33.1% - 100%.

Similarly, the comparison of the serial filter's ability to reduce iron (Fe) levels showed that the iron content of well water in Milala Housing ranges from 3.19 to 4.5 mg/l, with a percentage reduction ability of 81.9% - 96.2%. In Poerwodadi Village, the iron content of well water in both the community and the mosque ranges from 1 to 5 mg/l, with a percentage reduction in turbidity ranging from 58.3% - 100%.

The comparison of the serial filter's ability to reduce manganese (Mn) levels also follows a similar pattern. The manganese content of well water in Milala Housing ranges from 1.3 to 7.0 mg/l, with a percentage reduction ability of 76.9% - 100%. In Poerwodadi Village, the manganese content of well water in the community and the mosque ranges from 0.7 to 4 mg/l, with a percentage reduction in turbidity ranging from 67% - 100%.

The serial filter's ability to reduce hardness levels is also higher in Milala Housing. The hardness of well water in Milala Housing ranges from 170 to 850 mg/l, with a percentage reduction ability of 58.3% - 97.6%. In Poerwodadi Village, the hardness of well water in the community and the mosque is 124.6 - 320.4 mg/l, with a percentage reduction in hardness ranging from 16.7% - 88.9%.

CONCLUSIONS

The reduction percentage of hardness levels in the well water of the community in Milala Housing, Rumah Tengah Simpang Gardu, Pancurbatu District, is between 58.3% and 97.6%. There is also a decrease in the presence of E. coli in the well water at three out of five locations that initially tested positive for E. coli. The serial filter is effective in reducing turbidity, iron (Fe), manganese (Mn), the presence of E. coli, and the hardness of well water. However, the serial filter model has not been successful in reducing the Total Dissolved Solids (TDS) parameter.

Further research is needed to address the reduction of TDS parameters in well water. The researcher give suggestion of the need to improve the physical condition of dug wells, it is necessary to do the extension to the well water user community for drinking water about the physical condition of the dug well, the need to monitor and supervise the quality of drinking water, and should involve the community to independently meet the needs absolute i.e clean water to drink.

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