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Water Treatment Based on Ion Exchange Membrane Permeable Combined with The Field Electrodeionization (EDI)

Sugito [1*] Budi Prijo sembodo [2]
1.Environmental Engineering of Univ. PGRI Adi Buana Surabaya, Indonesia. Jl. Ngagel Dadi III.B/37 Surabaya, Post code ; 60245-East Java_Indonesia
2.Electrical Engineering of Univ. PGRI Adi Buana Surabaya, Indonesia. Jl. Ngagel Dadi III.B/37 Surabaya, Post code ; 60245-East Java_Indonesia
* Email correspondency : sugitobohar@gmail.com

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Abstract
Water treatment can be done by ; removal of cations / anions contained in the water used: ion exchange resin (ion exchanger), deionization, distillation membrane transfer, flash evaporation, and reverse osmosis. But the way that can be done separately, each has drawbacks. If done multiple, can simultaneously support for removal of cations anions process contained therein. Water treatment processing procedures in this study are ; filtration using polipropylena, absorption by Manganese zeolite treatment, then ion exchange resins using anion and cation resin, continued with treatment electrodeionization (EDI) using membrane permeable cation and anion permeable membrane, which is arranged in cross, where the anode electrode attached adjacent by cation permeable membrane, and vice versa. Water treatment by technology based filtration, absorption, and ion exchanger with permeable membrane combined with electrodeionization (EDI) field concluded that; removal of some of parameters are: Total Disolved Solid (TDS) 752 ppm, Turbidity 4.94 NTU scale, color 40 units PtCo, Iron 0.55 mg/L Fe, Total hardness 457.24 mg/L CaCO3, Chloride 500 ppm, Nitrate 0.82 ppm, Nitrite 0.49 mg/L NO2-N, Zinc 0.07 ppm, Sulfate 9.14 ppm, Sodium 575.46 ppm, Organic Substances 17.74 mg/L KMnO4, and Detergent 0:06 mg/L LAS.
Keywords: ion exchange, filtration, absorption, membrane permeable, electrodeionization (EDI)

1. Introduction

One of the treatment process is deionized water. Deionized water is a process of removal of the cation / anion contained therein, where in the 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), demineralization can be done by : filtration, absorption by manganese zeolite, ion exchange resin (ion exchange), elektrodeionisasi, transfer membrane distillation, flash evaporation, and reverse osmosis. But the way that can be done separately, each has drawbacks. For example, the desalination single treatment using ion exchange resin according to the results of previous studies (Purwoto 2009), water by salinity between 2500-6500 ppm, removal of achievement is still low salinity, which is about 500 ppm.

One of the separation methods are being developed at this time is a membrane technology. Separation technology by using membrane, beside to demineralisation water, can also be used to improve the efficiency of waste reduction and separating impurities mineral. Cation permeable membrane can only be penetrated by the ions (+) (cation), and can not be penetrated by the ions (-) (anion). While the anion permeable membrane, can only be penetrated by ions (-) (anion), and can not be penetrated by the cations (+ ions). With the performance of the DC current at electrode effect, then the effect of the electrode potential, cations (+ ions) will be heading to the cathode (negative pole) to penetrate the cation permeable membrane. Instead anion (ion -) to the anode (positive pole) to penetrate the anion permeable membrane. Discharged brine was concentrated by ion-exchange membrane electrodialysis. The concentrated solution was introduced into a diaphragm electrolytic bath, and chlorine and a cathode solution were produced. (Tanaka 2003). Electrodeionization (EDI), which combines electrodialysis (ED) and conventional ion-exchange (IX), is a mature process which has been applied since more than twenty years on commercial use for the production of ultrapure water (UPW). More recently, EDI system has found a number of new interesting applications in wastewater treatment, biotechnology industry, and other potential field. (Khoiruddin *at al.* 2014). Municipal water was purified by an electrodeionization (ED) process for use in the research and diagnostic laboratory. An extensive battery of physical, microbiologic, and chemical tests were performed to determine the effect of this technology on water quality and to demonstrate the interaction with the other components of a typical water purification system. (Highsmith *at al.* 1990).

The electrodeionization (EDI) and some integrated processes derived from EDI play important roles in some fields such as desalination, ion concentrating and chemical synthesis, but it is still needed to explore the mechanism of water decomposition at the membrane-liquid interface of ion-exchange membranes. (Zhaohui *at* *al*. 2012). An electrodeionization process has been developed using ion-exchange textiles (EDIT) instead of ion-exchange resins as currently used for the production of ultra-pure water. (Dejean *at al*. 1998). Continuous Electrodeionization (CEDI) is beginning to be used widely to water treatment systems for the microelectronics, pharmaceutical and power generation industries. (Osawa *at al*. 2003).

