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Brackish Water Tr...

A Practical Implementation of Brackish Water Treatment in Disaster Prone Area in Sidoarjo Regency, East Java, Indonesia

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Abstract

~~The global water crisis is becoming increasingly acute. It affects more than 40% of the worldwide population, leading to diseases such as cholera, diarrhea, dysentery, hepatitis A, typhoid, and polio.~~ Indonesia, an archipelago with vast coastal areas consisting of 809 coastal villages, still faces ~~the same~~ problems of clean water scarcity and accessibility. ~~Brackish water treatment systems are suitable for overcoming the clean water crisis, especially in a maritime country like Indonesia.~~ A suitable brackish water treatment system should be developed to produce clean water safe for daily consumption by communities in ~~disaster prone coastal areas~~. This study aimed to discover appropriate filtering media and lower the salinity of brackish water using reverse osmosis (RO) and ion exchangers. This research used an experimental method by combining a literature review, previous studies, including: physical filtration, reverse osmosis, and ion exchangers. The outcomes demonstrate that media filtration utilizing a combination of a 10-micron filter, kaolin, zeolite, kaolin, activated carbon, and kaolin is the best combination to produce the most transparent, and odorless water. It can reduce TDS and EC values by 8.59% and 7.18%, respectively, and reduce pH levels by 2.59%. On the other hand, reverse osmosis and ion exchange can achieve 99.5% and 67% reductions in TDS and EC values, respectively.

Keywords: Clean Water Crisis, Brackish Water; Local Filter Material, Reverse Osmosis; Ion Exchanger

1. Introduction

Water is an essential resource for humans to fulfill their daily needs~~, and the~~ The demand for clean water ~~will~~ increase yearly, so people worldwide are facing ~~a~~ water crisis. The term clean water crisis not only relates to the amount of water available but also relates to low water quality. Some factors that cause the clean water crisis to worsen are increasing population growth and rapidly increasing industry [1]. The bad habits of the community, especially urban communities, in wasting clean water and environmental pollution worsen water supply and quality. Due to the clean water crisis, nearly one (1) billion people are unable to access clean water, 3.4 million people die from drinking contaminated water, millions of people must travel an average of 6 km daily to access clean water, and at any given time, half of all hospitals in the world are full of patients with diseases related to the clean water crisis. [2]. The clean water crisis is ~~getting~~ worse for people living in coastal areas worldwide. The ~~southwestern~~ Southwestern coastal regions of Bangladesh and Europe are experiencing drinking water scarcity. Many factors contribute to water scarcity, including seawater intrusion, decreased upstream water discharge, sea level rise, disasters, polders, arsenic poisoning, overuse of subsurface water, and others. [3~~],[~~,4].

~~According to the Indonesia Statistic Bureau, t~~The Sustainable Development Goals (SDG) ~~have~~has set a global target of 100% ~~percent~~ access to drinkable water by 2030. However, there are still 80 million people who still need access to safe drinking water services. Even the capital city of Indonesia, Jakarta, has yet to reach 100% access to safe drinking water. It is problematic for Indonesia because clean water source availability and accessibility from one place to another are not equal [5]. The main problem for the rural and coastal communities is their need for clean water. The most accessible natural water source in this region for the community's everyday needs and drinking water is groundwater. Still, as the ecosystem changes and industrial aquifer contamination increases, the quality of this resource is declining [6]. As a result, the socioeconomic impacts on the community are health ~~difficulties~~ and rising costs for clean water supplies.

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The location for this research is Sidoarjo Regency, East Java, Indonesia (See Fig.1. 37 Sidoarjo Regency, East Java, Indonesia). As a river delta area between the Kalimas and Porong rivers and the coast, Sidoarjo has always been prone to natural disasters like flooding, typhoons, and tornadoes. In addition to the natural calamity, the local industrial region in Sidoarjo was the primary source of groundwater resource contamination. Both main factors above affect clean water resources availability for fulfilling the community's daily needs in farming and their daily consumption [7~~],[~~,8]. Hence, a suitable and cost-effective water treatment method must be developed and implemented ~~in this research~~ to resolve the clean water resources availability issue in this area.

Figure 1. Sidoarjo Regency, East Java, Indonesia. Research work location

The only water source available in this area is household wells filled with brackish water from the Porong River. Based on the research that has been conducted, it is known that the water quality is classified as moderate using the NSF-WQi index. It was found from the water samples obtained from two villages in Sidoarjo district, Tegal Sari and Tanjung Sari, in the Jabon sub-district, ~~that~~ the turbidity content was 68 mg/l, total dissolved solids content (TDS) was 223 mg/l, and Escherichia~~.~~ Coli content was 210 mg/100 ml, making it unsuitable for safe, clean water [9]. Therefore, clean water is purchased and periodically supplied by truck to the community to meet daily household needs. ~~Water samples were obtained from two villages in Sidoarjo district, Tegal Sari and Tanjung Sari, in the Jabon sub-district~~. An alternative solution besides a clean water supply is treating brackish water with local filter media, which is abundantly available [10]. Local filter materials, such as silica sand, pumice, bricks, charcoal, sponge, alum, kaolin, charcoal, active carbon, kaolin, and zeolite, can be used to treat the water.

Several studies have been conducted on brackish water treatment to address clean water supply. Jayaprakash et al. [11] have introduced a method to reduce iron, sulfate, chlorine, sodium, and TDS content in brackish water using activated carbon media. Khanzhanda et al. [12] have evaluated the performance of a combination of pretreatment and reverse osmosis. The first method combines cartridge pretreatment with RO, and the second uses ultrafiltration with RO. Yogafanny et al. [13] have introduced a method using local zeolite material to reduce dissolved solids levels. Yaqin et al. [14] found a portable water purifier using silica sand, zeolite stone, greensand sand, zeolite manganese, bio-balls, and activated carbon. Barahoei et al. [15] have introduced a method to reduce salinity using chemical photosynthetic desalination cells. Ansari. et al. [16] evaluated the performance of brackish water desalination using

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reverse osmosis under different operational conditions. Desmiarti. et al. [17] found a demineralized water method using a combination of continuous filtration and ion exchange processes.

Several references were also taken from several patents on brackish water purification devices. Tadd C. KIPPENY et al. [18] made a patent entitled Water Desalination Apparatus with patent number US8377297B2, discussing using a salt sponge unit to remove most salt from water. A parallel plate capacitor can be connected after the salt sponge to remove the remaining salt ions. Chen et al. [19] made a patent entitled A kind of processing method of brackish water and a sort of saliferous water treatment system with patent number CN105174512B, discussing a brackish water treatment method by performing nanofiltration separation to obtain production water and nanofiltration concentrated water. Nanofiltration production water is subjected to a reverse osmosis separation process. Shen et al. [20] made a patent with the title Bitter (brackish) saltwater purifying equipment with patent number CN103073136A, discussing the manufacture of brackish saltwater purification equipment with multi-medium filter, automatic cleaning filter, and ultrafiltration membrane device.

This study aimed to identify a technique for obtaining clean water from brackish water by choosing filtration with suitable local material, reverse osmosis, and ion exchanger. Based on the research results, it is expected that the implementation of this method can provide a practical solution for overcoming the clean water crisis. This study aims to identify a technique for obtaining clean water from brackish water by choosing filtration with suitable local material, reverse osmosis, and ion exchanger. Based on the results of the research, it is expected that this method can help solve the clean water crisis if it is put into practice. The test results will be compared to the WHO drinking water standard for water quality criteria, including pH (Power of Hydrogen), TDS (Total Dissolved Solids), EC (Electrical Conductivity), odor, and color.

2. Material and Methods

Experimental study use physical methods to discover the optimal combination for on-site brackish water treatment. silica Sand, lumajang sand, alum, carbon active, sponge, pumice, kaolin, red brick, red tile, charcoal, zeolite, bio ring, Clam shell, and a filter 10 micron comprise the filter module combination set. Reverse osmosis and ion exchanger equipment will be utilized to further treat the water purified by the filtration method.

2.1 Material

2.1.1 Silica Sand

Silica sand, or quartz sand, contains about 99.7% silicon dioxide (SiO2). Silica sand is a very effective water filtration medium because it can precipitate and retain impurities from the treated water. It is expected that silica sand can remove mud contained in brackish water (Fig 2.a). [21].

2.1.2 Lumajang Sand

Lumajang Sand is formed from silicon dioxide content or limestone. Generally, the size of sand is 0.0625 mm to 2 mm [22]. The function of sand for water filters is to hold silt and fine impurities. The type of sand used in this study comes from Lumajang, East Java, Indonesia. The characteristic of this sand is the color of the sand, the sand has a gray to black color (Fig 2.b).

2.1.3. Alum

Alum is found in nature as a chemical compound known as hydrated aluminum sulphate salt in the white crystalline form (Fig 2.c). Potassium alum or potash alum is used to coagulate the impurities so that the impurities can be separated [23]. As it has the characteristic as coagulant agent, it is not only utilized in water treatment, but also in industrial sector, i.e., medicine, food preparation, and textile industry. An appropriate dosage of Alum should be added during the water treatment so that the treated water is safe for daily consumption.

2.1.4. Active Carbon

Active carbon is widely known for its physical properties, which includes a large surface area and homogeneous pore size (Fig 2.d). It is chemically inert and stable [24]. Based on the characteristic mentioned above, odor and color, which is caused by the organic compound in water, can be removed by adsorption. Hence water's taste and appearance can be improved [25]. However, both coa1rse and fine impurities in the water can't be separated by active carbon absorption.

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2.1.5. Sponge

Sponge is commonly known as basic physical and mechanical filter media, which is simple and cost-effective. It is widely available and has a porous synthetic material capable of absorbing water and good aeration (Fig 2.e) [26]. The suspended solid particle in water can be separated by immersing it in the pore [27]. However, a limited number of dissolved impurities can be retained. Sponge, in terms of maintenance, can be effectively cleaned in specific periods and is easy to be utilized back as filter media.

2.1.6. Pumice

Pumice is a type of rock that is light in color and contains thick foam made of glass-walled bubbles (Fig 2.f) [28]. Pumice can remove coarse contaminants due to its large surface area and up to 90% porosity. Pumice can be an absorbent material to remove heavy metals, radioactive, and dyes in wastewater [29]. The disadvantage of using this material as a filter is that pumice cannot remove fine impurities like sand filters. In terms of maintenance, the pumice filter is easier to maintain when compared to a sand filter, but it still takes quite a bit of time long enough.

2.1.7. Kaolin

Kaolin or kaolinite is a type of primary clay material that exists in nature, with the chemical formula Al2O3.2SiO2.2H2O (Fig 2.g). Kaolin and activated carbon have similar physical properties with high surface area and stability. By absorption, Kaolin can remove toxic pollutants from water, such as chloride, sulfate, Cr, Cd, and Zn [30], [31]. The disadvantage of this filter media is that it cannot hold fine or coarse impurities.

2.1.8. Red Bricks

The function of red bricks in this water purification filter is to separate and precipitate the minerals in brackish water. The bricks used this time are red bricks. Red bricks have a large surface area and a high porosity making them suitable to be used as an absorbent material and filter waste (Fig 2.h)[32]. Given that red bricks are made of clay, this filter can help precipitate the minerals contained in the water. The disadvantage of this filter is that it cannot help purify water in terms of color.

2.1.9. Red Tile

Red tile is made from clay processing and then heated with coal with a certain degree of heat (Fig 2.i). The function of red tile in water filters is to help kill harmful minerals, and its weakness is that it cannot filter out impurities [33].

2.1.10. Charcoal

Another filter material known as an effective filter media is charcoal. The charcoal made from the coconut shell is high-quality, effective, and environmentally friendly. Like active carbon and kaolin, coconut shell charcoal can absorb and remove chemical pollutants in the water (Fig 2.j)[34]. As filtering media, shell charcoal has a slightly significant result, it can't hold the coarse impurities in brackish water, whereas odor and taste can be improved. In terms of maintenance, a periodic replacement is needed and is easy to obtain as this material is commonly used in water treatment.

2.1.11. Zeolite

A form of hydrated alumina-silicate chemical compound with sodium, potassium, and barium cation is known as zeolite. Zeolite is formed naturally from volcanic and sedimentation rock in nature. It can retain or separate chemical molecules as it has molecular-sized pores (Fig 2.k). Zeolite, as an adsorbent, can cation exchange due to its negative electrical charge in them. This negative electrical charge can bind cations generally found in groundwater, i.e., Fe, Al, Ca, and Mg. [35]. Zeolite is used not only in water treatment but also for treating wastewater treatment. It is expected to remove heavy metal cations in wastewater, i.e., Zn, Cr, Pb, Cd, Cu, Mn, Fe, etc.

2.1.12. Bio Ring

Bio ring is made from ceramic and found in white color. It has a cylindrical form of 20 mm in height and 18 mm in diameter (Fig 2.l)[36]. The function of the bio ring in this filtration 200 is to filter bacteria in brackish water. Bio rings have a large surface area and porosity. The number of pores in the bio ring gives the bio ring a high surface area, which is helpful for bacteria to colonize, allowing water to enter the pores easily [37]. The disadvantage of this filter is that it cannot filter impurities from the dirt in the brackish water.

2.1.13. Clam Shell

The public generally considers clamshell waste but have a high mineral content. The type of mineral present is calcium. Therefore the function of the shell in the water filter can be used as a natural mineral source (Fig 2.m)[38].

2.1.14. Filter 10 Micron

The 10 Micron filter consists of a filter cartridge made of polypropylene. Cartridge filters come in various sizes, with pore diameters ranging from 20 to 1 micron. Therefore, using 10-micron filters in water filters can retain small particles that enter and improve the quality of treated water (Fig 2.n). When the cartridge filter is saturated, it must be replaced to maintain its function [39].

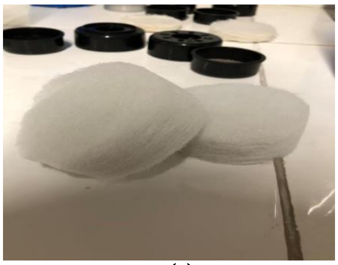
2.1.15. Reverse Osmosis (RO)

Reverse osmosis is the most modern type of water treatment. It is the most efficient separation technology used in some industrial locations for treating wastewater and seawater desalination for creating fresh water (Fig

2.o)[40,41,42]. Water pressure is applied through a semi-permeable membrane to remove dissolved inorganic contaminants from water. Fluoride, chlorine, nitrates, sulfate, pesticides, etc., dissolved pollutants in the water are removed during treatment [43]. Solid impurities must be separated using mechanical treatment, i.e., settling and filtration, so that it will not shorten the membrane interval maintenance and its lifespan time due to mechanical damage. To improve reverse osmosis performance, periodic maintenance and cleaning to remove fouling on the membrane surface must be conducted.

(a)

(b)



(c)

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(e)

(f)

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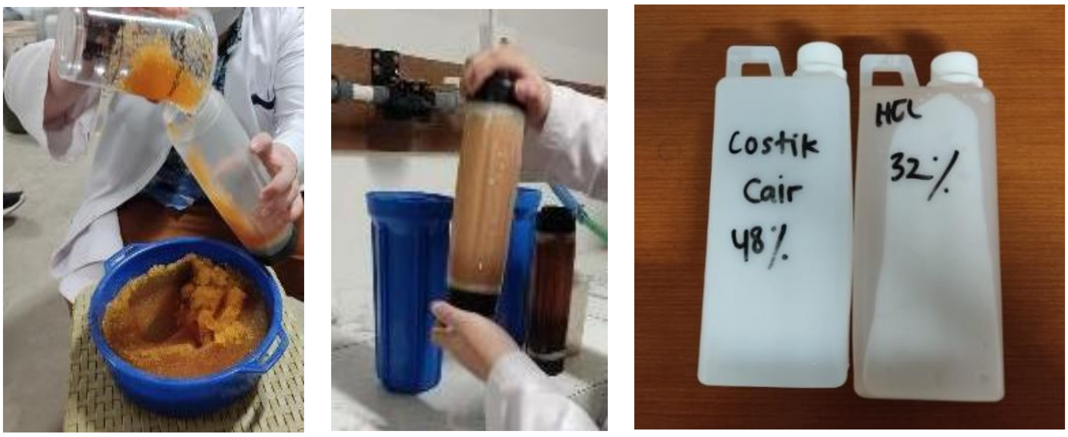
(m) **(n)** **(o)**

Figure 2. Filter media module. Materials for filter modules from local materials and reverse osmosis

2.1.16. Ion Exchanger

The ion exchanger is one of the desalination process's fundamental components. It functions by binding positive and negative ions with a substance called resin. There are two ion exchange resins: cation exchangers, which contain positively charged ions that are exchangeable (Fig 3.a and Fig 3.c), and anion exchangers, which have negatively charged ions that are exchangeable (Fig 3.b and Fig 3,c). Both cation and anion resins must be regenerated using a powerful acid or base. Using flow-through, column, or tank systems, the ion exchange process transforms produced brackish water into drinkable or disposable water [44]. Most often, ion exchange media are used to remediate waste, soil, and water. This study will employ ion exchange media to treat brackish water widely found in coastal and rural locations. Ion exchange therapy is one approach for fixing domestic water problems. It can eliminate toxic contaminants from water [45],[,46].



(a) **(b)** **(c)**

Figure 3. Material for Ion Exchanger. Anion and CKation Exchanger Resin

2.2. Research Methodology

The research methodology applied in this work is experimental research, including literature from previous studies. A case study will follow this. Related information and data about brackish water, e.g., recent research in treatment methods and properties of brackish water, are obtained as the basis for this work. Applying physical experiments in brackish water treatment in this work will be utilized by selecting local material as filter media. This local material will be prepared in a filtration module, and a combination of reverse osmosis and ion exchangers resin will be used as water treatment equipment.

2.2.1. Filter Media Preparation and Assembly

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b l Sari
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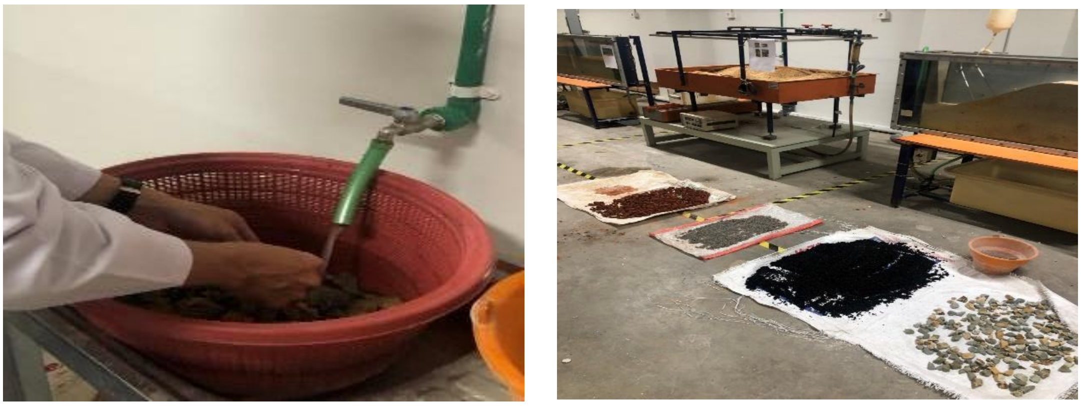
(a) **(b)**

(c) **(d)**

Figure 4. Water treatment equipment assembly. Preparation for filter module, reverse osmosis, ion exhanger in filter module and obtaining brackish water sample

There will be a pretreatment phase for filter media before it is filled into the filter module. Dirt and another contaminant will be eliminated by washing in the first phase (Fig. 5.a). Once the washing phase is completed, filter media will be dried in the oven. (Fig. 5. b). Mechanical phase, crushing, and screening are necessary for certain material to extend their surface area, which can be seen in (Fig. 5.c and 5.d).



(a) **(b)**

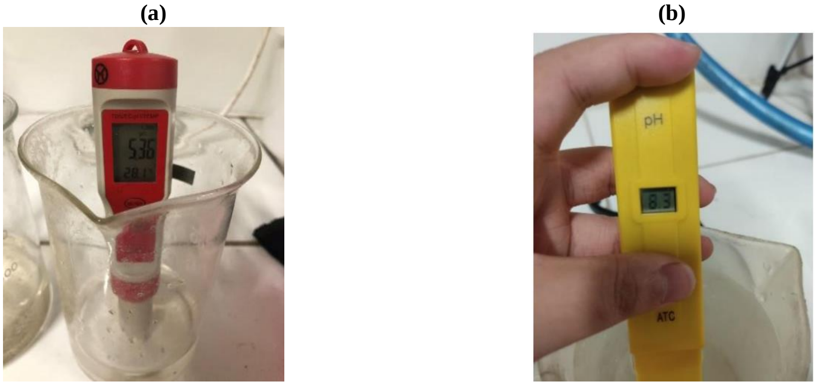
(c) **(d)**

Figure 5. Filter media pre treatment phase. Washing, drying, crushing and screening

2.2.2. Filter Module Assembly

As the filter media has completed its pretreatment phase, it will be filled into each filter module (Fig. 6.a). A brackish water sample will be pumped into the filtration module (Fig. 6.b). The treated brackish water from the filtration module will be analyzed for its water quality parameter, i.e., pH, TDS, EC, odor, and color will be observed and measured (Fig. 6.c and Fig 6.d). A number of combinations of local filter media in the filter module will be described in Tab. 1

(a) **(b)**



(c) **(d)**

Figure 6. Filter module assembly. Water quality parameter analysis for treated water after filtration

The brackish water sample will be analyzed before the treatment in the laboratory to get the initial water quality parameter value. It has an average pH of 8.0, a TDS value of 2550 ppm, EC value of 5070 µs/cm. Color, odor, and turbidity of the water sample before and after treatment are also observed. The standard water quality criterion will be based on the Minister of Health Republic of Indonesia Regulation No. 492, 2010, and the WHO drinking water quality standards. As per water parameter quality standards, clean water has an average pH between 6.5 – 8.5, a TDS value lower than 500 ppm, and an EC value lower than 300 µs/cm. As physical criteria, clean water must be odorless and colorless [47,48]. The water quality parameter after the treatment will be compared with the standard above..

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Table 2. Filter module combination with local filter media

No	Module 1	Module 2	Module 3	Module 4	Module 5	Module 6
1	Lumajang Sand	Charcoal	Bricks			
2	Lumajang Sand	Pumice	Bricks	Kaolin	Active Carbon	
3	Lumajang Sand	Pumice	Bricks	Kaolin	Active Carbon	
4	Lumajang Sand	Pumice	Bricks	Kaolin	Active Carbon	
5	Lumajang Sand	Carbon Active	Bricks	Zeolite	Kaolin	
6	Lumajang Sand	Red Tile	Zeolite	Zeolite	Kaolin	Active Carbon
7	Zeolite	Zeolite				
8	Clamshell					
9	Fliter					
10	Active Carbon					
11	Actice Carbon	Active Carbon				
12	Kaolin					
13	Bio Ring					
14	Filter	Kaolin	Zeolite	Kaolin	Kaolin	Kaolin
15	Fliter	Kaolin	Zeolite	Kaolin	Active Carbon	Kaolin
16	Bricks					
17	Lumajang Sand	Bricks				
18	Lumajang Sand	Bricks	Bricks			
19	Lumajang Sand	Bricks	Bricks	Sand		
20	Kaolin	Active Carbon	Active Carbon	Active Carbon	Filter 10 Micron	
21	Alum	Zeolite	Kaolin	Silica Sand		
22	Alum	Kaolin	Filter 10 Micron	Kaolin		
23	Zeolite	Silica Sand	Filter 10 Micron	Sponge		
24	Silica Sand	Zeolite	Charcoal	Filter 10 Micron		
25	Silica Sand	Zeolite	Sponge	Filter 10 Micron		

3. Results

Comment [B15]: This is not discuss in the text pH, TDS, and EC of the treated water, as the determining water quality parameter, will be measured and described in two sections. The analysis result after the filtration through the filter module combination will be shown in the first section. The analysis results from reverse osmosis and ion exchanger can be seen in the second section. Based on brackish water before and after treatment analysis results, the treatment effectiveness from both filtration method, reverse osmosis, and ion exchanger can be further evaluated.

3.1. Water Quality Parameter After Filtration with Local Filter Media

3.1.1 pH

As shown in Fig. 7, the filtration result shows that the pH value range is between 6.6 to 8.6. The highest increase in pH value from 7.7 to 8.4 is shown in experiments 6, while the highest decrease in pH value from 8.6 to 8 occurred in experiments 1. The pH value after treatment is still acceptable based on the quality standard except for experiments 21, and 22.

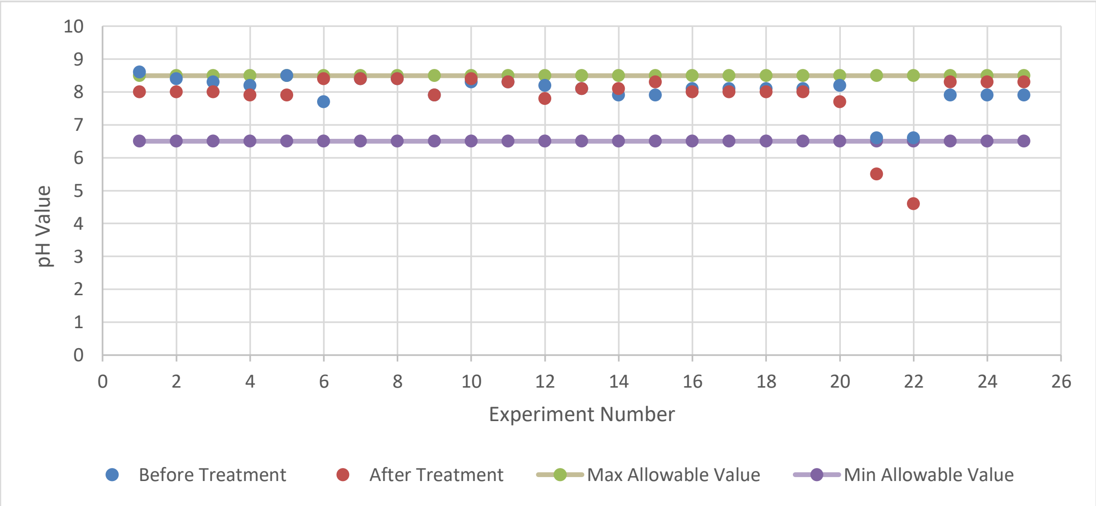

Figure 7. pH value comparison, before and after filtration

TDS value shows a decreasing trend after filtration. It can be seen in Fig. 8 that the TDS value after the treatment is in the range between 2340 – 4810 ppm. Experiment no. 15 result has the highest decrease in TDS value from 2560 ppm to 2340 ppm, equal to 8.59%.

