Journal of Natural Sciences Research www.iiste.org
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.4, No.24, 2014

The Combination of Coagulant Aid, Ion Exchanger, and Reverse Osmosis (RO) on Brackish Water Treatment

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The research is financed by the Directorate General of Higher Education, Ministry of Education and Culture, Indonesia through Grant Competition Research 2013-2014

Abstract
The high content of chloride salts, and other dissolved salts such as; $SO4^{2-}$, Na^+, and the presence of coliform criteria lead to non-compliance of brackish water as clean water. Decreasing of the content of water's parameters in brackish water can be done by treatment of Coagulant Aid and Ion Exchanger that followed serially by membrane technology reverse osmosis (RO). The flowing process of treatment in this study are : coagulant aid, filtration using sediment polipropylena (SPP), and absorption using manganese greensand, then continued by Ion Exchanger using synthetic resin anion and cation resin. As a finishing treatment is filtration micro using membrane of Reverse Osmosis (RO). The combination of coagulant aid, ion exchangers and reverse osmosis (RO) water treatment brackish obtained on removal parameters: Chloride of 2028 ppm, Turbidity 2.74 NTU scale, color 45 units PtCo, Iron 0.22 ppm, Total Disolved Solid (TDS) 3366 ppm, Total Hardness 621.43 mg/L, CaCO3, Organic Substances 19.84 mg/L KMnO4, Fluoride 0.62 ppm, Nitrate 0.06 ppm, Nitrite 0.64, Zinc 0.08 ppm, Sulfate 40.46 ppm, and Detergent at 0.12 mg/L LAS. Processing brackish water based on RO membrane techno combined with coagulant aid and ion exchanger are able to fulfill all of clean water requirements parameters
Keywords: brackish water, coagulant aid, ion exchanger, reverse osmosis (RO)

1. Introduction

Water is the necessary resource for human survival, is indispensable in daily life. BW has obvious peculiar smell and taste, which can cause cancer, calculus, cirrhosis and other diseases. High salinity in BW, especially the sulfate and organic humic acid, is the main reason for these diseases. BW with the degree of mineralization of more than 1000 mg/L, fluoride content than 1.0 mg/L and can't be used directly (Zhang *at al*. 2013). Sodium chloride salt (NaCl) is higher in brackish water causes excessive saltiness. Brackish water is caused by the presence of sea water intrusion into the groundwater pathway. This event is causing high salinity water wells in coastal areas. Salinity is caused by the presence of salt sodium chloride (NaCl) that very high, up to 10.000 ppm. In Lamongan's area of East Java Indonesia, found chloride's level is equal to 3000 ppm, Na^+ = 2000 ppm, Mg^{++} = 278 ppm, Ca^{++} = 407 ppm, Fe (tot) = 0,088 ppm, and TDS = 3600 ppm (Purwoto 2010). Nurhayati (2006), reported that a sample of Sidoarjo's coastal in East Java of Indonesia showing the results: chloride level is about 8580 mg/L while TDS is approximately 19,310 mg/L, and hardness is 7560 mg/L (as CaCO3), where the conditions are very far from fulfilling the criteria as clean water. According to Permenkes Republic of Indonesia Number: 416 / Menkes / Per / IX / 1990 on Clean Water Quality Requirements, Total dissolved solids (TDS) 1000 Mg/L, color 50 TCU, turbidity 25 NTU, Iron 1.0 mg/L, Manganese 0.5 mg/L, Chloride 600 mg/L, Hardness (CaC03) 500 mg/L, Total Coliform Bacteria 10 (Number per 100 ml sample) on piped water.

Some mineral content as a form of cation-anion in water macro include : Na^+, Ca^{+2}, Mg^{+2}, K^+, Fe^{3+}, Cl^-, SO_4^{-2}, and CO_3^{-2} (Lee *at al*. 2005). According to Montgomery (2005), the principle of demineralization can be done by : ion exchange resin (ion exchange), deionization, distillation membrane transfer, flash evaporation, and reverse osmosis (RO).