The main function of manganese zeolite (Greensand) content is to remove manganese (Mn^{2+}), and upper oily layer in the water as a catalyst and at the same time iron and manganese that are in the water is oxidized to become ferri-oxide and mangandiokxide insoluble in water. 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).

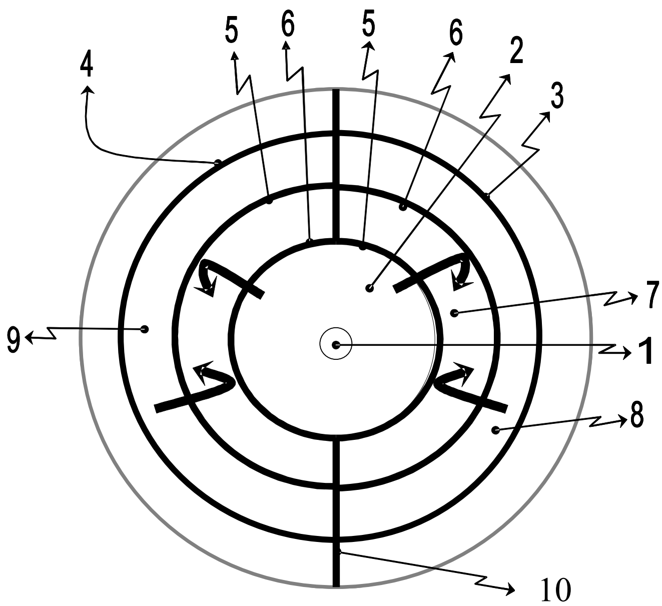
Ion exchange system (ion exchange) can be used synthetic resin that is anion resin and cation resin. According to Purwoto (2009), one of water samples in Lamongan, East Java coastal area, the content of Na^{+} = 3500 ppm, Mg^{++} = 278 ppm, Ca^{++} = 407 ppm, Fe (tot) = 0,088 ppm, Cl^{-} = 3000 ppm, SO_4^{-2} = 350 ppm, CO_3^{-2} = 235 ppm, while the salinity of water samples in SidoarjoEast Java coastal area ranged between 2500-6500 ppm. According to him, the use of a single resin can reduce chloride levels about 500 ppm. According to Montgomery (2005), the strength of cation expulsion preference is structured as follows; $Ba^{2+} > Pb^{2+} > Sr^{2+} > Ca^{2+} > Ni^{2+} > Cd^{2+} > Cu^{2+} > Co^{2+} > Zn^{2+} > Mg^{2+} > Ag^{+} > Cs^{+} > K^{+} > NH_4^{+} > \mathbf{Na^{+}} > H^{+}$ while the order of preference for the following anions: $SO_4^{2-} > NO_3^{-} > CrO_4^{2-} > Br^{-} > \mathbf{Cl^{-}} > OH^{-}$. The ion exchange reactions are classified as the topochemical reaction or the host-guest reaction in which neither the bond formation nor the bond breaking occurs. The unique property of such reaction is that the free energy change is rather small in contrast to the ordinary chemical reaction as well as that neither the guest molecule nor the host compound suffers from chemical change. In such reactions, the small free energy change causes the large selectivity change. **(**Kanzaki *at al*. 2001). 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.

Further potential exists for increasing the performance of the resin and for broadening the application of the process to a wider range of waters and needs; to these ends, research continues which backs up the current process-development and field-trial program. (Battaerd *et al*. 2001). Ion exchange technology was applied to this study to treat nickel ion from plating wastewater which contains heavy metal, bringing environmental problems such as chromium, zinc, copper, and lead. The leak of the ion appeared when rinse water that has a concentration of 1.8 g-Ni/L-distilled water flowed into the NRU as much as 20 times the bed volume. (Eom *at al*. 2005). The most important elemental technologies of ultra pure water system are ion exchange technology and membrane technology. Ion exchange technology not only removes ions in water but also is effective for removing organic matter and sterilizing bacteria as secondary functions. (Sezaki *at al*. 2005).

2. Materials And Methods

2.1. Tools and Materials Research

The main tool used in water treatment in this study are: cartridge filter housing, print tube Fibre-Reinforced Plastic (FRP), and tube Electrodeionization (EDI). Processing procedure performed by using material treatment such as: absorbent Poly Propylene Sediment (PPS), Carbon Block, Manganese Green Sand, anion resin and cation resin and also cation permeable membranes and anion permeable membranes.
Tube Design Electrodeionization (EDI) ;
The tube design Electrodeionization (EDI) is presented in Figure 1.