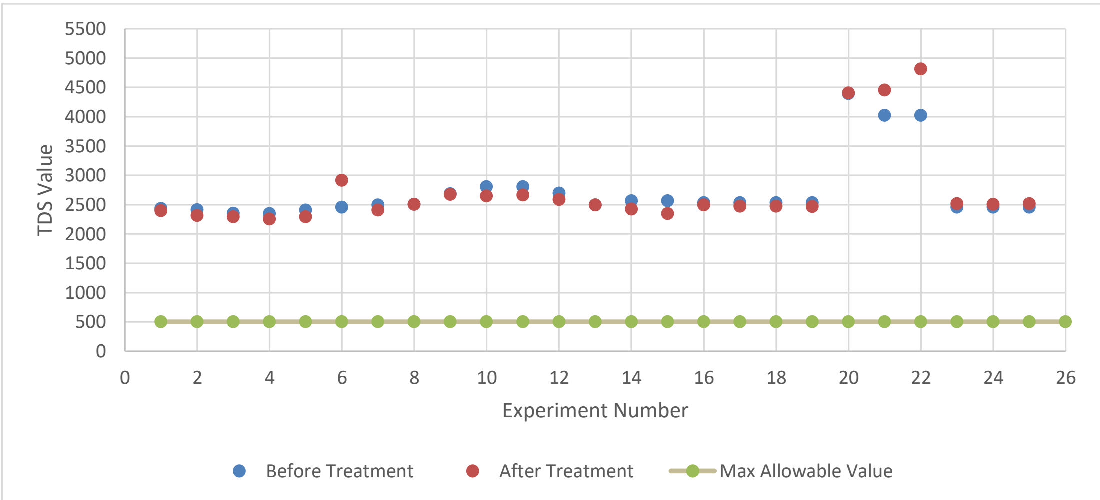

Figure 8. TDS value comparison, before and after filtration

The same decreasing trend in EC value is also obtained after filtration. The average EC value after filtration ranges between 4530 – 9800 µs/cm. Like the TDS value, experiment no. 15 has demonstrated the highest decrease in EC value from 5150 µs/cm to 4780 µs/cm. The filtration method can achieve an average reduction between 3.9% - 7.18% in EC value. The comparison of EC values before and after filtration is shown in Fig. 9.

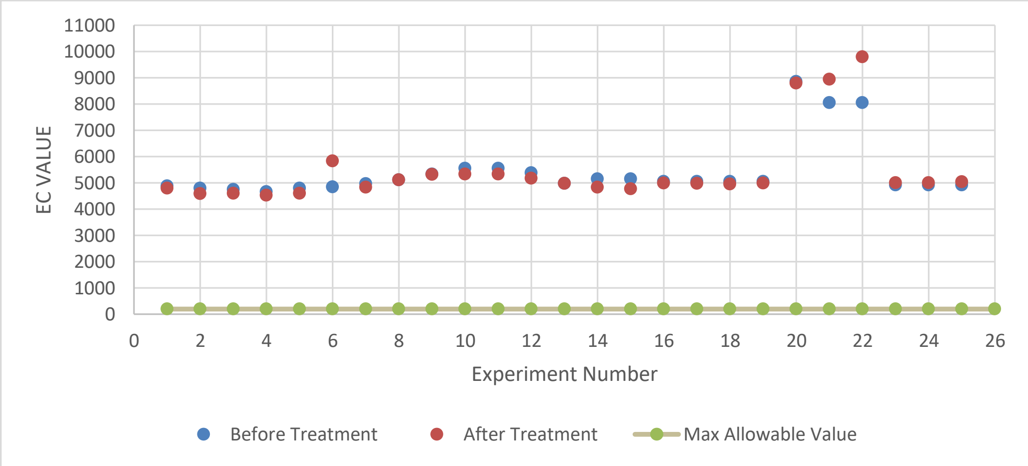

Figure 9. EC value comparison, before and after filtration

3.2. Water Quality Parameter from Reverse Osmosis and Ion Exchanger

As TDS and EC values from the treated water, the filtration method with selected local material still exceeds the WHO clean water standard guideline, reverse osmosis equipment is utilized to remove the TDC and EC value further. The filter module is also equipped with the reverse osmosis unit to remove dirt and other coarse contaminants as pretreatment. 10-micron filter, Chlorine Taste Odor (CTO), and Granular Active Carbon (GAC) are the main components in the filter module. The result in Tab. 2. shows the treatment result by reverse osmosis. TDS and EC value significantly reduced at approximately 95 – 98% from the initial value before the treatment.

Table 3. Reverse osmosis analysis result on pH, TDS, and EC

Time (minutes)	pH		TDS		EC	
	Before	After	Before	After	Before	After
5	8,0	8,2	2550	232	5070	467
10	8,0	8,2	2550	247	5070	496
15	8,0	8,2	2550	245	5070	493
20	8,0	8,2	2550	252	5070	500
25	8,0	8,2	2550	250	5070	503
30	8,0	8,2	2550	253	5070	504
35	8,0	8,2	2550	251	5070	505

TDS and EC analysis results after treatment with an ion exchanger is shown in Tab. 3. TDS value reduction by ion exchanger ranges between 67 – 70%, while EC value shows the same reduction range as TDS.

Table 4. Ion exchanger analysis result on pH, TDS, and EC

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Time (Minutes)	pH		TDS		EC	
	Before	After	Before	After	Before	After
5	8,0	8,3	2550	815	5070	1630
10	8,0	8,3	2550	793	5070	1586
15	8,0	8,3	2550	750	5070	1500
20	8.0	8.3	2550	729	5070	1458

4. Disscussion

There was little significant change in the pH value after treatment with the combined filter modules. There is an increase of about 2.5%–3.75%, so the filtered water tends to be alkaline, but the pH value is still within the standard guidelines for clean water. The TDS value has decreased by about 1.64–7.56%, which can be obtained with a combination of filter modules. Like the TDS value, the EC value also decreased between 1.84 and 7.37%. When compared with research conducted by Yaqin et al. [14], it was found that the filtration results for pH values dropped by about 6.25% so that the water tended to be neutral, and for TDS values, they increased by about 50%. Therefore, the combination of a 10-micron filter, silica sand, kaolin, zeolite, brick, and activated carbon in Experiment No. 14–20 showed better results in reducing TDS and EC values. These filter materials can remove minerals and salinity contained in brackish water. However, the salinity reduction was not significant enough. Odor, color, and turbidity can be removed by the filtration method.

The reverse osmosis performance in this study shows that it can effectively remove TDS and EC values around 99.5%. Compared to the research conducted by Ansari et al. [16], reverse osmosis can remove TDS values of around 98.8%. As a result, the reverse osmosis performance in this study is better than other studies, exceeding the maximum standards in standards set by the WHO. However, since the filtration method can remove odor, color, and turbidity, the brackish water is sufficient to meet daily household consumption needs.

Ion exchangers have the same ability to remove TDS and EC from brackish water. The treatment results show a decrease in TDS and EC values in the 67–70% range. Therefore, ion exchangers are less effective in removing TDS and EC than reverse osmosis. The TDS and EC values obtained after treatment with ion exchangers are higher than the standards set by the WHO, which are 500 ppm for TDS values and 300 s/cm for EC values—according to a study by Desmiarti et al. [17], using an ion exchanger and microfilter for water treatment results in a more significant reduction of TDS and EC values by approximately 89.01%-90.91% for four cartridges and one microfilter and approximately 95.94%-96.36% for six cartridges and one microfilter.

Reverse osmosis and ion exchanger are proven methods that can provide a sufficient treatment to get the clean water standard parameter. Reverse osmosis has the advantage of requiring no hazardous chemical agent, and a high-quality clean water standard can be achieved. However, the membrane is the sensitive item in reverse osmosis which requires careful attention and is costly. On the contrary side, the ion exchanger is more competitive even though it is less effective than reverse osmosis. The disadvantages of an ion exchanger lie in the requirement of the chemical agent to rinse or reactivate the resin, and is not able to remove bacterial or organic contamination.

The result may differ in each method because there are differences in parameters, such as raw water quality, filter materials, and the input flow rate before treatment. Combining physical methods by filtration and reverse osmosis or ion exchangers can remove contaminants in brackish water. Hence, the safe, clean drinking water quality parameter can be complied with.

5. Conclusion

The combination of local filter materials and applied water treatment equipment, especially in remote areas, proved to be cost-effective equipment. This equipment is very practical and helpful for local communities, especially in coastal regions in Indonesia and local communities in disaster-prone areas. Therefore, clean water can be produced locally and used for daily household consumption, as the filtration method can largely remove odor, color, and turbidity. In terms of maintenance, the filter is easy to maintain and clean regularly.

As the filtration method can't remove TDS and EC further, reverse osmosis, and ion exchanger can obtain the standard safe drink water quality according to WHO standard guidelines. Specific instructions for maintaining a semi-permeable membrane in reverse osmosis or how to do a chemical rinse for ion exchanger resin must be available for the community to do the maintenance themselves.

Based on the results of this study, it is expected that compact, effective water treatment equipment for disaster-prone locations can be created. The treated brackish water from the filtration method with local filter media can be treated further in conjunction with reverse osmosis or ion exchange. As there are two options for further treatment, the advantages and disadvantages from the economic and maintenance point of view should be considered. In terms of disaster-prone areas, the community will need to have simple water treatment equipment and low maintenance. Therefore, cost-effective and low-maintenance water treatment equipment in the long term can serve as the next step in this research.

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7. Conflicts of Interest

There is no conflict of interest stated by the authors.

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Apr 5, 2023, 4:21 PM

to Benjamin

Dear Prof. Ben

Berikut dilampirkan revisi paper dimaksud.
Mohon bantuan review nya.
Terimakasih

Salam,
Surya

...

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Brackish Water Tr...

A Practical Implementation of Brackish Water Treatment With Local Material in Sidoarjo Regency, East Java, Indonesia

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Abstract: Indonesia, an archipelago with vast coastal areas consisting of 809 coastal villages, still faces the same problems of clean water scarcity and accessibility. This research goals are to discover appropriate inexpensive local filtering media and lower the salinity of brackish water in Sidoarjo Regency Indonesia. Regarding previous invention and research, this study deploy an experimental method by physical experiment including local materials along with chemical experiment: ion exchangers as well as reverse osmosis (RO). The outcomes demonstrate that local media filtration utilizing a combination of a 10-micron filter, kaolin, zeolite, kaolin, activated carbon, and kaolin is the best combination to produce the most transparent, and odorless water. It can reduce Total Dissolved Solid (TDS) and Electrical Condactivity (EC) values by 8.59% and 7.18%, and reduce pH levels by 2.59%. On the other hand, reverse osmosis and ion exchange can achieve 99.5% and 67% reductions in TDS and EC values, respectively.

Keywords: clean water crisis, brackish water, local filter material, reverse osmosis, ion exchanger

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Introduction

Water is an essential resource for humans to fulfill their daily needs. The demand for clean water increase yearly, so people worldwide are facing water crisis. The term clean water crisis not only relates to the amount of water available but also relates to low water quality. Some factors that cause the clean water crisis to worsen are increasing population growth and rapidly increasing industry [1]. The bad habits of the community, especially urban communities, in wasting clean water and environmental pollution worsen water supply and quality. Due to the clean water crisis, nearly one (1) billion people are unable to access clean water, 3.4 million people die from drinking contaminated water, millions of people must travel an average of 6 km daily to access clean water, and at any given time, half of all hospitals in the world are full of patients with diseases related to the clean water crisis [2]. The clean water crisis is worse for people living in coastal areas worldwide. The Southwestern coastal regions of Bangladesh and Europe are experiencing drinking water scarcity. Many factors contribute to water scarcity,

including seawater intrusion, decreased upstream water discharge, sea level rise, disasters, polders, arsenic poisoning, overuse of subsurface water, and others [3,4].

The Sustainable Development Goals (SDG) has set a global target of 100% access to drinkable water by 2030. However, there are still 80 million people who still need access to safe drinking water services. Even the capital city of Indonesia, Jakarta has yet to reach 100% access to safe drinking water. It is problematic for Indonesia because clean water source availability and accessibility from one place to another are not equal [5]. The main problem for the rural and coastal communities is their need for clean water. The most accessible natural water source in this region for the community's everyday needs and drinking water is groundwater. Still, as the ecosystem changes and industrial aquifer contamination increases, the quality of this resource is declining [6]. As a result, the socioeconomic impacts on the community are health and rising costs for clean water supplies.

The location for this research is Sidoarjo Regency, East Java, Indonesia (See Figure 1). As a river delta area between the Kalimas and Porong rivers and the coast, Sidoarjo has always been prone to natural disasters like flooding, typhoons, and tornadoes. In addition to the natural calamity, the local industrial region in Sidoarjo was the primary source of groundwater resource contamination. Both main factors above affect clean water resources availability for fulfilling the community's daily needs in farming and their daily consumption [7,8]. Hence, a suitable and cost-effective water treatment method must be developed and implemented to resolve the clean water resources availability issue in this area.

Figure 1. Sidoarjo Regency, East Java, Indonesia. Research work location

The only water source available in this area is household wells filled with brackish water from the Porong River. Based on the research that has been conducted, it is known that the water quality is classified as moderate using the Nasional Sanitation Foundation – Water Quality Index

(NSF-Wqi). It was found from the water samples obtained from two villages in Sidoarjo district, Tegal Sari and Tanjung Sari, in the Jabon sub-district, the turbidity content was 68 mg/l, total dissolved solids content (TDS) was 223 mg/l, and Escherichia. Coli content was 210 mg/100 ml, making it unsuitable for safe, clean water [9]. Therefore, clean water is purchased and periodically supplied by truck to the community to meet daily household needs. An alternative solution besides a clean water supply is treating brackish water with local filter media, which is abundantly available [10]. Local filter materials, such as silica sand, lumajang sand, pumice, bricks, sponge, alum, charcoal, active carbon, kaolin, bio ring, clam shell, red tile, and zeolite, can be used to treat the water.

Several studies have been conducted on brackish water treatment to address clean water supply. Jayaprakash et al. [11] have introduced a method to reduce iron, sulfate, chlorine, sodium, and TDS content in brackish water using activated carbon media. Khanzhanda et al. [12] have evaluated the performance of a combination of pretreatment and reverse osmosis. The first method combines cartridge pretreatment with reverse osmosis, and the second uses ultrafiltration with RO. Yogafanny et al. [13] have introduced a method using local zeolite material to reduce dissolved solids levels. Yaqin et al. [14] found a portable water purifier using silica sand, zeolite stone, greensand sand, zeolite manganese, bio-balls, and activated carbon. Barahoei et al. [15] have introduced a method to reduce salinity using chemical photosynthetic desalination cells. Ansari. et al. [16] evaluated the performance of brackish water desalination using reverse osmosis under different operational conditions. Desmiarti et al. [17] found a demineralized water method using a combination of continuous filtration and ion exchange processes.

Several references were also taken from several patents on brackish water purification devices. Tadd C. Kippeny et al. [18] made a patent entitled Water Desalination Apparatus with patent number US8377297B2, discussing using a salt sponge unit to remove most salt from water. A parallel plate capacitor can be connected after the salt sponge to remove the remaining salt ions. Chen et al. [19] made a patent entitled A kind of processing method of brackish water and a sort of saliferous water treatment system with patent number CN105174512B, discussing a brackish water treatment method by performing nanofiltration separation to obtain production water and nanofiltration concentrated water. Nanofiltration production water is subjected to a reverse osmosis separation process. Shen et al. [20] made a patent with the title Bitter (brackish) saltwater purifying equipment with patent number CN103073136A, discussing the manufacture of brackish saltwater purification equipment with multi-medium filter, automatic cleaning filter, and ultrafiltration membrane device.

This study aimed to identify a technique for obtaining clean water from brackish water by choosing filtration with suitable local material, reverse osmosis, and ion exchanger. Based on the research results, it is expected that the implementation of this method can provide a practical solution for overcoming the clean water crisis if it is put into practice. The test results will be compared to the WHO drinking water standard for water quality criteria, including pH (Power of Hydrogen), TDS (Total Dissolved Solids), EC (Electrical Conductivity), odor, and color.

Material and Method

Experimental study use physical and chemical methods to discover the optimal combination for on-site brackish water treatment silica sand, lumajang sand, alum, carbon active, sponge, pumice, kaolin, red brick, red tile, charcoal, zeolite, bio ring, clam shell, and a filter 10 micron comprise the filter module combination set. Reverse osmosis and ion exchanger equipment will be utilized to further treat the water purified by the filtration method.

Material

Silica Sand

Silica sand, or quartz sand, contains about 99.7% silicon dioxide (SiO2). Silica sand is a very effective water filtration medium because it can precipitate and retain impurities from the treated water. It is expected that silica sand can remove mud contained in brackish water (Fig 2.a). [21].

Lumajang Sand

Lumajang Sand is formed from silicon dioxide content or limestone. Generally, the size of sand is 0.0625 mm to 2 mm [22]. The function of sand for water filters is to hold silt and fine impurities. The type of sand used in this study comes from Lumajang, East Java, Indonesia. The characteristic of this sand is the color of the sand, the sand has a gray to black color (Fig 2.b).

Alum

Alum is found in nature as a chemical compound known as hydrated aluminum sulphate salt in the white crystalline form (Fig 2.c). Potassium alum or potash alum is used to coagulate the impurities so that the impurities can be separated [23]. As it has the characteristic as coagulant agent, it is not only utilized in water treatment, but also in industrial sector, i.e., medicine, food preparation, and textile industry. An appropriate dosage of Alum should be added during the water treatment so that the treated water is safe for daily consumption.

Active Carbon

Active carbon is widely known for its physical properties, which includes a large surface area and homogeneous pore size (Fig 2.d). It is chemically inert and stable [24]. Based on the characteristic mentioned above, odor and color, which is caused by the organic compound in water, can be removed by adsorption. Hence water's taste and appearance can be improved [25]. However, both coarse and fine impurities in the water can't be separated by active carbon absorption.

Sponge

Sponge is commonly known as basic physical and mechanical filter media, which is simple and cost-effective. It is widely available and has a porous synthetic material capable of absorbing water and good aeration (Fig 2.e) [26]. The suspended solid particle in water can be separated by immersing it in the pore [27]. However, a limited number of dissolved impurities can be retained. Sponge, in terms of maintenance, can be effectively cleaned in specific periods and is easy to be utilized back as filter media.

Pumice

Pumice is a type of rock that is light in color and contains thick foam made of glass-walled bubbles (Fig 2.f) [28]. Pumice can remove coarse contaminants due to its large surface area and

up to 90% porosity. Pumice can be an absorbent material to remove heavy metals, radioactive, and dyes in wastewater [29]. The disadvantage of using this material as a filter is that pumice cannot remove fine impurities like sand filters. In terms of maintenance, the pumice filter is easier to maintain when compared to a sand filter, but it still takes quite a bit of time long enough.

Kaolin

Kaolin or kaolinite is a type of primary clay material that exists in nature, with the chemical formula $Al_2O_3.2SiO_2.2H_2O$ (Fig 2.g). Kaolin and activated carbon have similar physical properties with high surface area and stability. By absorption, Kaolin can remove toxic pollutants from water, such as chloride, sulfate, Cr, Cd, and Zn [30], [31]. The disadvantage of this filter media is that it cannot hold fine or coarse impurities.

Red Bricks

The function of red bricks in this water purification filter is to separate and precipitate the minerals in brackish water. The bricks used this time are red bricks. Red bricks have a large surface area and a high porosity making them suitable to be used as an absorbent material and filter waste (Fig 2.h) [32]. Given that red bricks are made of clay, this filter can help precipitate the minerals contained in the water. The disadvantage of this filter is that it cannot help purify water in terms of color.

Red Tile

Red tile is made from clay processing and then heated with coal with a certain degree of heat (Fig 2.i). The function of red tile in water filters is to help kill harmful minerals, and its weakness is that it cannot filter out impurities [33].

Charcoal

Another filter material known as an effective filter media is charcoal. The charcoal made from the coconut shell is high-quality, effective, and environmentally friendly. Like active carbon and kaolin, coconut shell charcoal can absorb and remove chemical pollutants in the water (Fig 2.j)[34]. As filtering media, shell charcoal has a slightly significant result, it can’t hold the coarse impurities in brackish water, whereas odor and taste can be improved. In terms of maintenance, a periodic replacement is needed and is easy to obtain as this material is commonly used in water treatment.

Zeolite

A form of hydrated alumina-silicate chemical compound with sodium, potassium, and barium cation is known as zeolite. Zeolite is formed naturally from volcanic and sedimentation rock in nature. It can retain or separate chemical molecules as it has molecular-sized pores (Fig 2.k). Zeolite, as an adsorbent, can cation exchange due to its negative electrical charge in them. This negative electrical charge can bind cations generally found in groundwater, i.e., Fe, Al, Ca, and Mg. [35]. Zeolite is used not only in water treatment but also for treating wastewater treatment. It is expected to remove heavy metal cations in wastewater, i.e., Zn, Cr, Pb, Cd, Cu, Mn, Fe, etc.

Bio Ring

Bio ring is made from ceramic and found in white color. It has a cylindrical form of 20 mm in height and 18 mm in diameter (Fig 2.l)[36]. The function of the bio ring in this filtration 200 is to

filter bacteria in brackish water. Bio rings have a large surface area and porosity. The number of pores in the bio ring gives the bio ring a high surface area, which is helpful for bacteria to colonize, allowing water to enter the pores easily [37]. The disadvantage of this filter is that it cannot filter impurities from the dirt in the brackish water.

Clam Shell

The public generally considers clamshell waste but have a high mineral content. The type of mineral present is calcium. Therefore the function of the shell in the water filter can be used as a natural mineral source (Fig 2.m)[38].

10 Micron Filter

The 10 Micron filter consists of a filter cartridge made of polypropylene. Cartridge filters come in various sizes, with pore diameters ranging from 20 to 1 micron. Therefore, using 10-micron filters in water filters can retain small particles that enter and improve the quality of treated water (Fig 2.n). When the cartridge filter is saturated, it must be replaced to maintain its function [39].

Reverse Osmosis (RO)

Reverse osmosis is the most modern type of water treatment. It is the most efficient separation technology used in some industrial locations for treating wastewater and seawater desalination for creating fresh water (Fig 2.o)[40,41,42]. Water pressure is applied through a semi-permeable membrane to remove dissolved inorganic contaminants from water. Fluoride, chlorine, nitrates, sulfate, pesticides, etc., dissolved pollutants in the water are removed during treatment [43]. Solid impurities must be separated using mechanical treatment, i.e., settling and filtration, so that it will not shorten the membrane interval maintenance and its lifespan time due to mechanical damage. To improve reverse osmosis performance, periodic maintenance and cleaning to remove fouling on the membrane surface must be conducted.

(a)

(b)

(c)

Figure 2. Materials for filter modules from local materials and reverse osmosis

Ion Exchanger

The ion exchanger is one of the desalination process's fundamental components. It functions by binding positive and negative ions with a substance called resin. There are two ion exchange resins: cation exchangers, which contain positively charged ions that are exchangeable (Fig 3.a and Fig 3.c), and anion exchangers, which have negatively charged ions that are exchangeable (Fig 3.b and Fig 3,c). Both cation and anion resins must be regenerated using a powerful acid or base. Using flow-through, column, or tank systems, the ion exchange process transforms produced brackish water into drinkable or disposable water [44]. Most often, ion exchange media are used to remediate waste, soil, and water. This study will employ ion exchange media to treat brackish water widely found in coastal and rural locations. Ion exchange therapy is one approach for fixing domestic water problems. It can eliminate toxic contaminants from water [45,46].

(a) **(b)** **(c)**

Figure 3. Material for Ion Exchanger. Anion and Kation Exchanger Resin

Research Methodology

The research methodology used in this study is experimental research, including literature from previous studies. A case study will follow. Related information and data on brackish water, for example, recent research on treatment methods and properties of brackish water, will be obtained as the basis of this research. The application of physical experiments in brackish water treatment in this research will be carried out by selecting local materials as filter media and reverse osmosis media. These local materials will be prepared in the filtration module. The application of chemical experiments using ion exchange resin will be used as water treatment equipment.

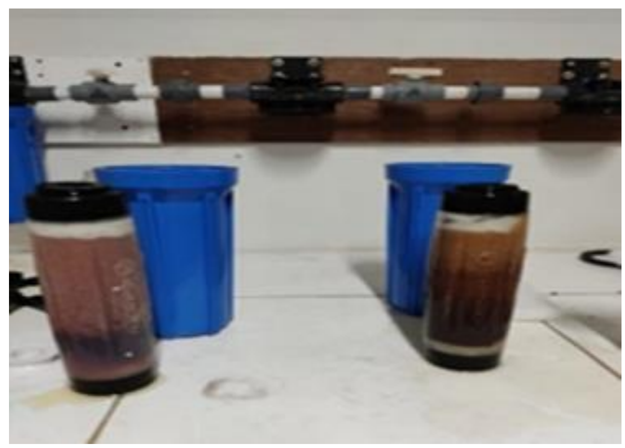
Filter Media Preparation and Assembly

Filter module assembly with selected local filter media was conducted in the laboratory (Fig.4.a). The brackish water sample is obtained from two villages, Tegal Sari and Kupang, in Jabon District, Sidoarjo Regency (Fig. 4.b). Reverse osmosis and ion exchanger cartridges will also be assembled in the laboratory (Fig .4.c and 4.d).