Brackish water treatment can be done through the techno membrane reverse osmosis (RO) combined with Coagulant Aid and Ion Exchanger. Remove capacity treatment zeolit as : P Alkalinity 9.5 ppm, M. Alkalinity 80.5 ppm, Total Hardness Total 185.72 ppm, Ca 100 ppm, Mg 85.72 ppm, Si 25 ppm, Chloride 52 ppm, Total Disolved Solid (TDS) 311 ppm, Iron 1.41 ppm, Mn 0.46 ppm, Energy of Passing Electrics (EPE) 517 mhos/cm. (Purwoto 2010). Water from natural sources usually contain a lot of dissolved and suspended solids. Large suspended particles such as sand are called discrete particles can be processed by sedimentation or filtration. The smaller suspended particles that are not easily deposited is called colloids. The colloidal particles can be processed with the addition of chemicals then deposited on the sedimentation and filter. Coagulant that can be used at Water Treatment Plant include Sucolite SP 211. Sucolite is liquid, colorless and odorless. Sucolite has pH at a temperature of 20^oC is about 11 to 11.5 others the fluid has a specific gravity of 1.35 g/cm^3. Meanwhile, according to the results of the analysis sheet Sucolite SP 211: Al2O3 content is 4.66%, pH of solution is 2% (pH of soluble is 2% in water) that is 3,553, part insoluble in water 0.060%. Flocculation was very rapid in pH range of 6.5 to 8.0 (Jadhav *at al*. 2013). The preparation, characterization, and adsorption properties of Mn^{2+} by manganese oxide coated zeolite (MOCZ) and its ability in removing Mn^{2+} by adsorption were investigated. Characterization analyses were used to monitor the surface properties (and their changes) of the coated layer and metal adsorption sites on the surface of MOCZ. The adsorption experiments were carried out as a function of solution pH, adsorbent concentration and contact time (Taffarel *at al*. 2010).

Ion exchange process involves a chemical reaction between ion in the liquid phase with ion in the solid phase. Certain ions in solution is more easily absorbed by the solid ion exchange, and because of elektronetrality must be maintained, solid ion exchanger remove ion and exchanged ion in solution. In the process of demineralization, then as an example; cation Na^+ and anion Cl^- are removed from water and solid resin lossing ion H^+ for exchanged with ion Na^+, and also OH^- exchanged with Cl^- from water so that the content of Na^+ and Cl^- in water be reduced or lost. The involvement of the cation-anion exchange's grups is described as the following reaction: where R is the anionic groups attached to the ion exchange resin, A^+ is the cation in resin and B^{n+} is the cation in the solution (Lee *at al*. 2005, Montgomery, 2005). Dissolved organic matter (DOM) and hardness cations are two common constituents of natural waters that substantially impact water treatment processes. Anion exchange treatment, and in particular magnetic ion exchange (MIEX), has been shown to effectively remove DOM from natural waters. Hardness ions can be removed with cation exchange resins, although typically using a fixed bed reactor at the end of a treatment train. In this research, the feasibility of combining anion and cation exchange treatment in a single completely mixed reactor for treatment of raw water was investigated. Simultaneous removal of DOM (70% as dissolved organic carbon) and hardness (>55% as total hardness) was achieved by combined ion exchange treatment. . Combined ion exchange is expected to be useful as a pre-treatment for membrane systems because both DOM and divalent cations are major foulants of membranes (Apell *at al*. 2010). The resin has been made successfully in pilot batches and is being tested in standard pilot-scale ion-exchange equipment. Field trials are showing considerable promise and are continuing on this resin with surface and underground waters. Some pretreatment will be necessary for most natural waters. Resin-life studies are so far promising and are continuing. Additional attractions of this process for desalination are the highly reliable and well-tested technology already developed for conventional ion-exchange, and ease of upscaling (Battaerd *et al*. 2001).

Membrane Reverse Osmosis (RO) is Porous semipermeable membrane of 0.0001 micron, TDS fluid maximum of 15 ppm, iron levels <0.1 mg/l, working with high pressure in stages through several stages of filtering process, among others; cartridge (sediment), carbon block and granular carbon where water-free results from water contaminants such as viruses, bacteria, chemicals and heavy metals. Depending on the quality of intake water, membrane process, posttreatment and desired quality of product water, a pretreatment system was designed. Results of previous experiences and present guidelines and schemes that are developed combining unit processes for pretreatment of reverse osmosis feed are reviewed (Shahalam *at al*. 2002). Reverse osmosis (RO) desalination is one of the main technologies for producing fresh waterfrom seawater and other saline water sources. The membrane properties greatly affect the water productivity and energy costs in the reverse osmosis desalinatin processes (Li *at al*. 2010). The high-efficiency seawater desalination technology which improves the recovery ratio of fresh water up to 60% developed by a manufacturing company of reverse osmosis membranes in Japan is explained (Magara *at al*. 2000).

2. Materials And Methods

2.1. Plant Materials

The samples of raw water as brackish water taken from Sidoarjo East Java Indonesia in October 2014.

2.2. Tools and Materials Research

The main tool used in brackish water treatment in this study are: housing filter, Fibre-Reinforced Plastic (FRP) tube, and reverse osmosis housing. Processing procedure performed by using material treatment such as: Coagulant Aid use Sucolite SP 211, Poly Propylene Sediment (PPS) as filtration, Carbon Block and Manganese Green Sand as **absorption**, Ion Exchanger use anion resin and cation resin, and also reverse osmosis membranes (RO).