Caption Figure 1. :
1 = inlet
2 = water ion exchange results
3 = cathode
4 = anode
5 = membrane permeabel cation
6 = membrane permeabel anion
7 = space between two membrane
8,9 = space between membrane and electroda

Figure 1. Top View Picture Reactor Design Electrodeionization (EDI) In Permeable Membrane

2.2.Treatment Research

Treatment research is done by; incorporation filtration treatment, ion exchanger, and Electrodeionization by cation permeable membranes and anion permeable membranes. The processing procedure can be done : filtration and absorption using poly propylene sediment (PPS) and Carbon Block using Cartridge Filter Housing, and Manganese Green Sand in print tube Fibre Reinforced Plastic (FRP). Ion Exchanger treatment using anion resin and cation resin in the print tube Fibre Reinforced Plastic (FRP) with a depth of 70 cm. The final stage is permeable membrane at tube Electrodeionization (EDI).

Table 1. Criteria of Prototype Reactor Water Treatment

No.	Item	Criteria
1.	reactor materials	1) Fiberglass Reinforced Plastic (FRP) tube 2) PVC pipe
2.	flow model	Up-flow with by-pass flow model went on nozle
3.	Tube size	FRP & PVC 10 inc.
4.	Strip inlet	To facilitate setting and flow efficiency, PVC pipe is used, the setting of connections water-nut system
5.	pipeline	Pipeline from the side and bottom
6.	pump supply	Using a submersible-pump plastic material to avoid corrosion
7.	temperature treatment	ambient temperature
8.	tube setting	Series
9.	filtration	poly propylene sediment (PPS)
10.	absorption	Manganese Zeolit (Greensand)
11.	Ion Exchanger	anion resin and cation resin, Thickness of 70 cm
12.	Electrodeionization (EDI)	Cation permeable membranes and anion permeable membranes arranged in cross, and the anode electrode mounted beside with membrane permeable cations, and vice versa.

2.3. Research Treatment Groove

Research reactor refers to a series of batch reactors Electrodeionization (EDI) water filtration results, manganese zeolite absorption, and ion exchange in permeable membrane treatment using a up-flow flow system. In the first tube was made ion exchange treatment using anion synthetic resin, both tubes using cation synthetic resin, and the third tube is electro deionization (EDI) treatment on permeable membrane treatment.

Water Treatment Procedures

Raw materials (water sample) was pumped using a submersible pump toward polipropylena filtration as the filter Cartridge Housing, followed by absorption Manganese Zeolite, and Carbon active. Treatment was continued by Ion Exchange process using synthetic resin (anion resin and cation resin) were placed on Fiberglass Reinforced Plastic (FRP) with Flow Up-Flow System. In order Electrodeionization performance is not too heavy, then the second stage is done using a sediment filter polipropylena as Cartridge. The results of that treatment followed by treatment permeable membrane at tube Electrodeionization (EDI).
The tube design Electrodeionization (EDI) is presented in Figure 1.

2.4. Analysis of The Laboratory Tests Results
Parameters test is done for; 1). Samples of raw water, 2). The results of treatment, and 3). Electrodeionization (EDI) product

3.Results And Discussion

3.1. Research Result
After did running study, continued with laboratory test analysis of research treatment result which sample (1) is raw water, sample (2) is treatment result; polipropylena filtration, manganese zeolite, and active carbon and Ion Exchange process using synthetic resin (anion resin and cation resin), sample (3) is treatment result of permeable membrane in Electrodeionization (EDI) tube.
The results of the study treatment as a laboratory test procedure refers to the criteria of water parameters are presented in Table 2.