(a)

(b)

(c)



(d)

Figure 4. Water treatment equipment assembly (preparation for filter module, reverse osmosis, ion exhanger in filter module and obtaining brackish water sample)

There will be a pretreatment phase for filter media before it is filled into the filter module. Dirt and another contaminant will be eliminated by washing in the first phase (Fig. 5.a). Once the washing phase is completed, filter media will be dried in the oven. (Fig. 5. b). Mechanical phase, crushing, and screening are necessary for certain material to extend their surface area, which can be seen in (Fig. 5.c and 5.d).

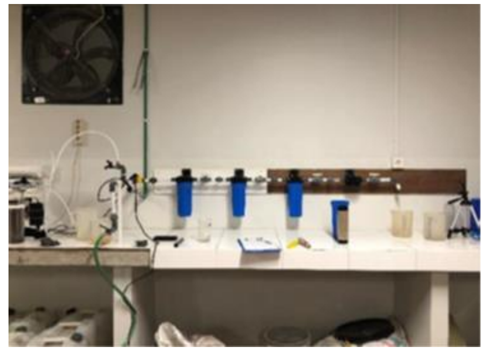
(a) (b)

(c) (d)

Figure 5. Filter media pre treatment phase (washing, drying, crushing and screening)

Filter Module Assembly

As the filter media has completed its pretreatment phase, it will be filled into each filter module (Fig. 6.a). A brackish water sample will be pumped into the filtration module (Fig. 6.b). The treated brackish water from the filtration module will be analyzed for its water quality parameter, i.e., pH, TDS, EC, odor, and color will be observed and measured (Fig. 6.c and Fig 6.d). The combination of local filter media used in this study amounted to 25 combinations which be described in Tabel 1. For instance: the first experiment, the combination module 1, 2, and 3 utilized: lumajang sand, charcoal, and bricks, respectively.



(a) **(b)**

(c) **(d)**

Figure 6. Filter module assembly (water quality parameter analysis for treated water after filtration)

The brackish water sample will be analyzed before the treatment in the laboratory to get the initial water quality parameter value. It has an average pH of 8.0, a TDS value of 2550 ppm, EC value of 5070 µs/cm. Color, odor, and turbidity of the water sample before and after treatment are also observed. The standard water quality criterion will be based on the Minister of Health Republic of Indonesia Regulation No. 492, 2010, and the WHO drinking water quality standards. As per water parameter quality standards, clean water has an average pH between 6.5 – 8.5, a TDS value lower than 500 ppm, and an EC value lower than 300 µs/cm. As physical criteria, clean water must be odorless and colorless [47,48]. The water quality parameter after the treatment will be compared with the standard above.

Table 1. Filter module combination with local filter media

No	Module 1	Module 2	Module 3	Module 4	Module 5	Module 6
1	Lumajang Sand	Charcoal	Bricks			
2	Lumajang Sand	Pumice	Bricks	Kaolin	Active Carbon	
3	Lumajang Sand	Pumice	Bricks	Kaolin	Active Carbon	
4	Lumajang Sand	Pumice	Bricks	Kaolin	Active Carbon	
5	Lumajang Sand	Carbon Active	Bricks	Zeolite	Kaolin	
6	Lumajang Sand	Red Tile	Zeolite	Zeolite	Kaolin	Active Carbon
7	Zeolite	Zeolite				
8	Clamshell					
9	Fliter					
10	Active Carbon					
11	Active Carbon	Active Carbon				
12	Kaolin					
13	Bio Ring					
14	Filter	Kaolin	Zeolite	Kaolin	Kaolin	Kaolin
15	Fliter	Kaolin	Zeolite	Kaolin	Active Carbon	Kaolin
16	Bricks					
17	Lumajang Sand	Bricks				
18	Lumajang Sand	Bricks	Bricks			
19	Lumajang Sand	Bricks	Bricks	Sand		
20	Kaolin	Active Carbon	Active Carbon	Active Carbon	Filter 10 Micron	
21	Alum	Zeolite	Kaolin	Silica Sand		
22	Alum	Kaolin	Filter 10 Micron	Kaolin		
23	Zeolite	Silica Sand	Filter 10 Micron	Sponge		
24	Silica Sand	Zeolite	Charcoal	Filter 10 Micron		
25	Silica Sand	Zeolite	Sponge	Filter 10 Micron		

Result

pH, TDS, and EC of the treated water, as the determining water quality parameter, will be measured and described in two sections. The analysis result after the filtration through the filter module combination will be shown in the first section. The analysis results from reverse osmosis and ion exchanger can be seen in the second section. Based on brackish water before and after treatment analysis results, the treatment effectiveness from both filtration method, reverse osmosis, and ion exchanger can be further evaluated.

Water Quality Parameter After Filtration with Local Filter Media

pH

As shown in Fig. 7, the filtration result shows that the pH value range is between 6.6 to 8.6. The highest increase in pH value from 7.7 to 8.4 is shown in experiments 6, while the highest decrease in pH value from 8.6 to 8 occurred in experiments 1. The pH value after treatment is still acceptable based on the quality standard except for experiments 21, and 22.

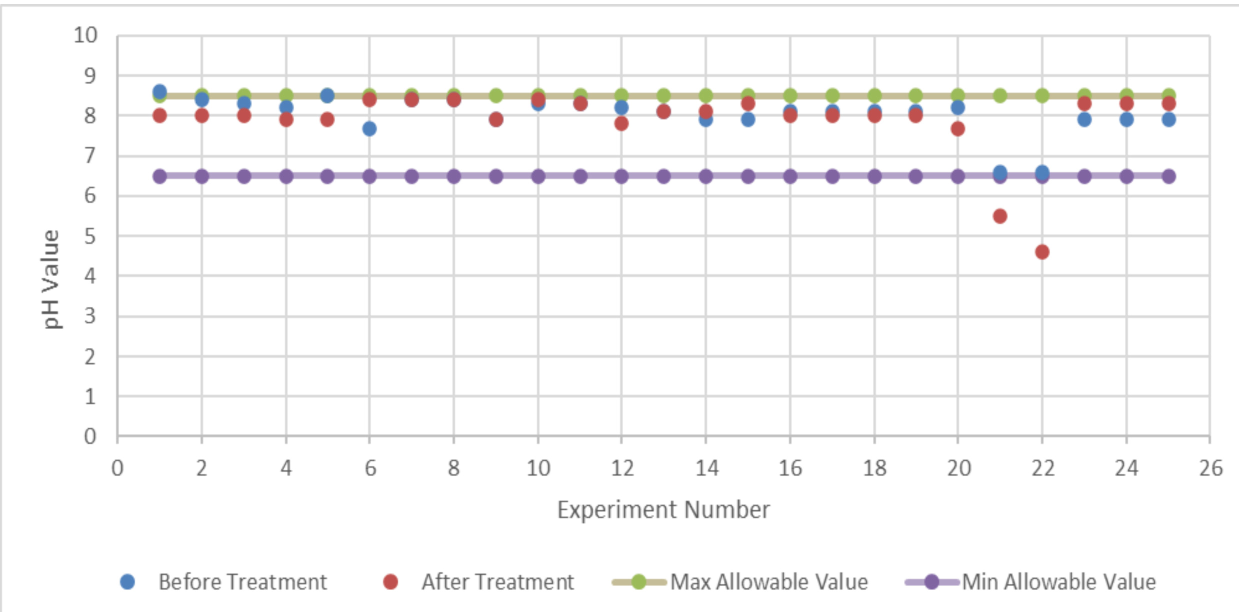


Figure 7. pH value comparison, before and after filtration

TDS value shows a decreasing trend after filtration. It can be seen in Fig. 8 that the TDS value after the treatment is in the range between 2340 – 4810 ppm. Experiment no. 15 result has the highest decrease in TDS value from 2560 ppm to 2340 ppm, equal to 8.59%.

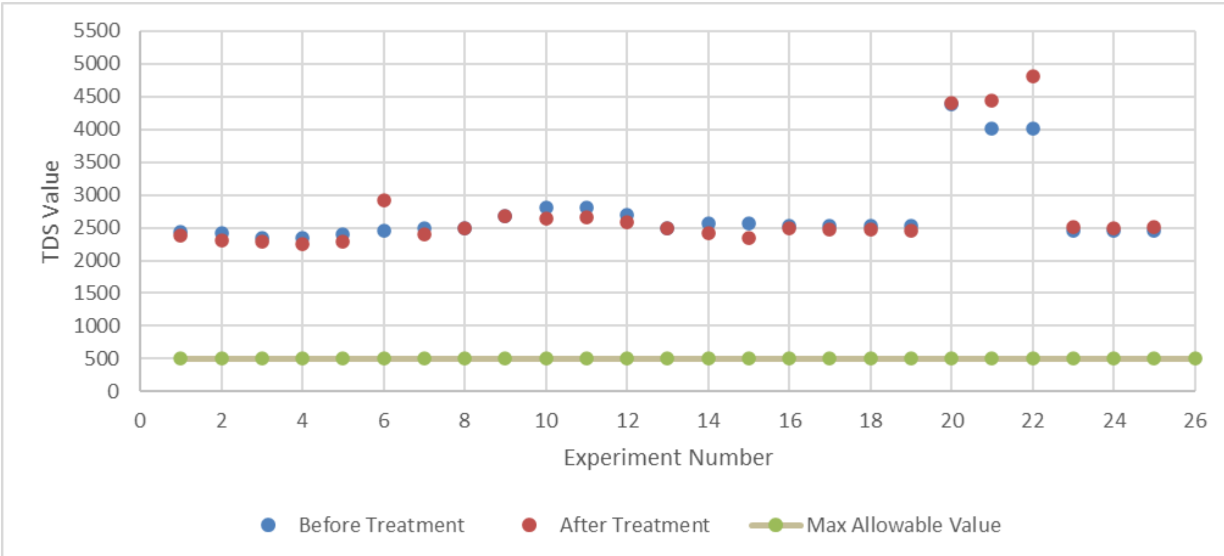


Figure 8. TDS value comparison, before and after filtration

The same decreasing trend in EC value is also obtained after filtration. The average EC value after filtration ranges between 4530 – 9800 μs/cm. Like the TDS value, experiment no. 15 has demonstrated the highest decrease in EC value from 5150 μs/cm to 4780 μs/cm. The filtration method can achieve an average reduction between 3.9% - 7.18% in EC value. The comparison of EC values before and after filtration is shown in Fig. 9.

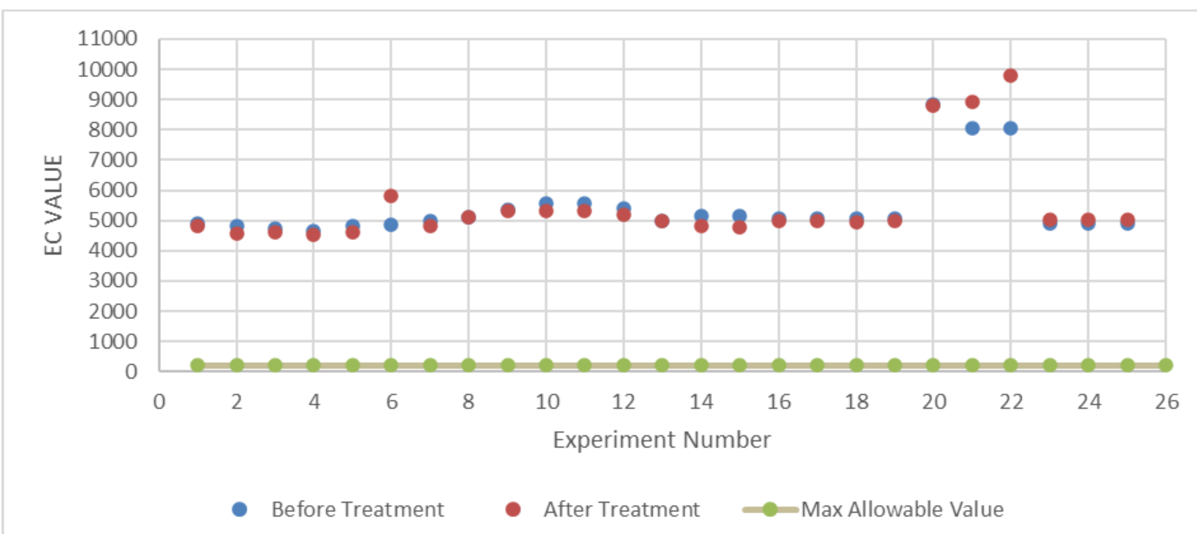


Figure 9. EC value comparison, before and after filtration

Water Quality Parameter from Reverse Osmosis and Ion Exchanger

As TDS and EC values from the treated water, the filtration method with selected local material still exceeds the WHO clean water standard guideline, reverse osmosis equipment is

utilized to remove the TDC and EC value further. The filter module is also equipped with the reverse osmosis unit to remove dirt and other coarse contaminants as pretreatment. 10-micron filter, Chlorine Taste Odor (CTO), and Granular Active Carbon (GAC) are the main components in the filter module. The result in Table 2 shows the treatment result by reverse osmosis. TDS and EC value significantly reduced at approximately 95 – 98% from the initial value before the treatment.

Table 2. Reverse osmosis analysis result on pH, TDS, and EC

Time	pH		TDS		EC	
(minutes)	Before	After	Before	After	Before	After
5	8	8,2	2550	232	5070	467
10	8	8,2	2550	247	5070	496
15	8	8,2	2550	245	5070	493
20	8	8,2	2550	252	5070	500
25	8	8,2	2550	250	5070	503
30	8	8,2	2550	253	5070	504
35	8	8,2	2550	251	5070	505

TDS and EC analysis results after treatment with an ion exchanger is shown in Table 3. TDS value reduction by ion exchanger ranges between 67 – 70%, while EC value shows the same reduction range as TDS.

Table 3. Ion exchanger analysis result on pH, TDS, and EC

Time	pH		TDS		EC	
(Minutes)	Before	After	Before	After	Before	After
5	8	8,3	2550	815	5070	1630
10	8	8,3	2550	793	5070	1586
15	8	8,3	2550	750	5070	1500
20	8.0	8.3	2550	729	5070	1458

Disscussion

There was little significant change in the pH value after treatment with the combined filter modules. There is an increase of about 2.23%, so the filtered water tends to be alkaline, but the pH value is still within the standard guidelines for clean water. The TDS value has decreased by about 1.64–7.56%, which can be obtained with a combination of filter modules. Like the TDS value, the EC value also decreased between 3.9% and 7.18%. When compared with research conducted by Yaqin et al. [14], it was found that the filtration results for pH values dropped by about 6.25% so that the water tended to be neutral, and for TDS values, they increased by about 50%. Therefore, the combination of a 10-micron filter, silica sand, kaolin, zeolite, brick, and activated carbon in Experiment No. 14–20 showed better results in reducing TDS and EC values. These filter materials can remove minerals and salinity contained in brackish water. However, the salinity reduction was not significant enough. Odor, color, and turbidity can be removed by the filtration method.

The reverse osmosis performance in this study shows that it can effectively remove TDS and EC values around 99.5%. Compared to the research conducted by Ansari et al. [16], reverse osmosis can remove TDS values of around 98.8%. As a result, the reverse osmosis performance in this study is better than other studies, exceeding the maximum standards in standards set by the WHO. However, since the filtration method can remove odor, color, and turbidity, the brackish water is sufficient to meet daily household consumption needs.

Ion exchangers have the same ability to remove TDS and EC from brackish water. The treatment results show a decrease in TDS and EC values in the 67–70% range. Therefore, ion exchangers are less effective in removing TDS and EC than reverse osmosis. The TDS and EC values obtained after treatment with ion exchangers are higher than the standards set by the WHO, which are 500 ppm for TDS values and 300 s/cm for EC values—according to a study by Desmiarti et al. [17], using an ion exchanger and microfilter for water treatment results in a more significant reduction of TDS and EC values by approximately 89.01%-90.91% for four cartridges and one microfilter and approximately 95.94%-96.36% for six cartridges and one microfilter.

Reverse osmosis and ion exchanger are proven methods that can provide a sufficient treatment to get the clean water standard parameter. Reverse osmosis has the advantage of requiring no hazardous chemical agent, and a high-quality clean water standard can be achieved. However, the membrane is the sensitive item in reverse osmosis which requires careful attention and is costly. On the contrary side, the ion exchanger is more competitive even though it is less effective than reverse osmosis. The disadvantages of an ion exchanger lie in the requirement of the chemical agent to rinse or reactivate the resin, and is not able to remove bacterial or organic contamination.

The result may differ in each method because there are differences in parameters, such as raw water quality, filter materials, and the input flow rate before treatment. Combining physical methods by filtration and reverse osmosis or ion exchangers can remove contaminants in brackish water. Hence, the safe, clean drinking water quality parameter can be complied with.

Conclusion

The combination of local filter materials and applied water treatment equipment, especially in remote areas, proved to be cost-effective equipment. This equipment is very practical and helpful for local communities, especially in coastal regions in Indonesia and local communities in disaster-prone areas. Therefore, clean water can be produced locally and used for daily household consumption, as the filtration method can largely remove odor, color, and turbidity. In terms of maintenance, the filter is easy to maintain and clean regularly.

The results of the research study showed that water filters using local materials are able to reduce TDS, EC, and pH values. The best combination to reduce TDS, EC, and pH values is a combination of a 10-micron filter, kaolin, zeolite, kaolin, activated carbon, and kaolin. It was found that the values of TDS, EC, and pH were able to be reduced by 8.59%, 7.18%, and 2.59%, respectively.

As the filtration method can't remove TDS and EC further, reverse osmosis, and ion exchanger can obtain the standard safe drink water quality according to WHO standard guidelines. Specific instructions for maintaining a semi-permeable membrane in reverse osmosis

or how to do a chemical rinse for ion exchanger resin must be available for the community to do the maintenance themselves.

Based on the results of this study, it is expected that compact, effective water treatment equipment for disaster-prone locations can be created. The treated brackish water from the filtration method with local filter media can be treated further in conjunction with reverse osmosis or ion exchange. As there are two options for further treatment, the advantages and disadvantages from the economic and maintenance point of view should be considered. In terms of disaster-prone areas, the community will need to have simple water treatment equipment and low maintenance. Therefore, cost-effective and low-maintenance water treatment equipment in the long term can serve as the next step in this research.

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Benjamin Lumantarna <bluman@petra.ac.id> Apr 6, 2023, 10:32 AM

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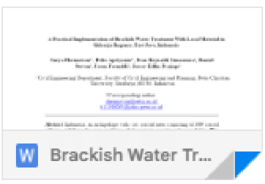

A Practical Implementation of Brackish Water Treatment With Local Material in Sidoarjo Regency, East Java, Indonesia

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Abstract: Indonesia, an archipelago with vast coastal areas consisting of 809 coastal villages, still faces the same problems of clean water scarcity and accessibility. This research goals are to discover appropriate inexpensive local filtering media and lower the salinity of brackish water in Sidoarjo Regency Indonesia. Regarding previous invention and research, this study deploy an experimental method by physical experiment including local materials along with chemical experiment: ion exchangers as well as reverse osmosis (RO). The outcomes demonstrate that local media filtration utilizing a combination of a 10-micron filter, kaolin, zeolite, kaolin, activated carbon, and kaolin is the best combination to produce the most transparent, and odorless water. It can reduce Total Dissolved Solid (TDS) and Electrical Condactivity (EC) values by 8.59% and 7.18%, and reduce pH levels by 2.59%. On the other hand, reverse osmosis and ion exchange can achieve 99.5% and 67% reductions in TDS and EC values, respectively.

Keywords: clean water crisis, brackish water, local filter material, reverse osmosis, ion exchanger

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Introduction

Water is an essential resource for humans to fulfill their daily needs. The demand for clean water increase yearly, so people worldwide are facing water crisis. The term clean water crisis not only relates to the amount of water available but also relates to low water quality. Some factors that cause the clean water crisis to worsen are increasing population growth and rapidly increasing industry [1]. The bad habits of the community, especially urban communities, in wasting clean water and environmental pollution worsen water supply and quality. Due to the clean water crisis, nearly one (1) billion people are unable to access clean water, 3.4 million people die from drinking contaminated water, millions of people must travel an average of 6 km daily to access clean water, and at any given time, half of all hospitals in the world are full of patients with diseases related to the clean water crisis [2]. The clean water crisis is worse for people living in coastal areas worldwide. The Southwestern coastal regions of Bangladesh and Europe are experiencing drinking water scarcity. Many factors contribute to water scarcity,

including seawater intrusion, decreased upstream water discharge, sea level rise, disasters, polders, arsenic poisoning, overuse of subsurface water, and others [3,4].

The Sustainable Development Goals (SDG) has set a global target of 100% access to drinkable water by 2030. However, there are still 80 million people who still need access to safe drinking water services. Even the capital city of Indonesia, Jakarta has yet to reach 100% access to safe drinking water. It is problematic for Indonesia because clean water source availability and accessibility from one place to another are not equal [5]. The main problem for the rural and coastal communities is their need for clean water. The most accessible natural water source in this region for the community's everyday needs and drinking water is groundwater. Still, as the ecosystem changes and industrial aquifer contamination increases, the quality of this resource is declining [6]. As a result, the socioeconomic impacts on the community are health and rising costs for clean water supplies.

The location for this research is Sidoarjo Regency, East Java, Indonesia (See Figure 1). As a river delta area between the Kalimas and Porong rivers and the coast, Sidoarjo has always been prone to natural disasters like flooding, typhoons, and tornadoes. In addition to the natural calamity, the local industrial region in Sidoarjo was the primary source of groundwater resource contamination. Both main factors above affect clean water resources availability for fulfilling the community's daily needs in farming and their daily consumption [7,8]. Hence, a suitable and cost-effective water treatment method must be developed and implemented to resolve the clean water resources availability issue in this area.

Figure 1. Sidoarjo Regency, East Java, Indonesia. Research work location

The only water source available in this area is household wells filled with brackish water from the Porong River. Based on the research that has been conducted, it is known that the water quality is classified as moderate using the Nasional Sanitation Foundation – Water Quality Index

(NSF-Wqi). It was found from the water samples obtained from two villages in Sidoarjo district, Tegal Sari and Tanjung Sari, in the Jabon sub-district, the turbidity content was 68 mg/l, total dissolved solids content (TDS) was 223 mg/l, and Escherichia. Coli content was 210 mg/100 ml, making it unsuitable for safe, clean water [9]. Therefore, clean water is purchased and periodically supplied by truck to the community to meet daily household needs. An alternative solution besides a clean water supply is treating brackish water with local filter media, which is abundantly available [10]. Local filter materials, such as silica sand, lumajang sand, pumice, bricks, sponge, alum, charcoal, active carbon, kaolin, bio ring, clam shell, red tile, and zeolite, can be used to treat the water.

Several studies have been conducted on brackish water treatment to address clean water supply. Jayaprakash et al. [11] have introduced a method to reduce iron, sulfate, chlorine, sodium, and TDS content in brackish water using activated carbon media. Khanzhanda et al. [12] have evaluated the performance of a combination of pretreatment and reverse osmosis. The first method combines cartridge pretreatment with reverse osmosis, and the second uses ultrafiltration with RO. Yogafanny et al. [13] have introduced a method using local zeolite material to reduce dissolved solids levels. Yaqin et al. [14] found a portable water purifier using silica sand, zeolite stone, greensand sand, zeolite manganese, bio-balls, and activated carbon. Barahoei et al. [15] have introduced a method to reduce salinity using chemical photosynthetic desalination cells. Ansari. et al. [16] evaluated the performance of brackish water desalination using reverse osmosis under different operational conditions. Desmiarti et al. [17] found a demineralized water method using a combination of continuous filtration and ion exchange processes.

Several references were also taken from several patents on brackish water purification devices. Tadd C. Kippeny et al. [18] made a patent entitled Water Desalination Apparatus with patent number US8377297B2, discussing using a salt sponge unit to remove most salt from water. A parallel plate capacitor can be connected after the salt sponge to remove the remaining salt ions. Chen et al. [19] made a patent entitled A kind of processing method of brackish water and a sort of saliferous water treatment system with patent number CN105174512B, discussing a brackish water treatment method by performing nanofiltration separation to obtain production water and nanofiltration concentrated water. Nanofiltration production water is subjected to a reverse osmosis separation process. Shen et al. [20] made a patent with the title Bitter (brackish) saltwater purifying equipment with patent number CN103073136A, discussing the manufacture of brackish saltwater purification equipment with multi-medium filter, automatic cleaning filter, and ultrafiltration membrane device.

This study aimed to identify a technique for obtaining clean water from brackish water by choosing filtration with suitable local material, reverse osmosis, and ion exchanger. Based on the research results, it is expected that the implementation of this method can provide a practical solution for overcoming the clean water crisis if it is put into practice. The test results will be compared to the WHO drinking water standard for water quality criteria, including pH (Power of Hydrogen), TDS (Total Dissolved Solids), EC (Electrical Conductivity), odor, and color.

Material and Method

Experimental study use physical and chemical methods to discover the optimal combination for on-site brackish water treatment silica sand, lumajang sand, alum, carbon active, sponge, pumice, kaolin, red brick, red tile, charcoal, zeolite, bio ring, clam shell, and a filter 10 micron comprise the filter module combination set. Reverse osmosis and ion exchanger equipment will be utilized to further treat the water purified by the filtration method.

Material

Silica Sand

Silica sand, or quartz sand, contains about 99.7% silicon dioxide (SiO2). Silica sand is a very effective water filtration medium because it can precipitate and retain impurities from the treated water. It is expected that silica sand can remove mud contained in brackish water (Fig 2.a). [21].