2.3. Design criteria

The treatment model design of brackish water treatment based on parameters criteria of clean water that is a series of the three stages of treatment, namely; radiant tube column of Coagulant Aid with Ion Exchanger then continue processing using Membrane techno reverse osmosis (RO), with reactor circuit components consisting of:Raw water tank, Housing Filter, tube column Fibre-Reinforced Plastic (FRP) resin, fiberglass tube, and Housing RO is equipped with a reservoir Products. Submersible pump as suction of raw material to be supplied to the treatment process, as well as booster pump to supply RO treatment.

2.4. General Experimental Procedures

Brackish water treatment process begins by affixing coagulant Sucolite SP 211 concentration of 90 ppm in reservoir (raw water), then by a vacuum pump (submersible pump) is passed to the Cartridge for the initial treatment process at first time using sediment polipropylena as filtration, and absorption using Carbon Block and manganese greensand. Treatment is continued with Ion Exchanger process consecutively using anion synthetic resin and cation resin in the tube of Fiberglass Reinforced Plastic (FRP) with Up-Flow flowing system. After exiting from ion exchanger, the water that has removaling process using anion kation, is refiltered by sediment polipropylena, and then stored in a fiberglass tube. As a final process, from fiberglass tube inhaled using a booster pump to be done micro-filtration using membrane Reverse Osmosis (RO) in housing RO tube. After passing through RO treatment, water has reduced the concentration of cleaning water criteria parameters, collected as a result of water (reservoirs product).

2.5. Analysis of The Laboratory Tests Results

Parameters test is done for; *a*). Samples of raw water, b). The results of treatment ; filtration, coagulant aid, and ion exchanger, and c). reverse osmosis filter product

3. Results And Discussion

3.1. Research Results

After treatment laboratory test results of research treatment, which sample (a) is Raw water, sample (b) is Coagulant Aid treatment result and Ion Exchangers, and sample (c) is treatment result of *reverse osmosis* membrane (RO).

The results of the study treatment as a laboratory test procedure refers to the criteria of water parameters are presented in Table 1.

Table 1. Parameters Removal Based on Water Requirements Parameter

No	Parameters	Units	Clean Water Requirements *)	(a) Raw Water	(c) Complete Treatment	Removal
	***A.* Physics**					
1	Odor	-	odorless	odorless	odorless	
2	Total Disolved Solid (TDS)	mg/L	1500	4116	750	3366
3	Turbidity	NTU Scale	25	2.96	0.22	2.74
4	Flavor	-	tasteless	-	-	
5	Temperature	oC	air temperature ± 3°C	25	25	0
6	Color	Unit PtCo	50	45	0	45
	***B.* Chemistry**					
	a. Inorganic Chemistry					
1	Mercury	mg/L Hg	0.001	0	0	0
2	Arsenic	mg/L As	0.05	0	0	0
3	Iron	mg/L Fe	1	0.52	0.3	0.22
4	Fluoride	mg/L F	1.5	1.26	0.64	0.62
5	Cadmium	mg/L Cd	0.005	0	0	0
6	Total Hardness	mg/L CaCO3	500	621.43	0	621.43
7	Chloride	mg/L Cl	600	2400	372	2028
8	Cromium, Val 6	mg/L Cr	0.05	0	0	0
9	Manganese	mg/L Mn	0.5	0	0	0
10	Nitrate	mg/L NO3-N	10	0.89	0.83	0.06
11	Nitrite	mg/L NO2-N	1	0.66	0.02	0.64
12	pH	-	6,5 - 9,0	7.9	8	-0.10
13	Selenium	mg/L Se	0.01	0	0	0
14	Zinc	mg/L Zn	15	0.18	0.1	0.08
15	Cyanide	mg/L CN	0.1	0	0	0
16	Sulfate	mg/L SO4	400	40.46	0	40.46
17	Lead	mg/L Pb	0.05	0	0	0
	b. Organic Chemistry					
1	Organic Substances	mg/L KMnO4	10	19.84	0	19.84
2	Detergent	mg/L LAS	0.5	0.14	0.02	0.12

*Note ; *) Permenkes Republic of Indonesia Number: 416 / Menkes / Per / IX / 1990 on Clean Water Quality Requirements*

3.2. Discussion

Referring to lab tests results, parameters removal according to clean water requirements by influence of RO membranes techno combined with coagulant aid and ion exchanger is reached on parameters ; chloride, turbidity, color, iron, total disolved solid (TDS), total hardness, Organic Matter, Fluoride, Nitrate, Nitrite, Zinc, Sulfate, and Detergent. The use of RO membranes in desalination processes need to consider about cost (Li, 2010).