Table 2. Parameters Removal Treatment Results Based On Clean Water Requirements

No	Parameters	Units	Clean Water Requirements *)	(1) Raw Water	(3) Treat ment	Removal
	A. PHYSICS					
1	Odor	-	odorless	odorless	odorless	
2	Total Disolved Solid (TDS)	mg/L	1500	2770	2018	752.00
3	Turbidity	NTU Scale	25	5.96	1.02	4.94
4	Flavor	-	tasteless	-	-	
5	Temperature	oC	ambient temperature ± 3°C	25	25	0.00
6	Color	Unit PtCo	50	50	10	40.00
	B. CHEMISTRY					
	a. Inorganic Chemistry					
1	Mercury	mg/L Hg	0.001	0	0	0.00
2	Arsenic	mg/L As	0.05	0	0	0.00
3	Iron	mg/L Fe	1	0.71	0.16	0.55
4	Fluoride	mg/L F	1.5	0.78	0.92	-0.14
5	Cadmium	mg/L Cd	0.005	0	0	0.00
6	Total Hardness	mg/L CaCO3	500	457.24	0	457.24
7	Chloride	mg/L Cl	600	1700	1200	500.00
8	Chromium, Val 6	mg/L Cr	0.05	0	0	0.00
9	Manganese	mg/L Mn	0.5	0	0	0.00
10	Nitrate	mg/L NO3-N	10	1.16	0.34	0.82
11	Nitrite	mg/L NO2-N	1	0.5	0.01	0.49
12	pH	-	6,5 - 9,0	8.05	8.45	-0.40
13	Selenium	mg/L Se	0.01	0	0	0.00
14	Zinc	mg/L Zn	15	0.15	0.08	0.07
15	Cyanide	mg/L CN	0.1	0	0	0.00
16	Sulfate	mg/L SO4	400	9.14	0	9.14
17	Lead	mg/L Pb	0.05	0	0	0.00
18	Sodium	mg/L Na	-	661.7	86.24	575.46
	b. Organic Chemistry					
1	Organic Substances	mg/L KMnO4	10	17.74	0	17.74
2	Detergent	mg/L LAS	0.5	0.1	0.04	0.06

*Note ; *)According to Permenkes Republic of Indonesia No: 416/Menkes/Per/IX/1990 on Clean Water Quality Requirements*

3.2. Discussion
Referring to Removal Treatment Table of Treatment Results based on Water Requirements, it appears removal achievement some parameters such as ; Total Disolved Solid (TDS), Turbidity, Color, Iron, Total Hardness, Chloride, Nitrate, Nitrite, Zinc Sulfate, Sodium, Organic Matter, and Detergents. TDS Decreasing of 752 ppm is a significant removal. This means a decrease in the concentration of dissolved solids is high enough.

TDS removal is followed by a drop of turbidity of 4.94 NTU scale, as well as about the color, in the water treatment is able to reduce color 40 units PtCo, which means turbidity and suspended substances have been widely absorbed in the treatment processing. In terms of total hardness, the results of lab test water in this treatment is able to zero. This shows that; cations Mg and Ca which is the hardness parameters has much decreased.

Chloride Parameters which is an important measure in brackish water criteria, which initially yield 1700 ppm (in raw water), after processing according to this study treatment is capable down up to 1200 pppm which means terremoval of 500 ppm. For Iron substances, this parameter decreased 0.55 mg/L Fe, which means the absorbance of manganese green sand has been functioning properly. The Decreasing of physical parameters caused by filtration using manganese zeolites media and activated carbon. Manganese-zeolites with K2Z.MnO.Mn2O7, serves as filter which the reaction occurs between ions dissolved in water with compounds in the filter. The reaction of Fe^{2+} and Mn^{2+} in water with high manganese oxide (higher manganese oxide) produces filtrate containing ferric-oxide and manganese-dioxide insoluble in water and can be separated by precipitation and filtration, as the filter Cartridge Housing. Reduction of anion and cation occurs as a result of ion exchange using resin. Ion exchange occurs in cation resin occurs optimally if previously done treatment by anion resin first to reduce anion to approach to OH^- form.

The Removal of cations and anions in Electrodeionization process occurs due to an electric current that causes encouragement or electron transport can take place with higher penetrate cation and anion permeable membrane. The process of ions removal due to the influence of potential electrode occur where the cation will be heading to cathode penetrate cation permeable membrane. After reaching cation anion permeable membrane is inhibited and can not penetrate, so that occur accumulationin in space between cation membrane permeable with anion permeable membrane.

4. Conclusion

Based on results discussion, it can be concluded that:
Portable compact reactor water treatment based ion exchange combined with permeable membrane in *electrodeionization* (EDI) field can reduce parameter : Total Disolved Solid (TDS) 752 ppm, Turbidity 4.94 NTU scale, color 40 units PtCo, Iron 0.55 mg/L Fe, Total hardness 457.24 mg/L CaCO3, Chloride 500 ppm, Nitrate 0.82 ppm, Nitrite 0.49 mg/L NO2-N, Zinc 0.07 ppm, Sulfate 9.14 ppm, Sodium 575.46 ppm, Organic Substances 17.74 mg/L KMnO4, and Detergent 0:06 mg/L LAS.

The Improving water quality can be done with application of a technology combination based on ion exchange in electrodeionization field.

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