Lumajang Sand

Lumajang Sand is formed from silicon dioxide content or limestone. Generally, the size of sand is 0.0625 mm to 2 mm [22]. The function of sand for water filters is to hold silt and fine impurities. The type of sand used in this study comes from Lumajang, East Java, Indonesia. The characteristic of this sand is the color of the sand, the sand has a gray to black color (Fig 2.b).

Alum

Alum is found in nature as a chemical compound known as hydrated aluminum sulphate salt in the white crystalline form (Fig 2.c). Potassium alum or potash alum is used to coagulate the impurities so that the impurities can be separated [23]. As it has the characteristic as coagulant agent, it is not only utilized in water treatment, but also in industrial sector, i.e., medicine, food preparation, and textile industry. An appropriate dosage of Alum should be added during the water treatment so that the treated water is safe for daily consumption.

Active Carbon

Active carbon is widely known for its physical properties, which includes a large surface area and homogeneous pore size (Fig 2.d). It is chemically inert and stable [24]. Based on the characteristic mentioned above, odor and color, which is caused by the organic compound in water, can be removed by adsorption. Hence water's taste and appearance can be improved [25]. However, both coarse and fine impurities in the water can't be separated by active carbon absorption.

Sponge

Sponge is commonly known as basic physical and mechanical filter media, which is simple and cost-effective. It is widely available and has a porous synthetic material capable of absorbing water and good aeration (Fig 2.e) [26]. The suspended solid particle in water can be separated by immersing it in the pore [27]. However, a limited number of dissolved impurities can be retained. Sponge, in terms of maintenance, can be effectively cleaned in specific periods and is easy to be utilized back as filter media.

Pumice

Pumice is a type of rock that is light in color and contains thick foam made of glass-walled bubbles (Fig 2.f) [28]. Pumice can remove coarse contaminants due to its large surface area and

up to 90% porosity. Pumice can be an absorbent material to remove heavy metals, radioactive, and dyes in wastewater [29]. The disadvantage of using this material as a filter is that pumice cannot remove fine impurities like sand filters. In terms of maintenance, the pumice filter is easier to maintain when compared to a sand filter, but it still takes quite a bit of time long enough.

Kaolin

Kaolin or kaolinite is a type of primary clay material that exists in nature, with the chemical formula Al2O3.2SiO2.2H2O (Fig 2.g). Kaolin and activated carbon have similar physical properties with high surface area and stability. By absorption, Kaolin can remove toxic pollutants from water, such as chloride, sulfate, Cr, Cd, and Zn [30], [31]. The disadvantage of this filter media is that it cannot hold fine or coarse impurities.

Red Bricks

The function of red bricks in this water purification filter is to separate and precipitate the minerals in brackish water. The bricks used this time are red bricks. Red bricks have a large surface area and a high porosity making them suitable to be used as an absorbent material and filter waste (Fig 2.h) [32]. Given that red bricks are made of clay, this filter can help precipitate the minerals contained in the water. The disadvantage of this filter is that it cannot help purify water in terms of color.

Red Tile

Red tile is made from clay processing and then heated with coal with a certain degree of heat (Fig 2.i). The function of red tile in water filters is to help kill harmful minerals, and its weakness is that it cannot filter out impurities [33].

Charcoal

Another filter material known as an effective filter media is charcoal. The charcoal made from the coconut shell is high-quality, effective, and environmentally friendly. Like active carbon and kaolin, coconut shell charcoal can absorb and remove chemical pollutants in the water (Fig 2.j)[34]. As filtering media, shell charcoal has a slightly significant result, it can't hold the coarse impurities in brackish water, whereas odor and taste can be improved. In terms of maintenance, a periodic replacement is needed and is easy to obtain as this material is commonly used in water treatment.

Zeolite

A form of hydrated alumina-silicate chemical compound with sodium, potassium, and barium cation is known as zeolite. Zeolite is formed naturally from volcanic and sedimentation rock in nature. It can retain or separate chemical molecules as it has molecular-sized pores (Fig 2.k). Zeolite, as an adsorbent, can cation exchange due to its negative electrical charge in them. This negative electrical charge can bind cations generally found in groundwater, i.e., Fe, Al, Ca, and Mg. [35]. Zeolite is used not only in water treatment but also for treating wastewater treatment. It is expected to remove heavy metal cations in wastewater, i.e., Zn, Cr, Pb, Cd, Cu, Mn, Fe, etc.

Bio Ring

Bio ring is made from ceramic and found in white color. It has a cylindrical form of 20 mm in height and 18 mm in diameter (Fig 2.l)[36]. The function of the bio ring in this filtration 200 is to

filter bacteria in brackish water. Bio rings have a large surface area and porosity. The number of pores in the bio ring gives the bio ring a high surface area, which is helpful for bacteria to colonize, allowing water to enter the pores easily [37]. The disadvantage of this filter is that it cannot filter impurities from the dirt in the brackish water.

Clam Shell

The public generally considers clamshell waste but have a high mineral content. The type of mineral present is calcium. Therefore the function of the shell in the water filter can be used as a natural mineral source (Fig 2.m)[38].

10 Micron Filter

The 10 Micron filter consists of a filter cartridge made of polypropylene. Cartridge filters come in various sizes, with pore diameters ranging from 20 to 1 micron. Therefore, using 10-micron filters in water filters can retain small particles that enter and improve the quality of treated water (Fig 2.n). When the cartridge filter is saturated, it must be replaced to maintain its function [39].

Reverse Osmosis (RO)

Reverse osmosis is the most modern type of water treatment. It is the most efficient separation technology used in some industrial locations for treating wastewater and seawater desalination for creating fresh water (Fig 2.o)[40,41,42]. Water pressure is applied through a semi-permeable membrane to remove dissolved inorganic contaminants from water. Fluoride, chlorine, nitrates, sulfate, pesticides, etc., dissolved pollutants in the water are removed during treatment [43]. Solid impurities must be separated using mechanical treatment, i.e., settling and filtration, so that it will not shorten the membrane interval maintenance and its lifespan time due to mechanical damage. To improve reverse osmosis performance, periodic maintenance and cleaning to remove fouling on the membrane surface must be conducted.

(a) **(b)** **(c)**

Comment [B1]: Please give label on all picture

Figure 2. Materials for filter modules from local materials and reverse osmosis

Ion Exchanger

The ion exchanger is one of the desalination process's fundamental components. It functions by binding positive and negative ions with a substance called resin. There are two ion exchange resins: cation exchangers, which contain positively charged ions that are exchangeable (Fig 3.a and Fig 3.c), and anion exchangers, which have negatively charged ions that are exchangeable (Fig 3.b and Fig 3,c). Both cation and anion resins must be regenerated using a powerful acid or base. Using flow-through, column, or tank systems, the ion exchange process transforms produced brackish water into drinkable or disposable water [44]. Most often, ion exchange media are used to remediate waste, soil, and water. This study will employ ion exchange media to treat brackish water widely found in coastal and rural locations. Ion exchange therapy is one approach for fixing domestic water problems. It can eliminate toxic contaminants from water [45,46].

(a) **(b)** **(c)**

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Figure 3. Material for Ion Exchanger. Anion and Kation Exchanger Resin

Research Methodology

The research methodology used in this study is experimental research, including literature from previous studies. A case study will follow. Related information and data on brackish water, for example, recent research on treatment methods and properties of brackish water, will be obtained as the basis of this research. The application of physical experiments in brackish water treatment in this research will be carried out by selecting local materials as filter media and reverse osmosis media. These local materials will be prepared in the filtration module. The application of chemical experiments using ion exchange resin will be used as water treatment equipment.

Filter Media Preparation and Assembly

Filter module assembly with selected local filter media was conducted in the laboratory (Fig.4.a). The brackish water sample is obtained from two villages, Tegal Sari and Kupang, in Jabon District, Sidoarjo Regency (Fig. 4.b). Reverse osmosis and ion exchanger cartridges will also be assembled in the laboratory (Fig .4.c and 4.d).

(a)

(b)

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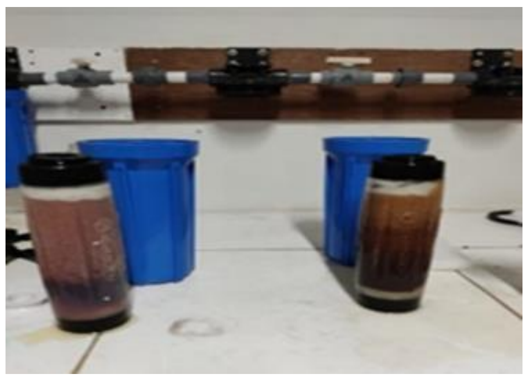
(c)



(d)

Figure 4. Water treatment equipment assembly (preparation for filter module, reverse osmosis, ion exhanger in filter module and obtaining brackish water sample)

There will be a pretreatment phase for filter media before it is filled into the filter module. Dirt and another contaminant will be eliminated by washing in the first phase (Fig. 5.a). Once the washing phase is completed, filter media will be dried in the oven. (Fig. 5. b). Mechanical phase, crushing, and screening are necessary for certain material to extend their surface area, which can be seen in (Fig. 5.c and 5.d).

(a) **(b)**

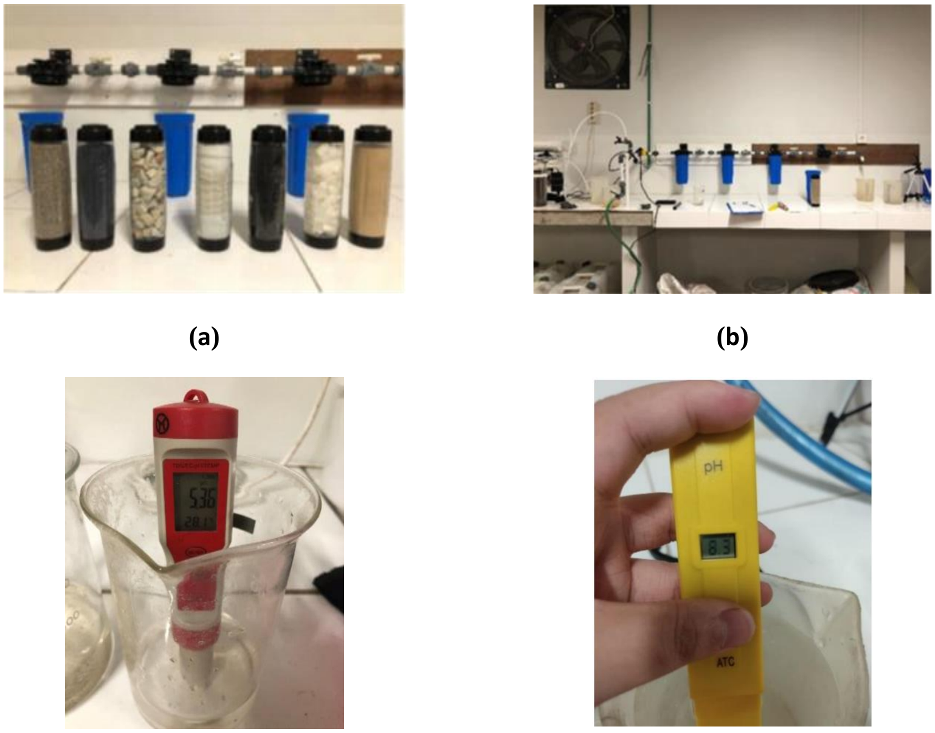
 

(c) **(d)**

Figure 5. Filter media pre treatment phase (washing, drying, crushing and screening)

Filter Module Assembly

As the filter media has completed its pretreatment phase, it will be filled into each filter module (Fig. 6.a). A brackish water sample will be pumped into the filtration module (Fig. 6.b). The treated brackish water from the filtration module will be analyzed for its water quality parameter, i.e., pH, TDS, EC, odor, and color will be observed and measured (Fig. 6.c and Fig 6.d). The combination of local filter media used in this study amount to 25 combinations which is described in Table 1. For instance: the first experiment, the combination module 1, 2, and 3 utilized: lumajang sand, charcoal, and bricks, respectively.



(a) (b)

(c) (d)

Figure 6. Filter module assembly (water quality parameter analysis for treated water after filtration)

The brackish water sample will be analyzed before the treatment in the laboratory to get the initial water quality parameter value. It has an average pH of 8.0, a TDS value of 2550 ppm, EC value of 5070 µs/cm. Color, odor, and turbidity of the water sample before and after treatment are also observed. The standard water quality criterion will be based on the Minister of Health Republic of Indonesia Regulation No. 492, 2010, and the WHO drinking water quality standards. As per water parameter quality standards, clean water has an average pH between 6.5 – 8.5, a TDS value lower than 500 ppm, and an EC value lower than 300 µs/cm. As physical criteria, clean water must be odorless and colorless [47,48]. The water quality parameter after the treatment will be compared with the standard above.

Table 1. Filter module combination with local filter media

No	Module 1	Module 2	Module 3	Module 4	Module 5	Module 6
1	Lumajang Sand	Charcoal	Bricks			
2	Lumajang Sand	Pumice	Bricks	Kaolin	Active Carbon	
3	Lumajang Sand	Pumice	Bricks	Kaolin	Active Carbon	
4	Lumajang Sand	Pumice	Bricks	Kaolin	Active Carbon	
5	Lumajang Sand	Carbon Active	Bricks	Zeolite	Kaolin	
6	Lumajang Sand	Red Tile	Zeolite	Zeolite	Kaolin	Active Carbon
7	Zeolite	Zeolite				
8	Clamshell					
9	Fliter					
10	Active Carbon					
11	Active Carbon	Active Carbon				
12	Kaolin					
13	Bio Ring					
14	Filter	Kaolin	Zeolite	Kaolin	Kaolin	Kaolin
15	Fliter	Kaolin	Zeolite	Kaolin	Active Carbon	Kaolin
16	Bricks					
17	Lumajang Sand	Bricks				
18	Lumajang Sand	Bricks	Bricks			
19	Lumajang Sand	Bricks	Bricks	Sand		
20	Kaolin	Active Carbon	Active Carbon	Active Carbon	Filter 10 Micron	
21	Alum	Zeolite	Kaolin	Silica Sand		
22	Alum	Kaolin	Filter 10 Micron	Kaolin		
23	Zeolite	Silica Sand	Filter 10 Micron	Sponge		
24	Silica Sand	Zeolite	Charcoal	Filter 10 Micron		
25	Silica Sand	Zeolite	Sponge	Filter 10 Micron		

Result

pH, TDS, and EC of the treated water, as the determining water quality parameter, will be measured and described in two sections. The analysis result after the filtration through the filter module combination will be shown in the first section. The analysis results from reverse osmosis and ion exchanger can be seen in the second section. Based on brackish water before and after treatment analysis results, the treatment effectiveness from both filtration method, reverse osmosis, and ion exchanger can be further evaluated.

Water Quality Parameter After Filtration with Local Filter Media

pH

As shown in Fig. 7, the filtration result shows that the pH value range is between 6.6 to 8.6. The highest increase in pH value from 7.7 to 8.4 is shown in experiments 6, while the highest decrease in pH value from 8.6 to 8 occurred in experiments 1. The pH value after treatment is still acceptable based on the quality standard except for experiments 21, and 22.

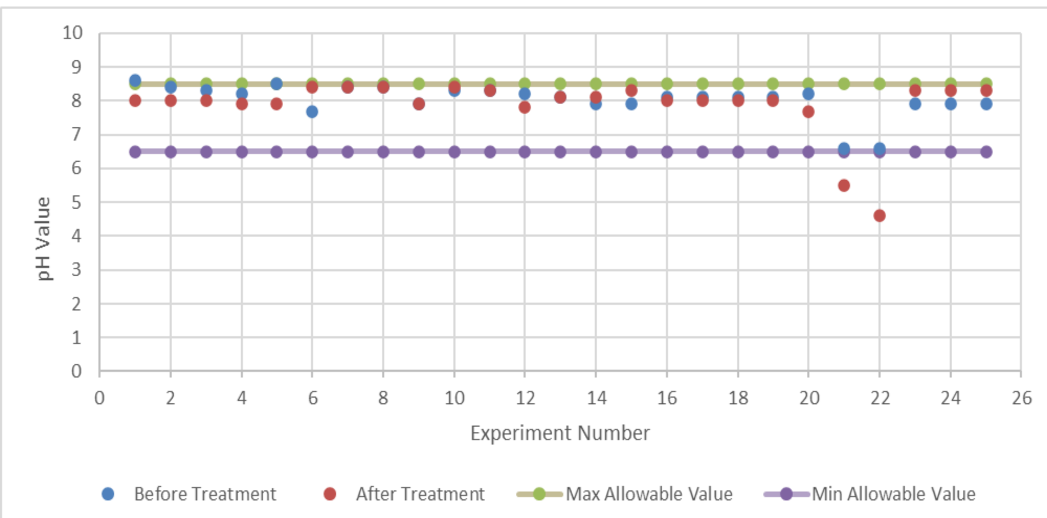


Figure 7. pH value comparison, before and after filtration

TDS value shows a decreasing trend after filtration. It can be seen in Fig. 8 that the TDS value after the treatment is in the range between 2340 – 4810 ppm. Experiment no. 15 result has the highest decrease in TDS value from 2560 ppm to 2340 ppm, equal to 8.59%.

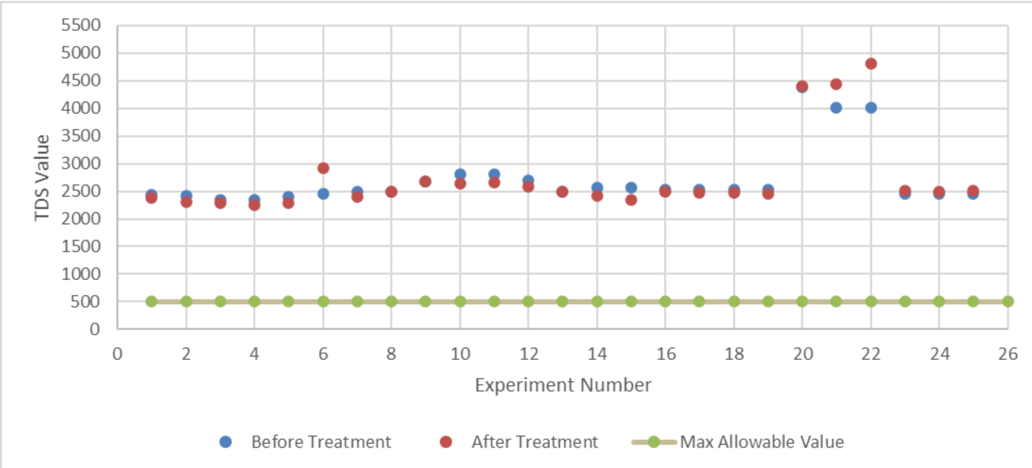


Figure 8. TDS value comparison, before and after filtration

The same decreasing trend in EC value is also obtained after filtration. The average EC value after filtration ranges between 4530 – 9800 µs/cm. Like the TDS value, experiment no. 15 has demonstrated the highest decrease in EC value from 5150 µs/cm to 4780 µs/cm. The filtration method can achieve an average reduction between 3.9% - 7.18% in EC value. The comparison of EC values before and after filtration is shown in Fig. 9.

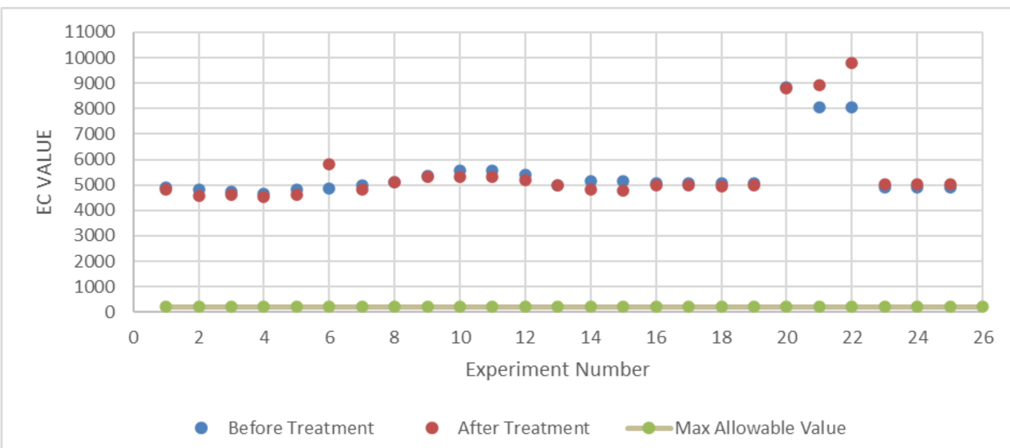


Figure 9. EC value comparison, before and after filtration

Water Quality Parameter from Reverse Osmosis and Ion Exchanger

As TDS and EC values from the treated water, the filtration method with selected local material still exceeds the WHO clean water standard guideline, reverse osmosis equipment is

utilized to remove the TDC and EC value further. The filter module is also equipped with the reverse osmosis unit to remove dirt and other coarse contaminants as pretreatment. 10-micron filter, Chlorine Taste Odor (CTO), and Granular Active Carbon (GAC) are the main components in the filter module. The result in Table 2 shows the treatment result by reverse osmosis. TDS and EC value significantly reduced at approximately 95 – 98% from the initial value before the treatment.

Table 2. Reverse osmosis analysis result on pH, TDS, and EC

Time	pH		TDS		EC	
(minutes)	Before	After	Before	After	Before	After
5	8	8,2	2550	232	5070	467
10	8	8,2	2550	247	5070	496
15	8	8,2	2550	245	5070	493
20	8	8,2	2550	252	5070	500
25	8	8,2	2550	250	5070	503
30	8	8,2	2550	253	5070	504
35	8	8,2	2550	251	5070	505

TDS and EC analysis results after treatment with an ion exchanger is shown in Table 3. TDS value reduction by ion exchanger ranges between 67 – 70%, while EC value shows the same reduction range as TDS.

Table 3. Ion exchanger analysis result on pH, TDS, and EC

Time	pH		TDS		EC	
(Minutes)	Before	After	Before	After	Before	After
5	8	8,3	2550	815	5070	1630
10	8	8,3	2550	793	5070	1586
15	8	8,3	2550	750	5070	1500
20	8.0	8.3	2550	729	5070	1458

Disscussion

There was little significant change in the pH value after treatment with the combined filter modules. There is an increase of about 2.23%, so the filtered water tends to be alkaline, but the pH value is still within the standard guidelines for clean water. The TDS value has decreased by about 1.64–7.56%, which can be obtained with a combination of filter modules. Like the TDS value, the EC value also decreased between 3.9% and 7.18%. When compared with research conducted by Yaqin et al. [14], it was found that the filtration results for pH values dropped by about 6.25% so that the water tended to be neutral, and for TDS values, they increased by about 50%. Therefore, the combination of a 10-micron filter, silica sand, kaolin, zeolite, brick, and activated carbon in Experiment No. 14–20 showed better results in reducing TDS and EC values. These filter materials can remove minerals and salinity contained in brackish water. However, the salinity reduction was not significant enough. Odor, color, and turbidity can be removed by the filtration method.

The reverse osmosis performance in this study shows that it can effectively remove TDS and EC values around 99.5%. Compared to the research conducted by Ansari et al. [16], reverse osmosis can remove TDS values of around 98.8%. As a result, the reverse osmosis performance in this study is better than other studies, exceeding the maximum standards in standards set by the WHO. However, since the filtration method can remove odor, color, and turbidity, the brackish water is sufficient to meet daily household consumption needs.

Ion exchangers have the same ability to remove TDS and EC from brackish water. The treatment results show a decrease in TDS and EC values in the 67–70% range. Therefore, ion exchangers are less effective in removing TDS and EC than reverse osmosis. The TDS and EC values obtained after treatment with ion exchangers are higher than the standards set by the WHO, which are 500 ppm for TDS values and 300 s/cm for EC values—according to a study by Desmiarti et al. [17], using an ion exchanger and microfilter for water treatment results in a more significant reduction of TDS and EC values by approximately 89.01%-90.91% for four cartridges and one microfilter and approximately 95.94%-96.36% for six cartridges and one microfilter.

Reverse osmosis and ion exchanger are proven methods that can provide a sufficient treatment to get the clean water standard parameter. Reverse osmosis has the advantage of requiring no hazardous chemical agent, and a high-quality clean water standard can be achieved. However, the membrane is the sensitive item in reverse osmosis which requires careful attention and is costly. On the contrary side, the ion exchanger is more competitive even though it is less effective than reverse osmosis. The disadvantages of an ion exchanger lie in the requirement of the chemical agent to rinse or reactivate the resin, and is not able to remove bacterial or organic contamination.

The result may differ in each method because there are differences in parameters, such as raw water quality, filter materials, and the input flow rate before treatment. Combining physical methods by filtration and reverse osmosis or ion exchangers can remove contaminants in brackish water. Hence, the safe, clean drinking water quality parameter can be complied with.

Conclusion

The combination of local filter materials and applied water treatment equipment, especially in remote areas, proved to be cost-effective equipment. This equipment is very practical and helpful for local communities, especially in coastal regions in Indonesia and local communities in disaster-prone areas. Therefore, clean water can be produced locally and used for daily household consumption, as the filtration method can largely remove odor, color, and turbidity. In terms of maintenance, the filter is easy to maintain and clean regularly.

The results of the research study showed that water filters using local materials are able to reduce TDS, EC, and pH values. The best combination to reduce TDS, EC, and pH values is a combination of a 10-micron filter, kaolin, zeolite, kaolin, activated carbon, and kaolin. It was found that the values of TDS, EC, and pH were able to be reduced by 8.59%, 7.18%, and 2.59%, respectively.