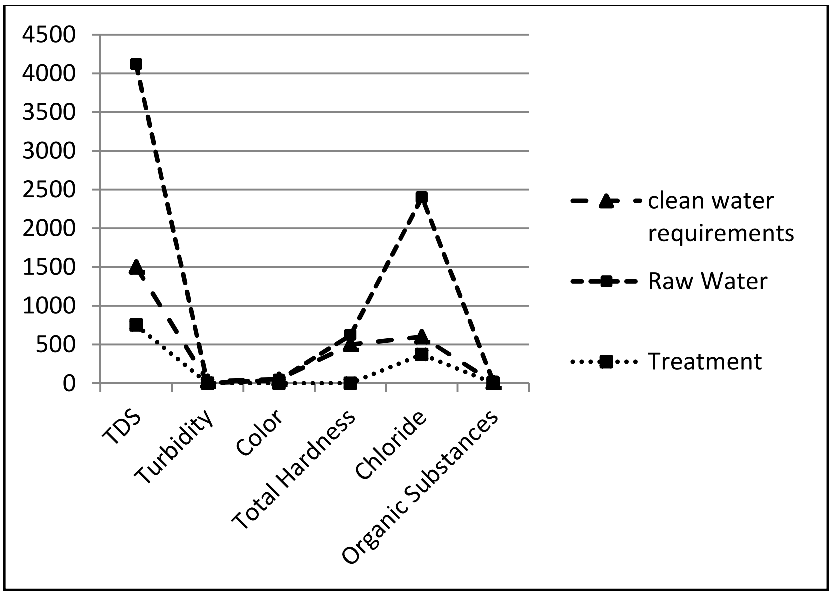

Figure 1. Graph Concentration Reduction of Some Parameters

As a review of raw water quality, raw water parameters in this study are still not fulfilled as clean water requirements are; Total Disolved Solid (TDS), Total Hardness, Chloride, and organic substances, all of which have declined to fulfilled requirements by processing in this study. Chloride; Referring to Purwoto (2010), that resin treatment can reduce levels of chloride of 484 mg/L, so the achievement chloride removal of this study results is greater, ie 2028 mg / L. pH; pH has an increase in RO process 0.10 units. It is possible the existence of residual alkaline substances in (carried by) fiber in fiberglass tube (reservoir results of previous treatment). Turbidity; There was a turbidity decrease in processed water 2.74 NTU scale. This shows that substances suspended on the wane.

Color; The color of water processed shows zero with value decreased by 45 units PtCo. This means that turbidity and suspended substances have been absorbed in treatment process. Iron; Iron decreased 0.22 ppm, mean manganese green sand has been functioning as well as absorbance. Total Disolved Solid (TDS); Total Disolved Solid has removal very much, that is equal to 3366 ppm. Is due to decrease concentration of dissolved solids were pretty much. Total Hardness; The hardness decrease of 621.43 mg/L CaCO3 showed that; cations Mg and Ca (as measured parameters hardness) has decreased quite significantly. Organic Substances; The whole organic substances (as measured in aggregate) levels of 19.84 mg/L KMnO4 contained all of the raw water has been absorbed in the treatment process. Detergent; Detergent which is disturber in use of clean water capable terremoval at 0.12 mg/L LAS. Electrical Conductivity (EC) from 6860 mhos/cm (in raw water) fell as much as 1264 mhos/cm. This gives an indication that ions in raw water has been absorbed during undergo processing.

4. Conclusion

Processing brackish water based on RO membrane techno combined with coagulant aid and ion exchanger are able to fulfill all of clean water requirements parameters.

Parameters removal according to clean water requirements by influence of brackish water treatment based on RO membranes techno combined with coagulant aid and ion exchanger is reached on parameters ; Chloride of 2028 ppm, Turbidity 2.74 NTU scale, color 45 units PtCo, Iron 0.22 ppm, Total Disolved Solid (TDS) 3366 ppm, Total Hardness 621.43 mg/L, CaCO3, Organic Substances 19.84 mg/L KMnO4**,** Fluoride 0.62 ppm, Nitrate 0.06 ppm, Nitrite 0.64, Zinc 0.08 ppm, Sulfate 40.46 ppm, and Detergent at 0.12 mg/L LAS.

5.Acknowledgements

We would like to thank to director of Research and Community Service Directorate General of Higher Education, Ministry of Education and Culture, Indonesia which has financed this research through KOPERTIS Region 7

East Java coordinator.

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