As the filtration method can’t remove TDS and EC further, reverse osmosis, and ion exchanger can obtain the standard safe drink water quality according to WHO standard guidelines. Specific instructions for maintaining a semi-permeable membrane in reverse osmosis

or how to do a chemical rinse for ion exchanger resin must be available for the community to do the maintenance themselves.

Based on the results of this study, it is expected that compact, effective water treatment equipment for disaster-prone locations can be created. The treated brackish water from the filtration method with local filter media can be treated further in conjunction with reverse osmosis or ion exchange. As there are two options for further treatment, the advantages and disadvantages from the economic and maintenance point of view should be considered. In terms of disaster-prone areas, the community will need to have simple water treatment equipment and low maintenance. Therefore, cost-effective and low-maintenance water treatment equipment in the long term can serve as the next step in this research.

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to Benjamin

Dear Prof. Ben

Baik Prof, berikut dilampirkan hasil revisi nya.
Terimakasih

Salam,
Surya

...

One attachment • Scanned by Gmail

Brackish Water Tr...

A Practical Implementation of Brackish Water Treatment With Local Material in Sidoarjo Regency, East Java, Indonesia

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Abstract: Indonesia, an archipelago with vast coastal areas consisting of 809 coastal villages, still faces the same problems of clean water scarcity and accessibility. This research goals are to discover appropriate inexpensive local filtering media and lower the salinity of brackish water in Sidoarjo Regency Indonesia. Regarding previous invention and research, this study deploy an experimental method by physical experiment including local materials along with chemical experiment: ion exchangers as well as reverse osmosis (RO). The outcomes demonstrate that local media filtration utilizing a combination of a 10-micron filter, kaolin, zeolite, kaolin, activated carbon, and kaolin is the best combination to produce the most transparent, and odorless water. It can reduce Total Dissolved Solid (TDS) and Electrical Condactivity (EC) values by 8.59% and 7.18%, and reduce pH levels by 2.59%. On the other hand, reverse osmosis and ion exchange can achieve 99.5% and 67% reductions in TDS and EC values, respectively.

Keywords: clean water crisis, brackish water, local filter material, reverse osmosis, ion exchanger

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Introduction

Water is an essential resource for humans to fulfill their daily needs. The demand for clean water increase yearly, so people worldwide are facing water crisis. The term clean water crisis not only relates to the amount of water available but also relates to low water quality. Some factors that cause the clean water crisis to worsen are increasing population growth and rapidly increasing industry [1]. The bad habits of the community, especially urban communities, in wasting clean water and environmental pollution worsen water supply and quality. Due to the clean water crisis, nearly one (1) billion people are unable to access clean water, 3.4 million people die from drinking contaminated water, millions of people must travel an average of 6 km daily to access clean water, and at any given time, half of all hospitals in the world are full of patients with diseases related to the clean water crisis [2]. The clean water crisis is worse for people living in coastal areas worldwide. The Southwestern coastal regions of Bangladesh and Europe are experiencing drinking water scarcity. Many factors contribute to water scarcity,

including seawater intrusion, decreased upstream water discharge, sea level rise, disasters, polders, arsenic poisoning, overuse of subsurface water, and others [3,4].

The Sustainable Development Goals (SDG) has set a global target of 100% access to drinkable water by 2030. However, there are still 80 million people who still need access to safe drinking water services. Even the capital city of Indonesia, Jakarta has yet to reach 100% access to safe drinking water. It is problematic for Indonesia because clean water source availability and accessibility from one place to another are not equal [5]. The main problem for the rural and coastal communities is their need for clean water. The most accessible natural water source in this region for the community's everyday needs and drinking water is groundwater. Still, as the ecosystem changes and industrial aquifer contamination increases, the quality of this resource is declining [6]. As a result, the socioeconomic impacts on the community are health and rising costs for clean water supplies.

The location for this research is Sidoarjo Regency, East Java, Indonesia (See Figure 1). As a river delta area between the Kalimas and Porong rivers and the coast, Sidoarjo has always been prone to natural disasters like flooding, typhoons, and tornadoes. In addition to the natural calamity, the local industrial region in Sidoarjo was the primary source of groundwater resource contamination. Both main factors above affect clean water resources availability for fulfilling the community's daily needs in farming and their daily consumption [7,8]. Hence, a suitable and cost-effective water treatment method must be developed and implemented to resolve the clean water resources availability issue in this area.

Figure 1. Sidoarjo Regency, East Java, Indonesia. Research work location

The only water source available in this area is household wells filled with brackish water from the Porong River. Based on the research that has been conducted, it is known that the water quality is classified as moderate using the Nasional Sanitation Foundation – Water Quality Index

(NSF-Wqi). It was found from the water samples obtained from two villages in Sidoarjo district, Tegal Sari and Tanjung Sari, in the Jabon sub-district, the turbidity content was 68 mg/l, total dissolved solids content (TDS) was 223 mg/l, and Escherichia. Coli content was 210 mg/100 ml, making it unsuitable for safe, clean water [9]. Therefore, clean water is purchased and periodically supplied by truck to the community to meet daily household needs. An alternative solution besides a clean water supply is treating brackish water with local filter media, which is abundantly available [10]. Local filter materials, such as silica sand, lumajang sand, pumice, bricks, sponge, alum, charcoal, active carbon, kaolin, bio ring, clam shell, red tile, and zeolite, can be used to treat the water.

Several studies have been conducted on brackish water treatment to address clean water supply. Jayaprakash et al. [11] have introduced a method to reduce iron, sulfate, chlorine, sodium, and TDS content in brackish water using activated carbon media. Khanzhanda et al. [12] have evaluated the performance of a combination of pretreatment and reverse osmosis. The first method combines cartridge pretreatment with reverse osmosis, and the second uses ultrafiltration with RO. Yogafanny et al. [13] have introduced a method using local zeolite material to reduce dissolved solids levels. Yaqin et al. [14] found a portable water purifier using silica sand, zeolite stone, greensand sand, zeolite manganese, bio-balls, and activated carbon. Barahoei et al. [15] have introduced a method to reduce salinity using chemical photosynthetic desalination cells. Ansari. et al. [16] evaluated the performance of brackish water desalination using reverse osmosis under different operational conditions. Desmiarti et al. [17] found a demineralized water method using a combination of continuous filtration and ion exchange processes.

Several references were also taken from several patents on brackish water purification devices. Tadd C. Kippeny et al. [18] made a patent entitled Water Desalination Apparatus with patent number US8377297B2, discussing using a salt sponge unit to remove most salt from water. A parallel plate capacitor can be connected after the salt sponge to remove the remaining salt ions. Chen et al. [19] made a patent entitled A kind of processing method of brackish water and a sort of saliferous water treatment system with patent number CN105174512B, discussing a brackish water treatment method by performing nanofiltration separation to obtain production water and nanofiltration concentrated water. Nanofiltration production water is subjected to a reverse osmosis separation process. Shen et al. [20] made a patent with the title Bitter (brackish) saltwater purifying equipment with patent number CN103073136A, discussing the manufacture of brackish saltwater purification equipment with multi-medium filter, automatic cleaning filter, and ultrafiltration membrane device.

This study aimed to identify a technique for obtaining clean water from brackish water by choosing filtration with suitable local material, reverse osmosis, and ion exchanger. Based on the research results, it is expected that the implementation of this method can provide a practical solution for overcoming the clean water crisis if it is put into practice. The test results will be compared to the WHO drinking water standard for water quality criteria, including pH (Power of Hydrogen), TDS (Total Dissolved Solids), EC (Electrical Conductivity), odor, and color.

Material and Method

Experimental study use physical and chemical methods to discover the optimal combination for on-site brackish water treatment silica sand, lumajang sand, alum, carbon active, sponge, pumice, kaolin, red brick, red tile, charcoal, zeolite, bio ring, clam shell, and a filter 10 micron comprise the filter module combination set. Reverse osmosis and ion exchanger equipment will be utilized to further treat the water purified by the filtration method.

Material

Silica Sand

Silica sand, or quartz sand, contains about 99.7% silicon dioxide (SiO2). Silica sand is a very effective water filtration medium because it can precipitate and retain impurities from the treated water. It is expected that silica sand can remove mud contained in brackish water (Fig 2.a). [21].

Lumajang Sand

Lumajang Sand is formed from silicon dioxide content or limestone. Generally, the size of sand is 0.0625 mm to 2 mm [22]. The function of sand for water filters is to hold silt and fine impurities. The type of sand used in this study comes from Lumajang, East Java, Indonesia. The characteristic of this sand is the color of the sand, the sand has a gray to black color (Fig 2.b).

Alum

Alum is found in nature as a chemical compound known as hydrated aluminum sulphate salt in the white crystalline form (Fig 2.c). Potassium alum or potash alum is used to coagulate the impurities so that the impurities can be separated [23]. As it has the characteristic as coagulant agent, it is not only utilized in water treatment, but also in industrial sector, i.e., medicine, food preparation, and textile industry. An appropriate dosage of Alum should be added during the water treatment so that the treated water is safe for daily consumption.

Active Carbon

Active carbon is widely known for its physical properties, which includes a large surface area and homogeneous pore size (Fig 2.d). It is chemically inert and stable [24]. Based on the characteristic mentioned above, odor and color, which is caused by the organic compound in water, can be removed by adsorption. Hence water's taste and appearance can be improved [25]. However, both coarse and fine impurities in the water can't be separated by active carbon absorption.

Sponge

Sponge is commonly known as basic physical and mechanical filter media, which is simple and cost-effective. It is widely available and has a porous synthetic material capable of absorbing water and good aeration (Fig 2.e) [26]. The suspended solid particle in water can be separated by immersing it in the pore [27]. However, a limited number of dissolved impurities can be retained. Sponge, in terms of maintenance, can be effectively cleaned in specific periods and is easy to be utilized back as filter media.

Pumice

Pumice is a type of rock that is light in color and contains thick foam made of glass-walled bubbles (Fig 2.f) [28]. Pumice can remove coarse contaminants due to its large surface area and

up to 90% porosity. Pumice can be an absorbent material to remove heavy metals, radioactive, and dyes in wastewater [29]. The disadvantage of using this material as a filter is that pumice cannot remove fine impurities like sand filters. In terms of maintenance, the pumice filter is easier to maintain when compared to a sand filter, but it still takes quite a bit of time long enough.

Kaolin

Kaolin or kaolinite is a type of primary clay material that exists in nature, with the chemical formula $Al2O3.2SiO2.2H2O$ (Fig 2.g). Kaolin and activated carbon have similar physical properties with high surface area and stability. By absorption, Kaolin can remove toxic pollutants from water, such as chloride, sulfate, Cr, Cd, and Zn [30], [31]. The disadvantage of this filter media is that it cannot hold fine or coarse impurities.

Red Bricks

The function of red bricks in this water purification filter is to separate and precipitate the minerals in brackish water. The bricks used this time are red bricks. Red bricks have a large surface area and a high porosity making them suitable to be used as an absorbent material and filter waste (Fig 2.h) [32]. Given that red bricks are made of clay, this filter can help precipitate the minerals contained in the water. The disadvantage of this filter is that it cannot help purify water in terms of color.

Red Tile

Red tile is made from clay processing and then heated with coal with a certain degree of heat (Fig 2.i). The function of red tile in water filters is to help kill harmful minerals, and its weakness is that it cannot filter out impurities [33].

Charcoal

Another filter material known as an effective filter media is charcoal. The charcoal made from the coconut shell is high-quality, effective, and environmentally friendly. Like active carbon and kaolin, coconut shell charcoal can absorb and remove chemical pollutants in the water (Fig 2.j)[34]. As filtering media, shell charcoal has a slightly significant result, it can’t hold the coarse impurities in brackish water, whereas odor and taste can be improved. In terms of maintenance, a periodic replacement is needed and is easy to obtain as this material is commonly used in water treatment.

Zeolite

A form of hydrated alumina-silicate chemical compound with sodium, potassium, and barium cation is known as zeolite. Zeolite is formed naturally from volcanic and sedimentation rock in nature. It can retain or separate chemical molecules as it has molecular-sized pores (Fig 2.k). Zeolite, as an adsorbent, can cation exchange due to its negative electrical charge in them. This negative electrical charge can bind cations generally found in groundwater, i.e., Fe, Al, Ca, and Mg. [35]. Zeolite is used not only in water treatment but also for treating wastewater treatment. It is expected to remove heavy metal cations in wastewater, i.e., Zn, Cr, Pb, Cd, Cu, Mn, Fe, etc.

Bio Ring

Bio ring is made from ceramic and found in white color. It has a cylindrical form of 20 mm in height and 18 mm in diameter (Fig 2.l)[36]. The function of the bio ring in this filtration 200 is to

filter bacteria in brackish water. Bio rings have a large surface area and porosity. The number of pores in the bio ring gives the bio ring a high surface area, which is helpful for bacteria to colonize, allowing water to enter the pores easily [37]. The disadvantage of this filter is that it cannot filter impurities from the dirt in the brackish water.

Clam Shell

The public generally considers clamshell waste but have a high mineral content. The type of mineral present is calcium. Therefore the function of the shell in the water filter can be used as a natural mineral source (Fig 2.m)[38].

10 Micron Filter

The 10 Micron filter consists of a filter cartridge made of polypropylene. Cartridge filters come in various sizes, with pore diameters ranging from 20 to 1 micron. Therefore, using 10-micron filters in water filters can retain small particles that enter and improve the quality of treated water (Fig 2.n). When the cartridge filter is saturated, it must be replaced to maintain its function [39].

Reverse Osmosis (RO)

Reverse osmosis is the most modern type of water treatment. It is the most efficient separation technology used in some industrial locations for treating wastewater and seawater desalination for creating fresh water (Fig 2.o)[40,41,42]. Water pressure is applied through a semi-permeable membrane to remove dissolved inorganic contaminants from water. Fluoride, chlorine, nitrates, sulfate, pesticides, etc., dissolved pollutants in the water are removed during treatment [43]. Solid impurities must be separated using mechanical treatment, i.e., settling and filtration, so that it will not shorten the membrane interval maintenance and its lifespan time due to mechanical damage. To improve reverse osmosis performance, periodic maintenance and cleaning to remove fouling on the membrane surface must be conducted.

(a) Silica Sand

(b) **Lumajang Sand**

(c) **Alum**

Comment [B1]: Please give label on all picture

(d) **Active Carbon** (e) **Sponge** (f) **Pumice**

(g) **Kaolin** (h) **Red Brick** (i) **Red Tile**

(j) **Charcoal** (k) **Zeolite** (l) **Bio Ring**

(m) **Clamshell** (n) **10 Micron Filter** (o) **Reverse Osmosis**

Figure 2. Materials for filter modules from local materials and reverse osmosis

Ion Exchanger

The ion exchanger is one of the desalination process's fundamental components. It functions by binding positive and negative ions with a substance called resin. There are two ion exchange resins: cation exchangers, which contain positively charged ions that are exchangeable (Fig 3.a and Fig 3.c), and anion exchangers, which have negatively charged ions that are exchangeable (Fig 3.b and Fig 3,c). Both cation and anion resins must be regenerated using a powerful acid or base. Using flow-through, column, or tank systems, the ion exchange process transforms produced brackish water into drinkable or disposable water [44]. Most often, ion exchange media are used to remediate waste, soil, and water. This study will employ ion exchange media to treat brackish water widely found in coastal and rural locations. Ion exchange therapy is one approach for fixing domestic water problems. It can eliminate toxic contaminants from water [45,46].

(a) Cation Exchanger **(b) Anion Exchanger** **(c) Cation and Anion Resin**

Figure 3. Material for Ion Exchanger. Anion and Kation Exchanger Resin

Research Methodology

The research methodology used in this study is experimental research, including literature from previous studies. A case study will follow. Related information and data on brackish water, for example, recent research on treatment methods and properties of brackish water, will be obtained as the basis of this research. The application of physical experiments in brackish water treatment in this research will be carried out by selecting local materials as filter media and reverse osmosis media. These local materials will be prepared in the filtration module. The application of chemical experiments using ion exchange resin will be used as water treatment equipment.

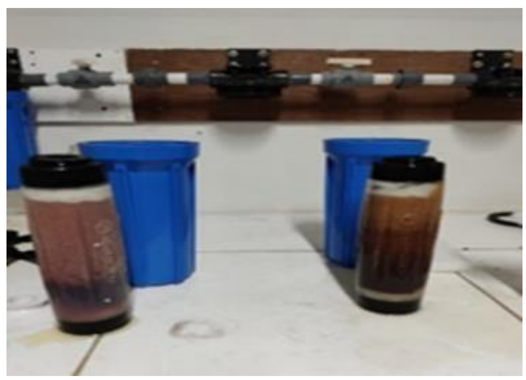
Filter Media Preparation and Assembly

Filter module assembly with selected local filter media was conducted in the laboratory (Fig.4.a). The brackish water sample is obtained from two villages, Tegal Sari and Kupang, in Jabon District, Sidoarjo Regency (Fig. 4.b). Reverse osmosis and ion exchanger cartridges will also be assembled in the laboratory (Fig .4.c and 4.d).

(a) Filter Module Preparations

(b) Water Samples

(c) Reverse Osmosis



(d) Ion Exchanger

Figure 4. Water treatment equipment assembly (preparation for filter module, reverse osmosis, ion exhanger in filter module and obtaining brackish water sample)

There will be a pretreatment phase for filter media before it is filled into the filter module. Dirt and another contaminant will be eliminated by washing in the first phase (Fig. 5.a). Once the washing phase is completed, filter media will be dried in the oven. (Fig. 5. b). Mechanical phase, crushing, and screening are necessary for certain material to extend their surface area, which can be seen in (Fig. 5.c and 5.d).

(a) Washing

(b) Drying

(c) Crushing

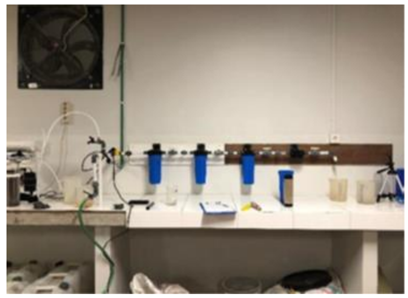
(d) Screening

Figure 5. Filter media pre treatment phase (washing, drying, crushing and screening)

Filter Module Assembly

As the filter media has completed its pretreatment phase, it will be filled into each filter module (Fig. 6.a). A brackish water sample will be pumped into the filtration module (Fig. 6.b). The treated brackish water from the filtration module will be analyzed for its water quality parameter, i.e., pH, TDS, EC, odor, and color will be observed and measured (Fig. 6.c and Fig 6.d). The combination of local filter media used in this study amount to 25 combinations which is described in Table 1. For instance: the first experiment, the combination module 1, 2, and 3 utilized: lumajang sand, charcoal, and bricks, respectively.

(a) Filter Module Materials



(b) Filter Module Installations

(c) EC Value Result

(d) pH Value Result

Figure 6. Filter module assembly (water quality parameter analysis for treated water after filtration)

The brackish water sample will be analyzed before the treatment in the laboratory to get the initial water quality parameter value. It has an average pH of 8.0, a TDS value of 2550 ppm, EC value of 5070 µs/cm. Color, odor, and turbidity of the water sample before and after treatment are also observed. The standard water quality criterion will be based on the Minister of Health Republic of Indonesia Regulation No. 492, 2010, and the WHO drinking water quality standards. As per water parameter quality standards, clean water has an average pH between 6.5 – 8.5, a TDS value lower than 500 ppm, and an EC value lower than 300 µs/cm. As physical criteria, clean water must be odorless and colorless [47,48]. The water quality parameter after the treatment will be compared with the standard above.

Table 1. Filter module combination with local filter media

No	Module 1	Module 2	Module 3	Module 4	Module 5	Module 6
1	Lumajang Sand	Charcoal	Bricks			
2	Lumajang Sand	Pumice	Bricks	Kaolin	Active Carbon	
3	Lumajang Sand	Pumice	Bricks	Kaolin	Active Carbon	
4	Lumajang Sand	Pumice	Bricks	Kaolin	Active Carbon	
5	Lumajang Sand	Carbon Active	Bricks	Zeolite	Kaolin	
6	Lumajang Sand	Red Tile	Zeolite	Zeolite	Kaolin	Active Carbon
7	Zeolite	Zeolite				
8	Clamshell					
9	Fliter					
10	Active Carbon					
11	Active Carbon	Active Carbon				
12	Kaolin					
13	Bio Ring					
14	Filter	Kaolin	Zeolite	Kaolin	Kaolin	Kaolin
15	Fliter	Kaolin	Zeolite	Kaolin	Active Carbon	Kaolin
16	Bricks					
17	Lumajang Sand	Bricks				
18	Lumajang Sand	Bricks	Bricks			
19	Lumajang Sand	Bricks	Bricks	Sand		
20	Kaolin	Active Carbon	Active Carbon	Active Carbon	Filter 10 Micron	
21	Alum	Zeolite	Kaolin	Silica Sand		
22	Alum	Kaolin	Filter 10 Micron	Kaolin		
23	Zeolite	Silica Sand	Filter 10 Micron	Sponge		
24	Silica Sand	Zeolite	Charcoal	Filter 10 Micron		
25	Silica Sand	Zeolite	Sponge	Filter 10 Micron		

Result

pH, TDS, and EC of the treated water, as the determining water quality parameter, will be measured and described in two sections. The analysis result after the filtration through the filter module combination will be shown in the first section. The analysis results from reverse osmosis and ion exchanger can be seen in the second section. Based on brackish water before and after treatment analysis results, the treatment effectiveness from both filtration method, reverse osmosis, and ion exchanger can be further evaluated.

Water Quality Parameter After Filtration with Local Filter Media

pH

As shown in Fig. 7, the filtration result shows that the pH value range is between 6.6 to 8.6. The highest increase in pH value from 7.7 to 8.4 is shown in experiments 6, while the highest decrease in pH value from 8.6 to 8 occurred in experiments 1. The pH value after treatment is still acceptable based on the quality standard except for experiments 21, and 22.

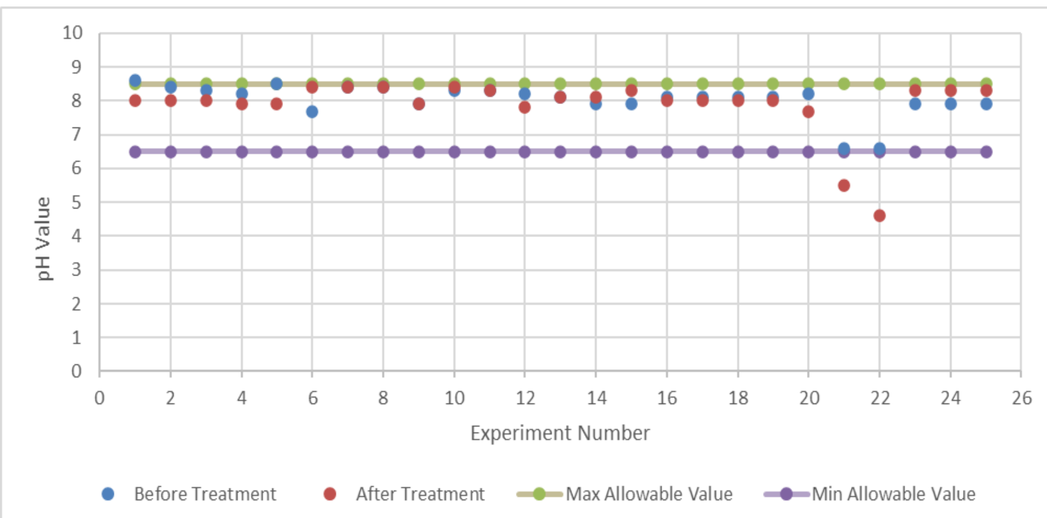


Figure 7. pH value comparison, before and after filtration

TDS value shows a decreasing trend after filtration. It can be seen in Fig. 8 that the TDS value after the treatment is in the range between 2340 – 4810 ppm. Experiment no. 15 result has the highest decrease in TDS value from 2560 ppm to 2340 ppm, equal to 8.59%.

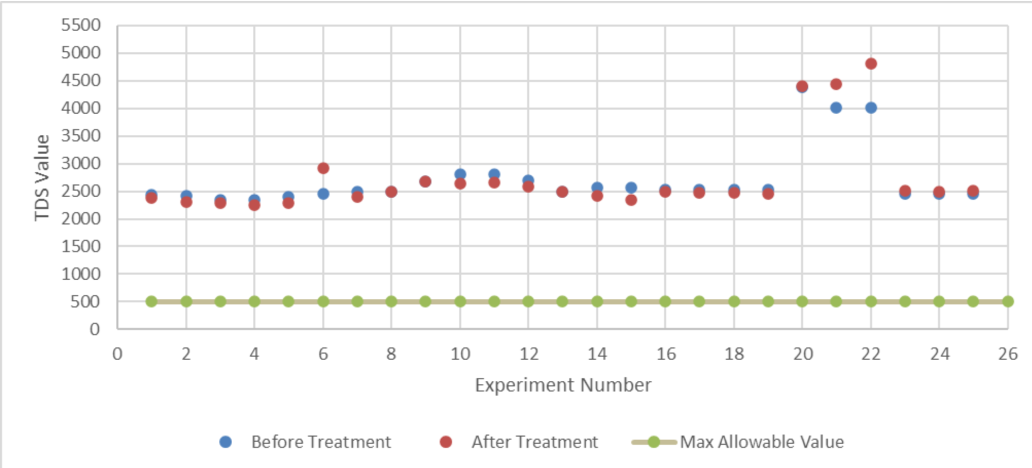


Figure 8. TDS value comparison, before and after filtration

The same decreasing trend in EC value is also obtained after filtration. The average EC value after filtration ranges between 4530 – 9800 µs/cm. Like the TDS value, experiment no. 15 has demonstrated the highest decrease in EC value from 5150 µs/cm to 4780 µs/cm. The filtration method can achieve an average reduction between 3.9% - 7.18% in EC value. The comparison of EC values before and after filtration is shown in Fig. 9.

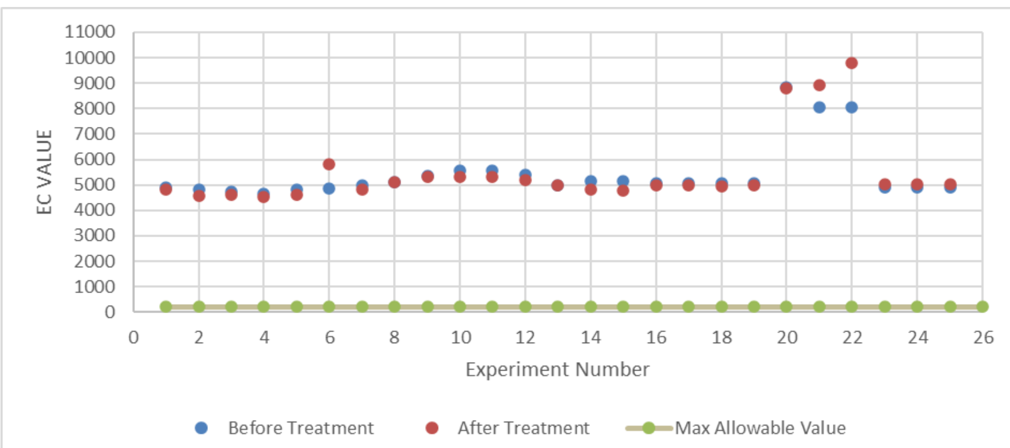


Figure 9. EC value comparison, before and after filtration

Water Quality Parameter from Reverse Osmosis and Ion Exchanger

As TDS and EC values from the treated water, the filtration method with selected local material still exceeds the WHO clean water standard guideline, reverse osmosis equipment is

utilized to remove the TDC and EC value further. The filter module is also equipped with the reverse osmosis unit to remove dirt and other coarse contaminants as pretreatment. 10-micron filter, Chlorine Taste Odor (CTO), and Granular Active Carbon (GAC) are the main components in the filter module. The result in Table 2 shows the treatment result by reverse osmosis. TDS and EC value significantly reduced at approximately 95 – 98% from the initial value before the treatment.

Table 2. Reverse osmosis analysis result on pH, TDS, and EC

Time	pH		TDS		EC	
(minutes)	Before	After	Before	After	Before	After
5	8	8,2	2550	232	5070	467
10	8	8,2	2550	247	5070	496
15	8	8,2	2550	245	5070	493
20	8	8,2	2550	252	5070	500
25	8	8,2	2550	250	5070	503
30	8	8,2	2550	253	5070	504
35	8	8,2	2550	251	5070	505

TDS and EC analysis results after treatment with an ion exchanger is shown in Table 3. TDS value reduction by ion exchanger ranges between 67 – 70%, while EC value shows the same reduction range as TDS.

Table 3. Ion exchanger analysis result on pH, TDS, and EC

Time	pH		TDS		EC	
(Minutes)	Before	After	Before	After	Before	After
5	8	8,3	2550	815	5070	1630
10	8	8,3	2550	793	5070	1586
15	8	8,3	2550	750	5070	1500
20	8.0	8.3	2550	729	5070	1458

Disscussion

There was little significant change in the pH value after treatment with the combined filter modules. There is an increase of about 2.23%, so the filtered water tends to be alkaline, but the pH value is still within the standard guidelines for clean water. The TDS value has decreased by about 1.64–7.56%, which can be obtained with a combination of filter modules. Like the TDS value, the EC value also decreased between 3.9% and 7.18%. When compared with research conducted by Yaqin et al. [14], it was found that the filtration results for pH values dropped by about 6.25% so that the water tended to be neutral, and for TDS values, they increased by about 50%. Therefore, the combination of a 10-micron filter, silica sand, kaolin, zeolite, brick, and activated carbon in Experiment No. 14–20 showed better results in reducing TDS and EC values. These filter materials can remove minerals and salinity contained in brackish water. However, the salinity reduction was not significant enough. Odor, color, and turbidity can be removed by the filtration method.

The reverse osmosis performance in this study shows that it can effectively remove TDS and EC values around 99.5%. Compared to the research conducted by Ansari et al. [16], reverse osmosis can remove TDS values of around 98.8%. As a result, the reverse osmosis performance in this study is better than other studies, exceeding the maximum standards in standards set by the WHO. However, since the filtration method can remove odor, color, and turbidity, the brackish water is sufficient to meet daily household consumption needs.

Ion exchangers have the same ability to remove TDS and EC from brackish water. The treatment results show a decrease in TDS and EC values in the 67–70% range. Therefore, ion exchangers are less effective in removing TDS and EC than reverse osmosis. The TDS and EC values obtained after treatment with ion exchangers are higher than the standards set by the WHO, which are 500 ppm for TDS values and 300 s/cm for EC values—according to a study by Desmiarti et al. [17], using an ion exchanger and microfilter for water treatment results in a more significant reduction of TDS and EC values by approximately 89.01%-90.91% for four cartridges and one microfilter and approximately 95.94%-96.36% for six cartridges and one microfilter.

Reverse osmosis and ion exchanger are proven methods that can provide a sufficient treatment to get the clean water standard parameter. Reverse osmosis has the advantage of requiring no hazardous chemical agent, and a high-quality clean water standard can be achieved. However, the membrane is the sensitive item in reverse osmosis which requires careful attention and is costly. On the contrary side, the ion exchanger is more competitive even though it is less effective than reverse osmosis. The disadvantages of an ion exchanger lie in the requirement of the chemical agent to rinse or reactivate the resin, and is not able to remove bacterial or organic contamination.

The result may differ in each method because there are differences in parameters, such as raw water quality, filter materials, and the input flow rate before treatment. Combining physical methods by filtration and reverse osmosis or ion exchangers can remove contaminants in brackish water. Hence, the safe, clean drinking water quality parameter can be complied with.

Conclusion

The combination of local filter materials and applied water treatment equipment, especially in remote areas, proved to be cost-effective equipment. This equipment is very practical and helpful for local communities, especially in coastal regions in Indonesia and local communities in disaster-prone areas. Therefore, clean water can be produced locally and used for daily household consumption, as the filtration method can largely remove odor, color, and turbidity. In terms of maintenance, the filter is easy to maintain and clean regularly.

The results of the research study showed that water filters using local materials are able to reduce TDS, EC, and pH values. The best combination to reduce TDS, EC, and pH values is a combination of a 10-micron filter, kaolin, zeolite, kaolin, activated carbon, and kaolin. It was found that the values of TDS, EC, and pH were able to be reduced by 8.59%, 7.18%, and 2.59%, respectively.

As the filtration method can’t remove TDS and EC further, reverse osmosis, and ion exchanger can obtain the standard safe drink water quality according to WHO standard guidelines. Specific instructions for maintaining a semi-permeable membrane in reverse osmosis

or how to do a chemical rinse for ion exchanger resin must be available for the community to do the maintenance themselves.

Based on the results of this study, it is expected that compact, effective water treatment equipment for disaster-prone locations can be created. The treated brackish water from the filtration method with local filter media can be treated further in conjunction with reverse osmosis or ion exchange. As there are two options for further treatment, the advantages and disadvantages from the economic and maintenance point of view should be considered. In terms of disaster-prone areas, the community will need to have simple water treatment equipment and low maintenance. Therefore, cost-effective and low-maintenance water treatment equipment in the long term can serve as the next step in this research.

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W Brackish Water Tr...

A Practical Implementation of Brackish Water Treatment With Local Material in Sidoarjo Regency, East Java, Indonesia

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Abstract: Indonesia, an archipelago with vast coastal areas consisting of 809 coastal villages, still faces the same problems of clean water scarcity and accessibility. This research goals are to discover appropriate inexpensive local filtering media and lower the salinity of brackish water in Sidoarjo Regency Indonesia. Regarding previous invention and research, this study deploy an experimental method by physical experiment including local materials along with chemical experiment: ion exchangers as well as reverse osmosis (RO). The outcomes demonstrate that local media filtration utilizing a combination of a 10-micron filter, kaolin, zeolite, kaolin, activated carbon, and kaolin is the best combination to produce the most transparent, and odorless water. It can reduce Total Dissolved Solid (TDS) and Electrical Condactivity (EC) values by 8.59% and 7.18%, and reduce pH levels by 2.59%. On the other hand, reverse osmosis and ion exchange can achieve 99.5% and 67% reductions in TDS and EC values, respectively.

Keywords: clean water crisis, brackish water, local filter material, reverse osmosis, ion exchanger

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Introduction

Water is an essential resource for humans to fulfill their daily needs. The demand for clean water increase yearly, so people worldwide are facing water crisis. The term clean water crisis not only relates to the amount of water available but also relates to low water quality. Some factors that cause the clean water crisis to worsen are increasing population growth and rapidly increasing industry [1]. The bad habits of the community, especially urban communities, in wasting clean water and environmental pollution worsen water supply and quality. Due to the clean water crisis, nearly one (1) billion people are unable to access clean water, 3.4 million people die from drinking contaminated water, millions of people must travel an average of 6 km daily to access clean water, and at any given time, half of all hospitals in the world are full of patients with diseases related to the clean water crisis [2]. The clean water crisis is worse for people living in coastal areas worldwide. The Southwestern coastal regions of Bangladesh and Europe are experiencing drinking water scarcity. Many factors contribute to water scarcity,

including seawater intrusion, decreased upstream water discharge, sea level rise, disasters, polders, arsenic poisoning, overuse of subsurface water, and others [3,4].

The Sustainable Development Goals (SDG) has set a global target of 100% access to drinkable water by 2030. However, there are still 80 million people who still need access to safe drinking water services. Even the capital city of Indonesia, Jakarta has yet to reach 100% access to safe drinking water. It is problematic for Indonesia because clean water source availability and accessibility from one place to another are not equal [5]. The main problem for the rural and coastal communities is their need for clean water. The most accessible natural water source in this region for the community's everyday needs and drinking water is groundwater. Still, as the ecosystem changes and industrial aquifer contamination increases, the quality of this resource is declining [6]. As a result, the socioeconomic impacts on the community are health and rising costs for clean water supplies.

The location for this research is Sidoarjo Regency, East Java, Indonesia (See Figure 1). As a river delta area between the Kalimas and Porong rivers and the coast, Sidoarjo has always been prone to natural disasters like flooding, typhoons, and tornadoes. In addition to the natural calamity, the local industrial region in Sidoarjo was the primary source of groundwater resource contamination. Both main factors above affect clean water resources availability for fulfilling the community's daily needs in farming and their daily consumption [7,8]. Hence, a suitable and cost-effective water treatment method must be developed and implemented to resolve the clean water resources availability issue in this area.

Figure 1. Sidoarjo Regency, East Java, Indonesia. Research work location

The only water source available in this area is household wells filled with brackish water from the Porong River. Based on the research that has been conducted, it is known that the water quality is classified as moderate using the Nasional Sanitation Foundation – Water Quality Index

(NSF-Wqi). It was found from the water samples obtained from two villages in Sidoarjo district, Tegal Sari and Tanjung Sari, in the Jabon sub-district, the turbidity content was 68 mg/l, total dissolved solids content (TDS) was 223 mg/l, and Escherichia. Coli content was 210 mg/100 ml, making it unsuitable for safe, clean water [9]. Therefore, clean water is purchased and periodically supplied by truck to the community to meet daily household needs. An alternative solution besides a clean water supply is treating brackish water with local filter media, which is abundantly available [10]. Local filter materials, such as silica sand, lumajang sand, pumice, bricks, sponge, alum, charcoal, active carbon, kaolin, bio ring, clam shell, red tile, and zeolite, can be used to treat the water.

Several studies have been conducted on brackish water treatment to address clean water supply. Jayaprakash et al. [11] have introduced a method to reduce iron, sulfate, chlorine, sodium, and TDS content in brackish water using activated carbon media. Khanzhanda et al. [12] have evaluated the performance of a combination of pretreatment and reverse osmosis. The first method combines cartridge pretreatment with reverse osmosis, and the second uses ultrafiltration with RO. Yogafanny et al. [13] have introduced a method using local zeolite material to reduce dissolved solids levels. Yaqin et al. [14] found a portable water purifier using silica sand, zeolite stone, greensand sand, zeolite manganese, bio-balls, and activated carbon. Barahoei et al. [15] have introduced a method to reduce salinity using chemical photosynthetic desalination cells. Ansari. et al. [16] evaluated the performance of brackish water desalination using reverse osmosis under different operational conditions. Desmiarti et al. [17] found a demineralized water method using a combination of continuous filtration and ion exchange processes.

Several references were also taken from several patents on brackish water purification devices. Tadd C. Kippeny et al. [18] made a patent entitled Water Desalination Apparatus with patent number US8377297B2, discussing using a salt sponge unit to remove most salt from water. A parallel plate capacitor can be connected after the salt sponge to remove the remaining salt ions. Chen et al. [19] made a patent entitled A kind of processing method of brackish water and a sort of saliferous water treatment system with patent number CN105174512B, discussing a brackish water treatment method by performing nanofiltration separation to obtain production water and nanofiltration concentrated water. Nanofiltration production water is subjected to a reverse osmosis separation process. Shen et al. [20] made a patent with the title Bitter (brackish) saltwater purifying equipment with patent number CN103073136A, discussing the manufacture of brackish saltwater purification equipment with multi-medium filter, automatic cleaning filter, and ultrafiltration membrane device.

This study aimed to identify a technique for obtaining clean water from brackish water by choosing filtration with suitable local material, reverse osmosis, and ion exchanger. Based on the research results, it is expected that the implementation of this method can provide a practical solution for overcoming the clean water crisis if it is put into practice. The test results will be compared to the WHO drinking water standard for water quality criteria, including pH (Power of Hydrogen), TDS (Total Dissolved Solids), EC (Electrical Conductivity), odor, and color.

Material and Method

Experimental study use physical and chemical methods to discover the optimal combination for on-site brackish water treatment silica sand, lumajang sand, alum, carbon active, sponge, pumice, kaolin, red brick, red tile, charcoal, zeolite, bio ring, clam shell, and a filter 10 micron comprise the filter module combination set. Reverse osmosis and ion exchanger equipment will be utilized to further treat the water purified by the filtration method.

Material

Silica Sand

Silica sand, or quartz sand, contains about 99.7% silicon dioxide (SiO2). Silica sand is a very effective water filtration medium because it can precipitate and retain impurities from the treated water. It is expected that silica sand can remove mud contained in brackish water (Fig 2.a). [21].

Lumajang Sand

Lumajang Sand is formed from silicon dioxide content or limestone. Generally, the size of sand is 0.0625 mm to 2 mm [22]. The function of sand for water filters is to hold silt and fine impurities. The type of sand used in this study comes from Lumajang, East Java, Indonesia. The characteristic of this sand is the color of the sand, the sand has a gray to black color (Fig 2.b).

Alum

Alum is found in nature as a chemical compound known as hydrated aluminum sulphate salt in the white crystalline form (Fig 2.c). Potassium alum or potash alum is used to coagulate the impurities so that the impurities can be separated [23]. As it has the characteristic as coagulant agent, it is not only utilized in water treatment, but also in industrial sector, i.e., medicine, food preparation, and textile industry. An appropriate dosage of Alum should be added during the water treatment so that the treated water is safe for daily consumption.

Active Carbon

Active carbon is widely known for its physical properties, which includes a large surface area and homogeneous pore size (Fig 2.d). It is chemically inert and stable [24]. Based on the characteristic mentioned above, odor and color, which is caused by the organic compound in water, can be removed by adsorption. Hence water's taste and appearance can be improved [25]. However, both coarse and fine impurities in the water can't be separated by active carbon absorption.

Sponge

Sponge is commonly known as basic physical and mechanical filter media, which is simple and cost-effective. It is widely available and has a porous synthetic material capable of absorbing water and good aeration (Fig 2.e) [26]. The suspended solid particle in water can be separated by immersing it in the pore [27]. However, a limited number of dissolved impurities can be retained. Sponge, in terms of maintenance, can be effectively cleaned in specific periods and is easy to be utilized back as filter media.

Pumice

Pumice is a type of rock that is light in color and contains thick foam made of glass-walled bubbles (Fig 2.f) [28]. Pumice can remove coarse contaminants due to its large surface area and

up to 90% porosity. Pumice can be an absorbent material to remove heavy metals, radioactive, and dyes in wastewater [29]. The disadvantage of using this material as a filter is that pumice cannot remove fine impurities like sand filters. In terms of maintenance, the pumice filter is easier to maintain when compared to a sand filter, but it still takes quite a bit of time long enough.

Kaolin

Kaolin or kaolinite is a type of primary clay material that exists in nature, with the chemical formula Al2O3.2SiO2.2H2O (Fig 2.g). Kaolin and activated carbon have similar physical properties with high surface area and stability. By absorption, Kaolin can remove toxic pollutants from water, such as chloride, sulfate, Cr, Cd, and Zn [30], [31]. The disadvantage of this filter media is that it cannot hold fine or coarse impurities.

Red Bricks

The function of red bricks in this water purification filter is to separate and precipitate the minerals in brackish water. The bricks used this time are red bricks. Red bricks have a large surface area and a high porosity making them suitable to be used as an absorbent material and filter waste (Fig 2.h) [32]. Given that red bricks are made of clay, this filter can help precipitate the minerals contained in the water. The disadvantage of this filter is that it cannot help purify water in terms of color.

Red Tile

Red tile is made from clay processing and then heated with coal with a certain degree of heat (Fig 2.i). The function of red tile in water filters is to help kill harmful minerals, and its weakness is that it cannot filter out impurities [33].

Charcoal

Another filter material known as an effective filter media is charcoal. The charcoal made from the coconut shell is high-quality, effective, and environmentally friendly. Like active carbon and kaolin, coconut shell charcoal can absorb and remove chemical pollutants in the water (Fig 2.j)[34]. As filtering media, shell charcoal has a slightly significant result, it can’t hold the coarse impurities in brackish water, whereas odor and taste can be improved. In terms of maintenance, a periodic replacement is needed and is easy to obtain as this material is commonly used in water treatment.

Zeolite

A form of hydrated alumina-silicate chemical compound with sodium, potassium, and barium cation is known as zeolite. Zeolite is formed naturally from volcanic and sedimentation rock in nature. It can retain or separate chemical molecules as it has molecular-sized pores (Fig 2.k). Zeolite, as an adsorbent, can cation exchange due to its negative electrical charge in them. This negative electrical charge can bind cations generally found in groundwater, i.e., Fe, Al, Ca, and Mg. [35]. Zeolite is used not only in water treatment but also for treating wastewater treatment. It is expected to remove heavy metal cations in wastewater, i.e., Zn, Cr, Pb, Cd, Cu, Mn, Fe, etc.

Bio Ring

Bio ring is made from ceramic and found in white color. It has a cylindrical form of 20 mm in height and 18 mm in diameter (Fig 2.l)[36]. The function of the bio ring in this filtration 200 is to

filter bacteria in brackish water. Bio rings have a large surface area and porosity. The number of pores in the bio ring gives the bio ring a high surface area, which is helpful for bacteria to colonize, allowing water to enter the pores easily [37]. The disadvantage of this filter is that it cannot filter impurities from the dirt in the brackish water.

Clam Shell

The public generally considers clamshell waste but have a high mineral content. The type of mineral present is calcium. Therefore the function of the shell in the water filter can be used as a natural mineral source (Fig 2.m)[38].

10 Micron Filter

The 10 Micron filter consists of a filter cartridge made of polypropylene. Cartridge filters come in various sizes, with pore diameters ranging from 20 to 1 micron. Therefore, using 10-micron filters in water filters can retain small particles that enter and improve the quality of treated water (Fig 2.n). When the cartridge filter is saturated, it must be replaced to maintain its function [39].

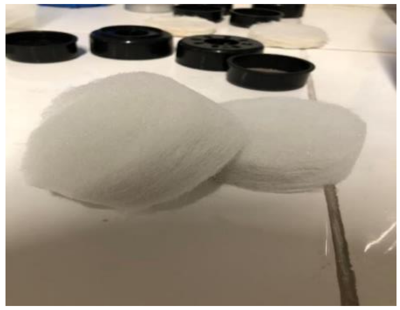
Reverse Osmosis (RO)

Reverse osmosis is the most modern type of water treatment. It is the most efficient separation technology used in some industrial locations for treating wastewater and seawater desalination for creating fresh water (Fig 2.o)[40,41,42]. Water pressure is applied through a semi-permeable membrane to remove dissolved inorganic contaminants from water. Fluoride, chlorine, nitrates, sulfate, pesticides, etc., dissolved pollutants in the water are removed during treatment [43]. Solid impurities must be separated using mechanical treatment, i.e., settling and filtration, so that it will not shorten the membrane interval maintenance and its lifespan time due to mechanical damage. To improve reverse osmosis performance, periodic maintenance and cleaning to remove fouling on the membrane surface must be conducted.

Silica Sand (a)

Lumajang Sand (b)

Alum (c)



Active Carbon (d) **Sponge (e)** **Pumice (f)**

Kaolin (g) **Red Brick (h)** **Red Tile (i)**

Charcoal (j) **Zeolite (k)** **Bio Ring (l)**

Clamshell (m) **10 Micron Filter (n)** **Reverse Osmosis (o)**

Figure 2. Materials for filter modules from local materials and reverse osmosis

Ion Exchanger

The ion exchanger is one of the desalination process's fundamental components. It functions by binding positive and negative ions with a substance called resin. There are two ion exchange resins: cation exchangers, which contain positively charged ions that are exchangeable (Fig 3.a and Fig 3.c), and anion exchangers, which have negatively charged ions that are exchangeable (Fig 3.b and Fig 3,c). Both cation and anion resins must be regenerated using a powerful acid or base. Using flow-through, column, or tank systems, the ion exchange process transforms produced brackish water into drinkable or disposable water [44]. Most often, ion exchange media are used to remediate waste, soil, and water. This study will employ ion exchange media to treat brackish water widely found in coastal and rural locations. Ion exchange therapy is one approach for fixing domestic water problems. It can eliminate toxic contaminants from water [45,46].

Cation Exchanger (a) **Anion Exchanger (b)** **Cation and Anion Resin (c)**

Figure 3. Material for Ion Exchanger. Anion and Kation Exchanger Resin

Research Methodology

The research methodology used in this study is experimental research, including literature from previous studies. A case study will follow. Related information and data on brackish water, for example, recent research on treatment methods and properties of brackish water, will be obtained as the basis of this research. The application of physical experiments in brackish water treatment in this research will be carried out by selecting local materials as filter media and reverse osmosis media. These local materials will be prepared in the filtration module. The application of chemical experiments using ion exchange resin will be used as water treatment equipment.

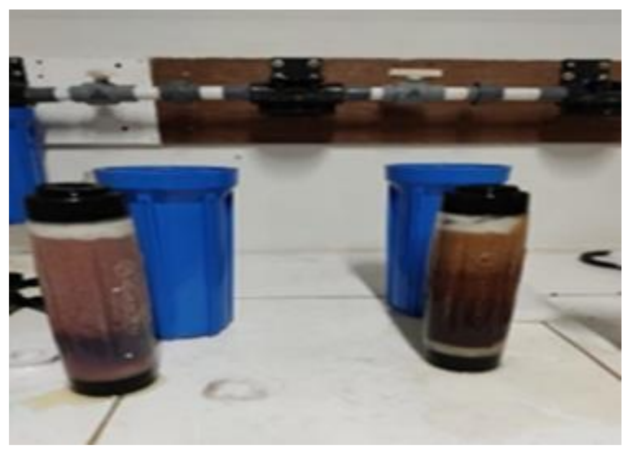
Filter Media Preparation and Assembly

Filter module assembly with selected local filter media was conducted in the laboratory (Fig.4.a). The brackish water sample is obtained from two villages, Tegal Sari and Kupang, in Jabon District, Sidoarjo Regency (Fig. 4.b). Reverse osmosis and ion exchanger cartridges will also be assembled in the laboratory (Fig .4.c and 4.d).

Filter Module Preparations (a)

Water Samples (b)

Reverse Osmosis (c)



Ion Exchanger (d)

Figure 4. Water treatment equipment assembly (preparation for filter module, reverse osmosis, ion exhanger in filter module and obtaining brackish water sample)

There will be a pretreatment phase for filter media before it is filled into the filter module. Dirt and another contaminant will be eliminated by washing in the first phase (Fig. 5.a). Once the washing phase is completed, filter media will be dried in the oven. (Fig. 5. b). Mechanical phase, crushing, and screening are necessary for certain material to extend their surface area, which can be seen in (Fig. 5.c and 5.d).

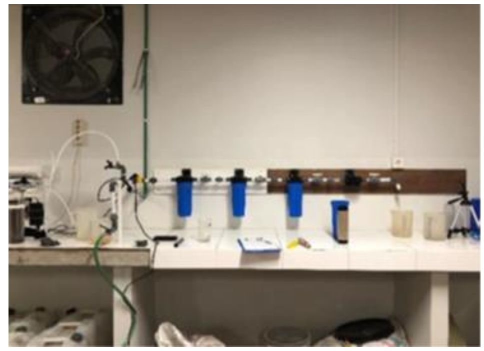
Washing (a) **Drying (b)**

Crushing (c) **Screening (d)**

Figure 5. Filter media pre treatment phase (washing, drying, crushing and screening)

Filter Module Assembly

As the filter media has completed its pretreatment phase, it will be filled into each filter module (Fig. 6.a). A brackish water sample will be pumped into the filtration module (Fig. 6.b). The treated brackish water from the filtration module will be analyzed for its water quality parameter, i.e., pH, TDS, EC, odor, and color will be observed and measured (Fig. 6.c and Fig 6.d). The combination of local filter media used in this study amount to 25 combinations which is described in Table 1. For instance: the first experiment, the combination module 1, 2, and 3 utilized: lumajang sand, charcoal, and bricks, respectively.



Filter Module Materials (a) **Filter Module Installations (b)**

EC Value Result (c) **pH Value Result (d)**

Figure 6. Filter module assembly (water quality parameter analysis for treated water after filtration)

The brackish water sample will be analyzed before the treatment in the laboratory to get the initial water quality parameter value. It has an average pH of 8.0, a TDS value of 2550 ppm, EC value of 5070 µs/cm. Color, odor, and turbidity of the water sample before and after treatment are also observed. The standard water quality criterion will be based on the Minister of Health Republic of Indonesia Regulation No. 492, 2010, and the WHO drinking water quality standards. As per water parameter quality standards, clean water has an average pH between 6.5 – 8.5, a TDS value lower than 500 ppm, and an EC value lower than 300 µs/cm. As physical criteria, clean water must be odorless and colorless [47,48]. The water quality parameter after the treatment will be compared with the standard above.

Table 1. Filter module combination with local filter media

No	Module 1	Module 2	Module 3	Module 4	Module 5	Module 6
1	Lumajang Sand	Charcoal	Bricks			
2	Lumajang Sand	Pumice	Bricks	Kaolin	Active Carbon	
3	Lumajang Sand	Pumice	Bricks	Kaolin	Active Carbon	
4	Lumajang Sand	Pumice	Bricks	Kaolin	Active Carbon	
5	Lumajang Sand	Carbon Active	Bricks	Zeolite	Kaolin	
6	Lumajang Sand	Red Tile	Zeolite	Zeolite	Kaolin	Active Carbon
7	Zeolite	Zeolite				
8	Clamshell					
9	Fliter					
10	Active Carbon					
11	Active Carbon	Active Carbon				
12	Kaolin					
13	Bio Ring					
14	Filter	Kaolin	Zeolite	Kaolin	Kaolin	Kaolin
15	Fliter	Kaolin	Zeolite	Kaolin	Active Carbon	Kaolin
16	Bricks					
17	Lumajang Sand	Bricks				
18	Lumajang Sand	Bricks	Bricks			
19	Lumajang Sand	Bricks	Bricks	Sand		
20	Kaolin	Active Carbon	Active Carbon	Active Carbon	Filter 10 Micron	
21	Alum	Zeolite	Kaolin	Silica Sand		
22	Alum	Kaolin	Filter 10 Micron	Kaolin		
23	Zeolite	Silica Sand	Filter 10 Micron	Sponge		
24	Silica Sand	Zeolite	Charcoal	Filter 10 Micron		
25	Silica Sand	Zeolite	Sponge	Filter 10 Micron		

Result

pH, TDS, and EC of the treated water, as the determining water quality parameter, will be measured and described in two sections. The analysis result after the filtration through the filter module combination will be shown in the first section. The analysis results from reverse osmosis and ion exchanger can be seen in the second section. Based on brackish water before and after treatment analysis results, the treatment effectiveness from both filtration method, reverse osmosis, and ion exchanger can be further evaluated.

Water Quality Parameter After Filtration with Local Filter Media

pH

As shown in Fig. 7, the filtration result shows that the pH value range is between 6.6 to 8.6. The highest increase in pH value from 7.7 to 8.4 is shown in experiments 6, while the highest decrease in pH value from 8.6 to 8 occurred in experiments 1. The pH value after treatment is still acceptable based on the quality standard except for experiments 21, and 22.

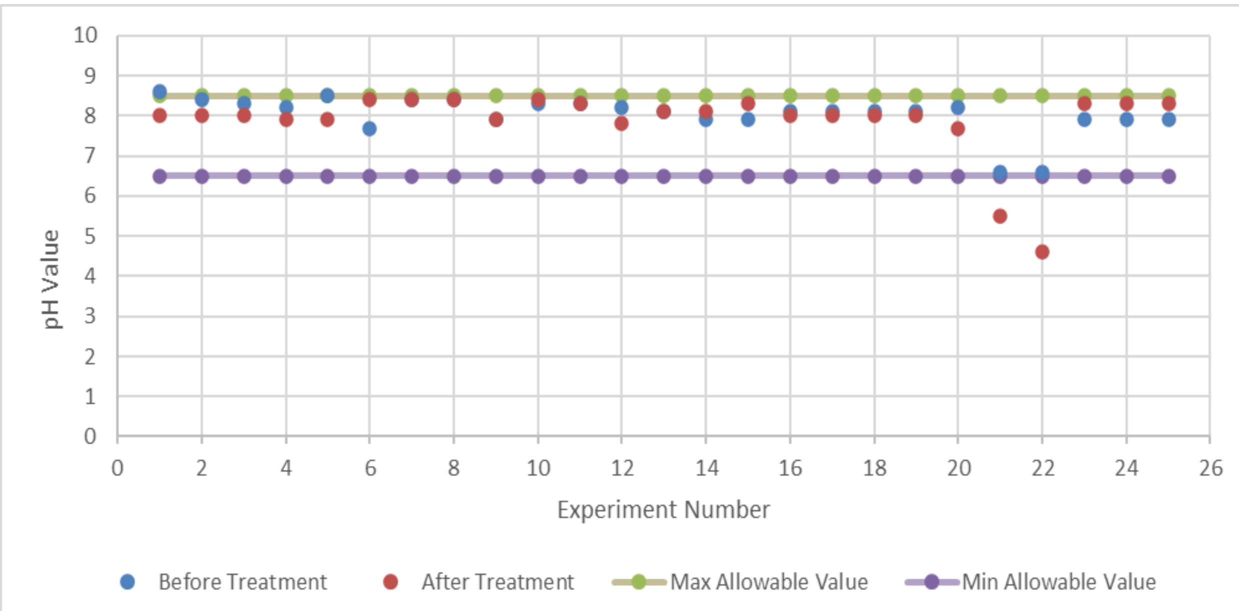


Figure 7. pH value comparison, before and after filtration

TDS value shows a decreasing trend after filtration. It can be seen in Fig. 8 that the TDS value after the treatment is in the range between 2340 – 4810 ppm. Experiment no. 15 result has the highest decrease in TDS value from 2560 ppm to 2340 ppm, equal to 8.59%.

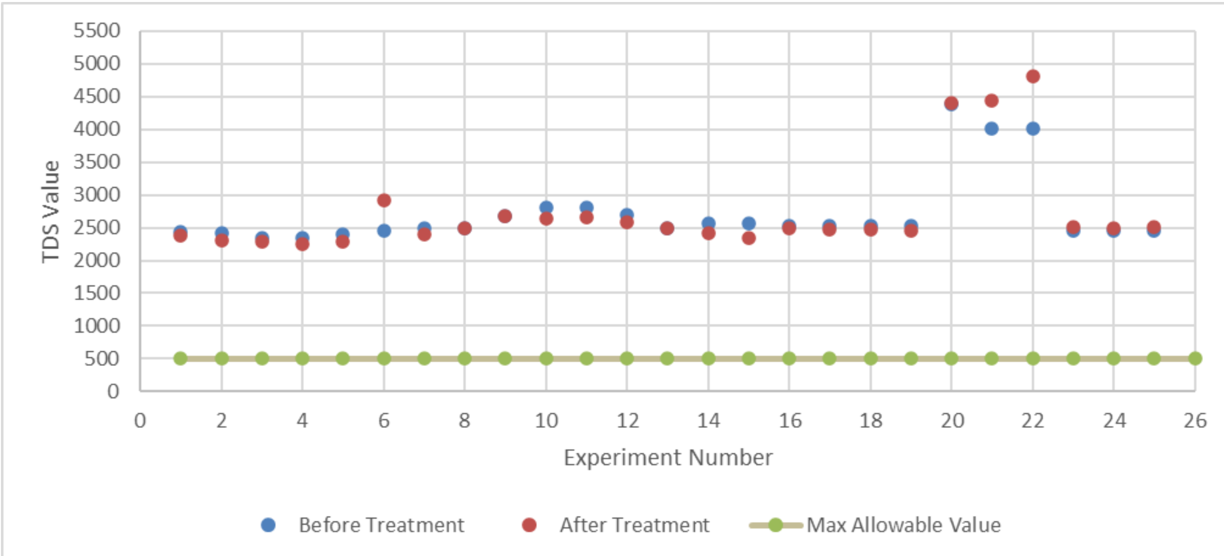


Figure 8. TDS value comparison, before and after filtration

The same decreasing trend in EC value is also obtained after filtration. The average EC value after filtration ranges between 4530 – 9800 µs/cm. Like the TDS value, experiment no. 15 has demonstrated the highest decrease in EC value from 5150 µs/cm to 4780 µs/cm. The filtration method can achieve an average reduction between 3.9% - 7.18% in EC value. The comparison of EC values before and after filtration is shown in Fig. 9.

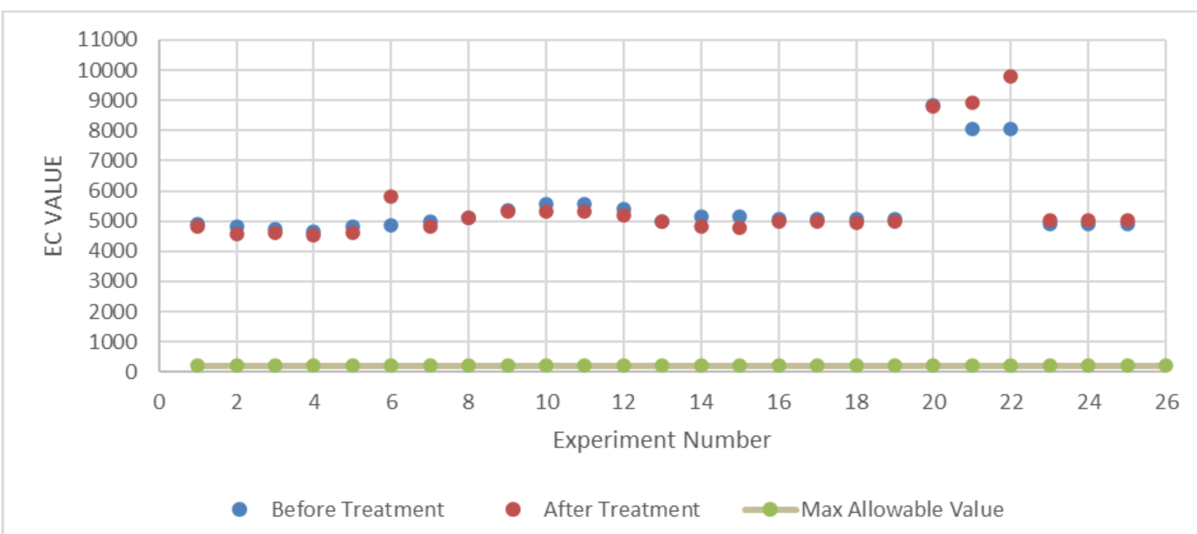


Figure 9. EC value comparison, before and after filtration

Water Quality Parameter from Reverse Osmosis and Ion Exchanger

As TDS and EC values from the treated water, the filtration method with selected local material still exceeds the WHO clean water standard guideline, reverse osmosis equipment is

utilized to remove the TDC and EC value further. The filter module is also equipped with the reverse osmosis unit to remove dirt and other coarse contaminants as pretreatment. 10-micron filter, Chlorine Taste Odor (CTO), and Granular Active Carbon (GAC) are the main components in the filter module. The result in Table 2 shows the treatment result by reverse osmosis. TDS and EC value significantly reduced at approximately 95 – 98% from the initial value before the treatment.

Table 2. Reverse osmosis analysis result on pH, TDS, and EC

Time	pH		TDS		EC	
(minutes)	Before	After	Before	After	Before	After
5	8	8,2	2550	232	5070	467
10	8	8,2	2550	247	5070	496
15	8	8,2	2550	245	5070	493
20	8	8,2	2550	252	5070	500
25	8	8,2	2550	250	5070	503
30	8	8,2	2550	253	5070	504
35	8	8,2	2550	251	5070	505

TDS and EC analysis results after treatment with an ion exchanger is shown in Table 3. TDS value reduction by ion exchanger ranges between 67 – 70%, while EC value shows the same reduction range as TDS.

Table 3. Ion exchanger analysis result on pH, TDS, and EC

Time	pH		TDS		EC	
(Minutes)	Before	After	Before	After	Before	After
5	8	8,3	2550	815	5070	1630
10	8	8,3	2550	793	5070	1586
15	8	8,3	2550	750	5070	1500
20	8.0	8.3	2550	729	5070	1458

Disscussion

There was little significant change in the pH value after treatment with the combined filter modules. There is an increase of about 2.23%, so the filtered water tends to be alkaline, but the pH value is still within the standard guidelines for clean water. The TDS value has decreased by about 1.64–7.56%, which can be obtained with a combination of filter modules. Like the TDS value, the EC value also decreased between 3.9% and 7.18%. When compared with research conducted by Yaqin et al. [14], it was found that the filtration results for pH values dropped by about 6.25% so that the water tended to be neutral, and for TDS values, they increased by about 50%. Therefore, the combination of a 10-micron filter, silica sand, kaolin, zeolite, brick, and activated carbon in Experiment No. 14–20 showed better results in reducing TDS and EC values. These filter materials can remove minerals and salinity contained in brackish water. However, the salinity reduction was not significant enough. Odor, color, and turbidity can be removed by the filtration method.

The reverse osmosis performance in this study shows that it can effectively remove TDS and EC values around 99.5%. Compared to the research conducted by Ansari et al. [16], reverse osmosis can remove TDS values of around 98.8%. As a result, the reverse osmosis performance in this study is better than other studies, exceeding the maximum standards in standards set by the WHO. However, since the filtration method can remove odor, color, and turbidity, the brackish water is sufficient to meet daily household consumption needs.

Ion exchangers have the same ability to remove TDS and EC from brackish water. The treatment results show a decrease in TDS and EC values in the 67–70% range. Therefore, ion exchangers are less effective in removing TDS and EC than reverse osmosis. The TDS and EC values obtained after treatment with ion exchangers are higher than the standards set by the WHO, which are 500 ppm for TDS values and 300 s/cm for EC values—according to a study by Desmiarti et al. [17], using an ion exchanger and microfilter for water treatment results in a more significant reduction of TDS and EC values by approximately 89.01%-90.91% for four cartridges and one microfilter and approximately 95.94%-96.36% for six cartridges and one microfilter.

Reverse osmosis and ion exchanger are proven methods that can provide a sufficient treatment to get the clean water standard parameter. Reverse osmosis has the advantage of requiring no hazardous chemical agent, and a high-quality clean water standard can be achieved. However, the membrane is the sensitive item in reverse osmosis which requires careful attention and is costly. On the contrary side, the ion exchanger is more competitive even though it is less effective than reverse osmosis. The disadvantages of an ion exchanger lie in the requirement of the chemical agent to rinse or reactivate the resin, and is not able to remove bacterial or organic contamination.

The result may differ in each method because there are differences in parameters, such as raw water quality, filter materials, and the input flow rate before treatment. Combining physical methods by filtration and reverse osmosis or ion exchangers can remove contaminants in brackish water. Hence, the safe, clean drinking water quality parameter can be complied with.

Conclusion

The combination of local filter materials and applied water treatment equipment, especially in remote areas, proved to be cost-effective equipment. This equipment is very practical and helpful for local communities, especially in coastal regions in Indonesia and local communities in disaster-prone areas. Therefore, clean water can be produced locally and used for daily household consumption, as the filtration method can largely remove odor, color, and turbidity. In terms of maintenance, the filter is easy to maintain and clean regularly.

The results of the research study showed that water filters using local materials are able to reduce TDS, EC, and pH values. The best combination to reduce TDS, EC, and pH values is a combination of a 10-micron filter, kaolin, zeolite, kaolin, activated carbon, and kaolin. It was found that the values of TDS, EC, and pH were able to be reduced by 8.59%, 7.18%, and 2.59%, respectively.

As the filtration method can't remove TDS and EC further, reverse osmosis, and ion exchanger can obtain the standard safe drink water quality according to WHO standard guidelines. Specific instructions for maintaining a semi-permeable membrane in reverse osmosis

or how to do a chemical rinse for ion exchanger resin must be available for the community to do the maintenance themselves.

Based on the results of this study, it is expected that compact, effective water treatment equipment for disaster-prone locations can be created. The treated brackish water from the filtration method with local filter media can be treated further in conjunction with reverse osmosis or ion exchange. As there are two options for further treatment, the advantages and disadvantages from the economic and maintenance point of view should be considered. In terms of disaster-prone areas, the community will need to have simple water treatment equipment and low maintenance. Therefore, cost-effective and low-maintenance water treatment equipment in the long term can serve as the next step in this research.

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Djwantoro Hardjito <djwantoro.h@petra.ac.id>
Apr 6, 2023, 3:03 PM
to Benjamin, me, marno, SARITA

Pak Ben dan pak Surya yth.

Trmksh pak Ben untuk very quick review nya. Pak Surya, minta tolong Daftar Pustakanya bisa disesuaikan formatnya dengan ketentuan Guide for Authorsnya CED ya pak. Kalau pakai Mendeley mestinya mudah proses reformatnya. Trmksh.

Salam,
DH

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Surya Hermawan <shermawan@petra.ac.id> Apr 6, 2023, 6:47 PM

to Djwantoro

Dear Prof. Djwan

Berikut dilampirkan paper yang sudah di revisi daftar pustaka nya.
Terimakasih

Salam,
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...

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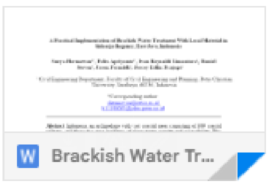

A Practical Implementation of Brackish Water Treatment With Local Material in Sidoarjo Regency, East Java, Indonesia

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Abstract: Indonesia, an archipelago with vast coastal areas consisting of 809 coastal villages, still faces the same problems of clean water scarcity and accessibility. This research goals are to discover appropriate inexpensive local filtering media and lower the salinity of brackish water in Sidoarjo Regency Indonesia. Regarding previous invention and research, this study deploy an experimental method by physical experiment including local materials along with chemical experiment: ion exchangers as well as reverse osmosis (RO). The outcomes demonstrate that local media filtration utilizing a combination of a 10-micron filter, kaolin, zeolite, kaolin, activated carbon, and kaolin is the best combination to produce the most transparent, and odorless water. It can reduce Total Dissolved Solid (TDS) and Electrical Condactivity (EC) values by 8.59% and 7.18%, and reduce pH levels by 2.59%. On the other hand, reverse osmosis and ion exchange can achieve 99.5% and 67% reductions in TDS and EC values, respectively.

Keywords: clean water crisis, brackish water, local filter material, reverse osmosis, ion exchanger

Introduction

Water is an essential resource for humans to fulfill their daily needs. The demand for clean water increase yearly, so people worldwide are facing water crisis. The term clean water crisis not only relates to the amount of water available but also relates to low water quality. Some factors that cause the clean water crisis to worsen are increasing population growth and rapidly increasing industry [1]. The bad habits of the community, especially urban communities, in wasting clean water and environmental pollution worsen water supply and quality. Due to the clean water crisis, nearly one (1) billion people are unable to access clean water, 3.4 million people die from drinking contaminated water, millions of people must travel an average of 6 km daily to access clean water, and at any given time, half of all hospitals in the world are full of patients with diseases related to the clean water crisis [2]. The clean water crisis is worse for people living in coastal areas worldwide. The Southwestern coastal regions of Bangladesh and Europe are experiencing drinking water scarcity. Many factors contribute to water scarcity,

including seawater intrusion, decreased upstream water discharge, sea level rise, disasters, polders, arsenic poisoning, overuse of subsurface water, and others [3,4].

The Sustainable Development Goals (SDG) has set a global target of 100% access to drinkable water by 2030. However, there are still 80 million people who still need access to safe drinking water services. Even the capital city of Indonesia, Jakarta has yet to reach 100% access to safe drinking water. It is problematic for Indonesia because clean water source availability and accessibility from one place to another are not equal [5]. The main problem for the rural and coastal communities is their need for clean water. The most accessible natural water source in this region for the community's everyday needs and drinking water is groundwater. Still, as the ecosystem changes and industrial aquifer contamination increases, the quality of this resource is declining [6]. As a result, the socioeconomic impacts on the community are health and rising costs for clean water supplies.

The location for this research is Sidoarjo Regency, East Java, Indonesia (See Figure 1). As a river delta area between the Kalimas and Porong rivers and the coast, Sidoarjo has always been prone to natural disasters like flooding, typhoons, and tornadoes. In addition to the natural calamity, the local industrial region in Sidoarjo was the primary source of groundwater resource contamination. Both main factors above affect clean water resources availability for fulfilling the community's daily needs in farming and their daily consumption [7,8]. Hence, a suitable and cost-effective water treatment method must be developed and implemented to resolve the clean water resources availability issue in this area.

Figure 1. Sidoarjo Regency, East Java, Indonesia. Research work location

The only water source available in this area is household wells filled with brackish water from the Porong River. Based on the research that has been conducted, it is known that the water quality is classified as moderate using the Nasional Sanitation Foundation – Water Quality Index

(NSF-Wqi). It was found from the water samples obtained from two villages in Sidoarjo district, Tegal Sari and Tanjung Sari, in the Jabon sub-district, the turbidity content was 68 mg/l, total dissolved solids content (TDS) was 223 mg/l, and Escherichia. Coli content was 210 mg/100 ml, making it unsuitable for safe, clean water [9]. Therefore, clean water is purchased and periodically supplied by truck to the community to meet daily household needs. An alternative solution besides a clean water supply is treating brackish water with local filter media, which is abundantly available [10]. Local filter materials, such as silica sand, lumajang sand, pumice, bricks, sponge, alum, charcoal, active carbon, kaolin, bio ring, clam shell, red tile, and zeolite, can be used to treat the water.

Several studies have been conducted on brackish water treatment to address clean water supply. Jayaprakash et al. [11] have introduced a method to reduce iron, sulfate, chlorine, sodium, and TDS content in brackish water using activated carbon media. Khanzhanda et al. [12] have evaluated the performance of a combination of pretreatment and reverse osmosis. The first method combines cartridge pretreatment with reverse osmosis, and the second uses ultrafiltration with RO. Yogafanny et al. [13] have introduced a method using local zeolite material to reduce dissolved solids levels. Yaqin et al. [14] found a portable water purifier using silica sand, zeolite stone, greensand sand, zeolite manganese, bio-balls, and activated carbon. Barahoei et al. [15] have introduced a method to reduce salinity using chemical photosynthetic desalination cells. Ansari. et al. [16] evaluated the performance of brackish water desalination using reverse osmosis under different operational conditions. Desmiarti et al. [17] found a demineralized water method using a combination of continuous filtration and ion exchange processes.

Several references were also taken from several patents on brackish water purification devices. Tadd C. Kippeny et al. [18] made a patent entitled Water Desalination Apparatus with patent number US8377297B2, discussing using a salt sponge unit to remove most salt from water. A parallel plate capacitor can be connected after the salt sponge to remove the remaining salt ions. Chen et al. [19] made a patent entitled A kind of processing method of brackish water and a sort of saliferous water treatment system with patent number CN105174512B, discussing a brackish water treatment method by performing nanofiltration separation to obtain production water and nanofiltration concentrated water. Nanofiltration production water is subjected to a reverse osmosis separation process. Shen et al. [20] made a patent with the title Bitter (brackish) saltwater purifying equipment with patent number CN103073136A, discussing the manufacture of brackish saltwater purification equipment with multi-medium filter, automatic cleaning filter, and ultrafiltration membrane device.

This study aimed to identify a technique for obtaining clean water from brackish water by choosing filtration with suitable local material, reverse osmosis, and ion exchanger. Based on the research results, it is expected that the implementation of this method can provide a practical solution for overcoming the clean water crisis if it is put into practice. The test results will be compared to the WHO drinking water standard for water quality criteria, including pH (Power of Hydrogen), TDS (Total Dissolved Solids), EC (Electrical Conductivity), odor, and color.

Material and Method

Experimental study use physical and chemical methods to discover the optimal combination for on-site brackish water treatment silica sand, lumajang sand, alum, carbon active, sponge, pumice, kaolin, red brick, red tile, charcoal, zeolite, bio ring, clam shell, and a filter 10 micron comprise the filter module combination set. Reverse osmosis and ion exchanger equipment will be utilized to further treat the water purified by the filtration method.

Material

Silica Sand

Silica sand, or quartz sand, contains about 99.7% silicon dioxide (SiO2). Silica sand is a very effective water filtration medium because it can precipitate and retain impurities from the treated water. It is expected that silica sand can remove mud contained in brackish water (Fig 2.a). [21].

Lumajang Sand

Lumajang Sand is formed from silicon dioxide content or limestone. Generally, the size of sand is 0.0625 mm to 2 mm [22]. The function of sand for water filters is to hold silt and fine impurities. The type of sand used in this study comes from Lumajang, East Java, Indonesia. The characteristic of this sand is the color of the sand, the sand has a gray to black color (Fig 2.b).

Alum

Alum is found in nature as a chemical compound known as hydrated aluminum sulphate salt in the white crystalline form (Fig 2.c). Potassium alum or potash alum is used to coagulate the impurities so that the impurities can be separated [23]. As it has the characteristic as coagulant agent, it is not only utilized in water treatment, but also in industrial sector, i.e., medicine, food preparation, and textile industry. An appropriate dosage of Alum should be added during the water treatment so that the treated water is safe for daily consumption.

Active Carbon

Active carbon is widely known for its physical properties, which includes a large surface area and homogeneous pore size (Fig 2.d). It is chemically inert and stable [24]. Based on the characteristic mentioned above, odor and color, which is caused by the organic compound in water, can be removed by adsorption. Hence water's taste and appearance can be improved [25]. However, both coarse and fine impurities in the water can't be separated by active carbon absorption.

Sponge

Sponge is commonly known as basic physical and mechanical filter media, which is simple and cost-effective. It is widely available and has a porous synthetic material capable of absorbing water and good aeration (Fig 2.e) [26]. The suspended solid particle in water can be separated by immersing it in the pore [27]. However, a limited number of dissolved impurities can be retained. Sponge, in terms of maintenance, can be effectively cleaned in specific periods and is easy to be utilized back as filter media.

Pumice

Pumice is a type of rock that is light in color and contains thick foam made of glass-walled bubbles (Fig 2.f) [28]. Pumice can remove coarse contaminants due to its large surface area and

up to 90% porosity. Pumice can be an absorbent material to remove heavy metals, radioactive, and dyes in wastewater [29]. The disadvantage of using this material as a filter is that pumice cannot remove fine impurities like sand filters. In terms of maintenance, the pumice filter is easier to maintain when compared to a sand filter, but it still takes quite a bit of time long enough.

Kaolin

Kaolin or kaolinite is a type of primary clay material that exists in nature, with the chemical formula Al2O3.2SiO2.2H2O (Fig 2.g). Kaolin and activated carbon have similar physical properties with high surface area and stability. By absorption, Kaolin can remove toxic pollutants from water, such as chloride, sulfate, Cr, Cd, and Zn [30], [31]. The disadvantage of this filter media is that it cannot hold fine or coarse impurities.

Red Bricks

The function of red bricks in this water purification filter is to separate and precipitate the minerals in brackish water. The bricks used this time are red bricks. Red bricks have a large surface area and a high porosity making them suitable to be used as an absorbent material and filter waste (Fig 2.h) [32]. Given that red bricks are made of clay, this filter can help precipitate the minerals contained in the water. The disadvantage of this filter is that it cannot help purify water in terms of color.

Red Tile

Red tile is made from clay processing and then heated with coal with a certain degree of heat (Fig 2.i). The function of red tile in water filters is to help kill harmful minerals, and its weakness is that it cannot filter out impurities [33].

Charcoal

Another filter material known as an effective filter media is charcoal. The charcoal made from the coconut shell is high-quality, effective, and environmentally friendly. Like active carbon and kaolin, coconut shell charcoal can absorb and remove chemical pollutants in the water (Fig 2.j)[34]. As filtering media, shell charcoal has a slightly significant result, it can’t hold the coarse impurities in brackish water, whereas odor and taste can be improved. In terms of maintenance, a periodic replacement is needed and is easy to obtain as this material is commonly used in water treatment.

Zeolite

A form of hydrated alumina-silicate chemical compound with sodium, potassium, and barium cation is known as zeolite. Zeolite is formed naturally from volcanic and sedimentation rock in nature. It can retain or separate chemical molecules as it has molecular-sized pores (Fig 2.k). Zeolite, as an adsorbent, can cation exchange due to its negative electrical charge in them. This negative electrical charge can bind cations generally found in groundwater, i.e., Fe, Al, Ca, and Mg. [35]. Zeolite is used not only in water treatment but also for treating wastewater treatment. It is expected to remove heavy metal cations in wastewater, i.e., Zn, Cr, Pb, Cd, Cu, Mn, Fe, etc.

Bio Ring

Bio ring is made from ceramic and found in white color. It has a cylindrical form of 20 mm in height and 18 mm in diameter (Fig 2.l)[36]. The function of the bio ring in this filtration 200 is to

filter bacteria in brackish water. Bio rings have a large surface area and porosity. The number of pores in the bio ring gives the bio ring a high surface area, which is helpful for bacteria to colonize, allowing water to enter the pores easily [37]. The disadvantage of this filter is that it cannot filter impurities from the dirt in the brackish water.

Clam Shell

The public generally considers clamshell waste but have a high mineral content. The type of mineral present is calcium. Therefore the function of the shell in the water filter can be used as a natural mineral source (Fig 2.m)[38].

10 Micron Filter

The 10 Micron filter consists of a filter cartridge made of polypropylene. Cartridge filters come in various sizes, with pore diameters ranging from 20 to 1 micron. Therefore, using 10-micron filters in water filters can retain small particles that enter and improve the quality of treated water (Fig 2.n). When the cartridge filter is saturated, it must be replaced to maintain its function [39].

Reverse Osmosis (RO)

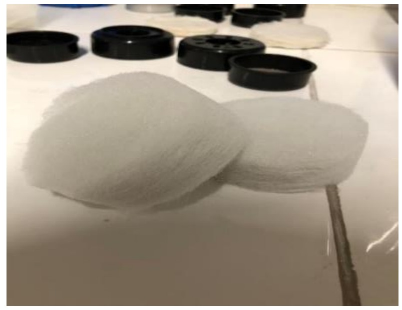
Reverse osmosis is the most modern type of water treatment. It is the most efficient separation technology used in some industrial locations for treating wastewater and seawater desalination for creating fresh water (Fig 2.o)[40,41,42]. Water pressure is applied through a semi-permeable membrane to remove dissolved inorganic contaminants from water. Fluoride, chlorine, nitrates, sulfate, pesticides, etc., dissolved pollutants in the water are removed during treatment [43]. Solid impurities must be separated using mechanical treatment, i.e., settling and filtration, so that it will not shorten the membrane interval maintenance and its lifespan time due to mechanical damage. To improve reverse osmosis performance, periodic maintenance and cleaning to remove fouling on the membrane surface must be conducted.

Silica Sand (a)

Lumajang Sand (b)

Alum (c)

Active Carbon (d)



Sponge (e)

Pumice (f)

Kaolin (g)

Red Brick (h)

Red Tile (i)

Charcoal (j)

Zeolite (k)

Bio Ring (l)

Clamshell (m)

10 Micron Filter (n)

Reverse Osmosis (o)

Figure 2. Materials for filter modules from local materials and reverse osmosis

Ion Exchanger

The ion exchanger is one of the desalination process's fundamental components. It functions by binding positive and negative ions with a substance called resin. There are two ion exchange resins: cation exchangers, which contain positively charged ions that are exchangeable (Fig 3.a and Fig 3.c), and anion exchangers, which have negatively charged ions that are exchangeable (Fig 3.b and Fig 3,c). Both cation and anion resins must be regenerated using a powerful acid or base. Using flow-through, column, or tank systems, the ion exchange process transforms produced brackish water into drinkable or disposable water [44]. Most often, ion exchange media are used to remediate waste, soil, and water. This study will employ ion exchange media to treat brackish water widely found in coastal and rural locations. Ion exchange therapy is one approach for fixing domestic water problems. It can eliminate toxic contaminants from water [45,46].

Cation Exchanger (a) Anion Exchanger (b) Cation and Anion Resin (c)

Figure 3. Material for Ion Exchanger. Anion and Kation Exchanger Resin

Research Methodology

The research methodology used in this study is experimental research, including literature from previous studies. A case study will follow. Related information and data on brackish water, for example, recent research on treatment methods and properties of brackish water, will be obtained as the basis of this research. The application of physical experiments in brackish water treatment in this research will be carried out by selecting local materials as filter media and reverse osmosis media. These local materials will be prepared in the filtration module. The application of chemical experiments using ion exchange resin will be used as water treatment equipment.

Filter Media Preparation and Assembly

Filter module assembly with selected local filter media was conducted in the laboratory (Fig.4.a). The brackish water sample is obtained from two villages, Tegal Sari and Kupang, in Jabon District, Sidoarjo Regency (Fig. 4.b). Reverse osmosis and ion exchanger cartridges will also be assembled in the laboratory (Fig .4.c and 4.d).

Filter Module Preparations (a)

Water Samples (b)

Reverse Osmosis (c)

Ion Exchanger (d)

Figure 4. Water treatment equipment assembly (preparation for filter module, reverse osmosis, ion exhanger in filter module and obtaining brackish water sample)

There will be a pretreatment phase for filter media before it is filled into the filter module. Dirt and another contaminant will be eliminated by washing in the first phase (Fig. 5.a). Once the washing phase is completed, filter media will be dried in the oven. (Fig. 5. b). Mechanical phase, crushing, and screening are necessary for certain material to extend their surface area, which can be seen in (Fig. 5.c and 5.d).

Washing (a)

Drying (b)

Crushing (c)

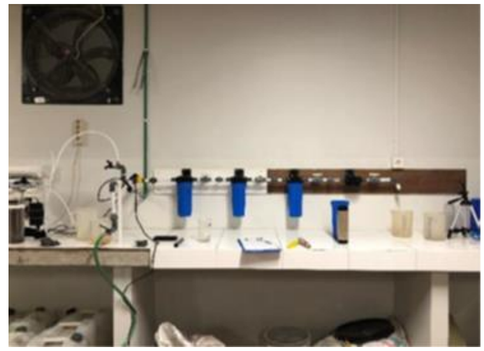
Screening (d)

Figure 5. Filter media pre treatment phase (washing, drying, crushing and screening)

Filter Module Assembly

As the filter media has completed its pretreatment phase, it will be filled into each filter module (Fig. 6.a). A brackish water sample will be pumped into the filtration module (Fig. 6.b). The treated brackish water from the filtration module will be analyzed for its water quality parameter, i.e., pH, TDS, EC, odor, and color will be observed and measured (Fig. 6.c and Fig 6.d). The combination of local filter media used in this study amount to 25 combinations which is described in Table 1. For instance: the first experiment, the combination module 1, 2, and 3 utilized: lumajang sand, charcoal, and bricks, respectively.

Filter Module Materials (a)



Filter Module Installations (b)

EC Value Result (c)

pH Value Result (d)

Figure 6. Filter module assembly (water quality parameter analysis for treated water after filtration)

The brackish water sample will be analyzed before the treatment in the laboratory to get the initial water quality parameter value. It has an average pH of 8.0, a TDS value of 2550 ppm, EC value of 5070 µs/cm. Color, odor, and turbidity of the water sample before and after treatment are also observed. The standard water quality criterion will be based on the Minister of Health Republic of Indonesia Regulation No. 492, 2010, and the WHO drinking water quality standards. As per water parameter quality standards, clean water has an average pH between 6.5 – 8.5, a TDS value lower than 500 ppm, and an EC value lower than 300 µs/cm. As physical criteria, clean water must be odorless and colorless [47,48]. The water quality parameter after the treatment will be compared with the standard above.

Table 1. Filter module combination with local filter media

No	Module 1	Module 2	Module 3	Module 4	Module 5	Module 6
1	Lumajang Sand	Charcoal	Bricks			
2	Lumajang Sand	Pumice	Bricks	Kaolin	Active Carbon	
3	Lumajang Sand	Pumice	Bricks	Kaolin	Active Carbon	
4	Lumajang Sand	Pumice	Bricks	Kaolin	Active Carbon	
5	Lumajang Sand	Carbon Active	Bricks	Zeolite	Kaolin	
6	Lumajang Sand	Red Tile	Zeolite	Zeolite	Kaolin	Active Carbon
7	Zeolite	Zeolite				
8	Clamshell					
9	Fliter					
10	Active Carbon					
11	Active Carbon	Active Carbon				
12	Kaolin					
13	Bio Ring					
14	Filter	Kaolin	Zeolite	Kaolin	Kaolin	Kaolin
15	Fliter	Kaolin	Zeolite	Kaolin	Active Carbon	Kaolin
16	Bricks					
17	Lumajang Sand	Bricks				
18	Lumajang Sand	Bricks	Bricks			
19	Lumajang Sand	Bricks	Bricks	Sand		
20	Kaolin	Active Carbon	Active Carbon	Active Carbon	Filter 10 Micron	
21	Alum	Zeolite	Kaolin	Silica Sand		
22	Alum	Kaolin	Filter 10 Micron	Kaolin		
23	Zeolite	Silica Sand	Filter 10 Micron	Sponge		
24	Silica Sand	Zeolite	Charcoal	Filter 10 Micron		
25	Silica Sand	Zeolite	Sponge	Filter 10 Micron		

Result

pH, TDS, and EC of the treated water, as the determining water quality parameter, will be measured and described in two sections. The analysis result after the filtration through the filter module combination will be shown in the first section. The analysis results from reverse osmosis and ion exchanger can be seen in the second section. Based on brackish water before and after treatment analysis results, the treatment effectiveness from both filtration method, reverse osmosis, and ion exchanger can be further evaluated.

Water Quality Parameter After Filtration with Local Filter Media

pH

As shown in Fig. 7, the filtration result shows that the pH value range is between 6.6 to 8.6. The highest increase in pH value from 7.7 to 8.4 is shown in experiments 6, while the highest decrease in pH value from 8.6 to 8 occurred in experiments 1. The pH value after treatment is still acceptable based on the quality standard except for experiments 21, and 22.

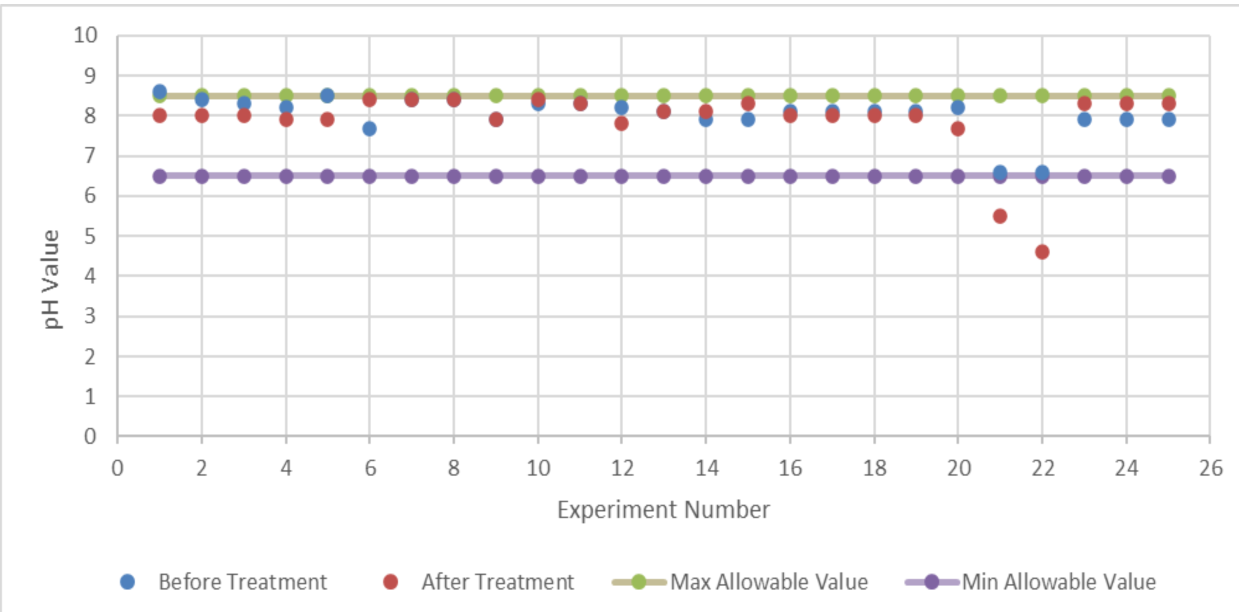


Figure 7. pH value comparison, before and after filtration

TDS value shows a decreasing trend after filtration. It can be seen in Fig. 8 that the TDS value after the treatment is in the range between 2340 – 4810 ppm. Experiment no. 15 result has the highest decrease in TDS value from 2560 ppm to 2340 ppm, equal to 8.59%.

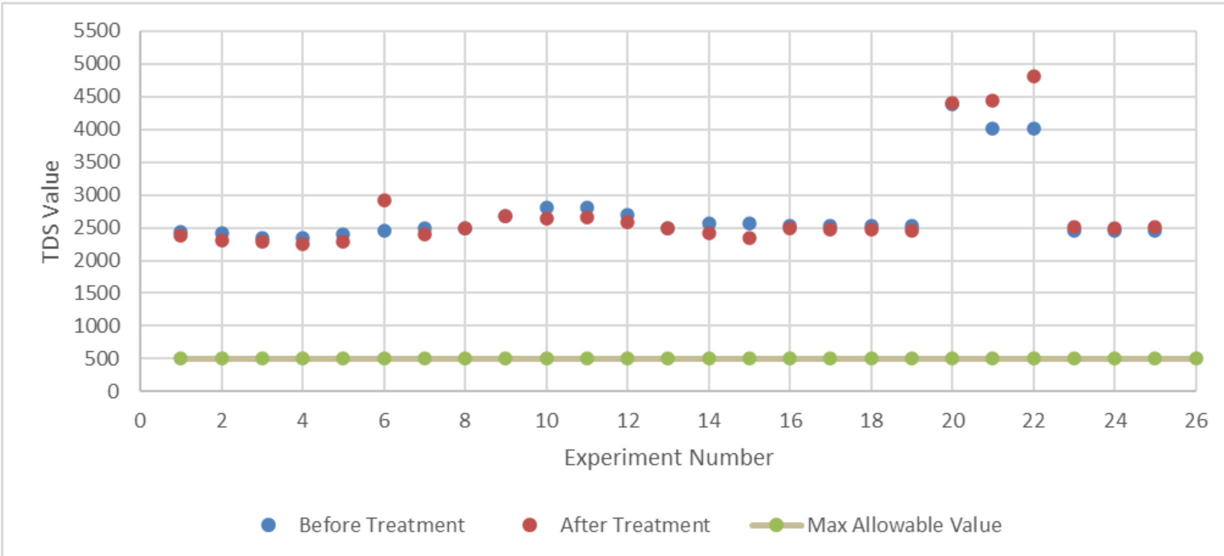


Figure 8. TDS value comparison, before and after filtration

The same decreasing trend in EC value is also obtained after filtration. The average EC value after filtration ranges between 4530 – 9800 μs/cm. Like the TDS value, experiment no. 15 has demonstrated the highest decrease in EC value from 5150 μs/cm to 4780 μs/cm. The filtration method can achieve an average reduction between 3.9% - 7.18% in EC value. The comparison of EC values before and after filtration is shown in Fig. 9.

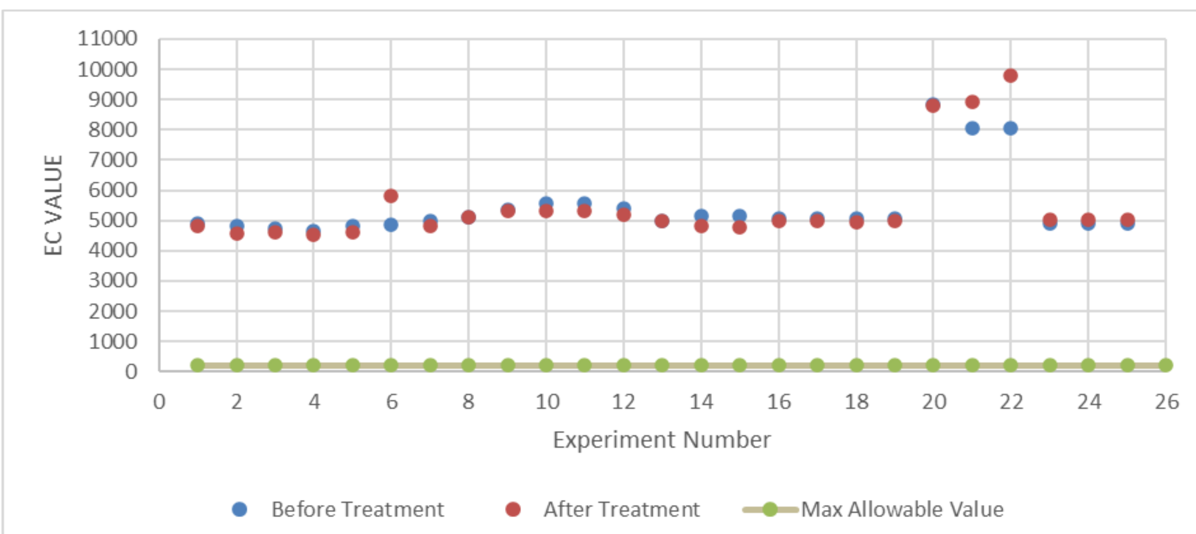


Figure 9. EC value comparison, before and after filtration

Water Quality Parameter from Reverse Osmosis and Ion Exchanger

As TDS and EC values from the treated water, the filtration method with selected local material still exceeds the WHO clean water standard guideline, reverse osmosis equipment is

utilized to remove the TDC and EC value further. The filter module is also equipped with the reverse osmosis unit to remove dirt and other coarse contaminants as pretreatment. 10-micron filter, Chlorine Taste Odor (CTO), and Granular Active Carbon (GAC) are the main components in the filter module. The result in Table 2 shows the treatment result by reverse osmosis. TDS and EC value significantly reduced at approximately 95 – 98% from the initial value before the treatment.

Table 2. Reverse osmosis analysis result on pH, TDS, and EC

Time	pH		TDS		EC	
(minutes)	Before	After	Before	After	Before	After
5	8	8,2	2550	232	5070	467
10	8	8,2	2550	247	5070	496
15	8	8,2	2550	245	5070	493
20	8	8,2	2550	252	5070	500
25	8	8,2	2550	250	5070	503
30	8	8,2	2550	253	5070	504
35	8	8,2	2550	251	5070	505

TDS and EC analysis results after treatment with an ion exchanger is shown in Table 3. TDS value reduction by ion exchanger ranges between 67 – 70%, while EC value shows the same reduction range as TDS.

Table 3. Ion exchanger analysis result on pH, TDS, and EC

Time	pH		TDS		EC	
(Minutes)	Before	After	Before	After	Before	After
5	8	8,3	2550	815	5070	1630
10	8	8,3	2550	793	5070	1586
15	8	8,3	2550	750	5070	1500
20	8.0	8.3	2550	729	5070	1458

Disscussion

There was little significant change in the pH value after treatment with the combined filter modules. There is an increase of about 2.23%, so the filtered water tends to be alkaline, but the pH value is still within the standard guidelines for clean water. The TDS value has decreased by about 1.64–7.56%, which can be obtained with a combination of filter modules. Like the TDS value, the EC value also decreased between 3.9% and 7.18%. When compared with research conducted by Yaqin et al. [14], it was found that the filtration results for pH values dropped by about 6.25% so that the water tended to be neutral, and for TDS values, they increased by about 50%. Therefore, the combination of a 10-micron filter, silica sand, kaolin, zeolite, brick, and activated carbon in Experiment No. 14–20 showed better results in reducing TDS and EC values. These filter materials can remove minerals and salinity contained in brackish water. However, the salinity reduction was not significant enough. Odor, color, and turbidity can be removed by the filtration method.

The reverse osmosis performance in this study shows that it can effectively remove TDS and EC values around 99.5%. Compared to the research conducted by Ansari et al. [16], reverse osmosis can remove TDS values of around 98.8%. As a result, the reverse osmosis performance in this study is better than other studies, exceeding the maximum standards in standards set by the WHO. However, since the filtration method can remove odor, color, and turbidity, the brackish water is sufficient to meet daily household consumption needs.

Ion exchangers have the same ability to remove TDS and EC from brackish water. The treatment results show a decrease in TDS and EC values in the 67–70% range. Therefore, ion exchangers are less effective in removing TDS and EC than reverse osmosis. The TDS and EC values obtained after treatment with ion exchangers are higher than the standards set by the WHO, which are 500 ppm for TDS values and 300 s/cm for EC values—according to a study by Desmiarti et al. [17], using an ion exchanger and microfilter for water treatment results in a more significant reduction of TDS and EC values by approximately 89.01%-90.91% for four cartridges and one microfilter and approximately 95.94%-96.36% for six cartridges and one microfilter.

Reverse osmosis and ion exchanger are proven methods that can provide a sufficient treatment to get the clean water standard parameter. Reverse osmosis has the advantage of requiring no hazardous chemical agent, and a high-quality clean water standard can be achieved. However, the membrane is the sensitive item in reverse osmosis which requires careful attention and is costly. On the contrary side, the ion exchanger is more competitive even though it is less effective than reverse osmosis. The disadvantages of an ion exchanger lie in the requirement of the chemical agent to rinse or reactivate the resin, and is not able to remove bacterial or organic contamination.

The result may differ in each method because there are differences in parameters, such as raw water quality, filter materials, and the input flow rate before treatment. Combining physical methods by filtration and reverse osmosis or ion exchangers can remove contaminants in brackish water. Hence, the safe, clean drinking water quality parameter can be complied with.

Conclusion

The combination of local filter materials and applied water treatment equipment, especially in remote areas, proved to be cost-effective equipment. This equipment is very practical and helpful for local communities, especially in coastal regions in Indonesia and local communities in disaster-prone areas. Therefore, clean water can be produced locally and used for daily household consumption, as the filtration method can largely remove odor, color, and turbidity. In terms of maintenance, the filter is easy to maintain and clean regularly.

The results of the research study showed that water filters using local materials are able to reduce TDS, EC, and pH values. The best combination to reduce TDS, EC, and pH values is a combination of a 10-micron filter, kaolin, zeolite, kaolin, activated carbon, and kaolin. It was found that the values of TDS, EC, and pH were able to be reduced by 8.59%, 7.18%, and 2.59%, respectively.

As the filtration method can't remove TDS and EC further, reverse osmosis, and ion exchanger can obtain the standard safe drink water quality according to WHO standard guidelines. Specific instructions for maintaining a semi-permeable membrane in reverse osmosis

or how to do a chemical rinse for ion exchanger resin must be available for the community to do the maintenance themselves.

Based on the results of this study, it is expected that compact, effective water treatment equipment for disaster-prone locations can be created. The treated brackish water from the filtration method with local filter media can be treated further in conjunction with reverse osmosis or ion exchange. As there are two options for further treatment, the advantages and disadvantages from the economic and maintenance point of view should be considered. In terms of disaster-prone areas, the community will need to have simple water treatment equipment and low maintenance. Therefore, cost-effective and low-maintenance water treatment equipment in the long term can serve as the next step in this research.

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to me

Yth pak Surya,

Terimakasih pak, ini sedang difollow up pak Marno dan bu Sarita. Terimakasih.

Salam,
DH

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