Drinking Water Processing Using UV Rays

S Purwoto1,*, Rusdiyantoro2, B P Sembodo3, Y D Nurcahyanie2

1. Department of Environmental Engineering, University of PGRI Adi Buana Surabaya, Indonesia
2. Department of Industrial Engineering, University of PGRI Adi Buana Surabaya, Indonesia
3. Department of Electrical Engineering, University of PGRI Adi Buana Surabaya, Indonesia

Corresponding author’s e-mail: setyopurwoto.enviro@gmail.com

Abstract. Pollution by pathogenic bacteria and other parasites can occur in groundwater. To reduce such pollution, disinfection can be used, including the use of ozone, chlorine gas, and ultraviolet light. The purpose of this study is to determine the ability to reduce parameters in groundwater according to drinking water quality standards of the following treatments: coagulation, filtration, absorption, deionization, and disinfection. The method of treating drinking water using UV light was carried out following the procedure where affixing of coagulant aid was the initial treatment and the filtration treatment used polypropylene sediments. Furthermore, treatments removed Fe and Mn using ferrolite, reduced hardness using manganese greensand, reduced cations using anion resins, and reduced anions using cation resins. Coliform bacteria were decreased using UV light. The findings of this study showed the following reductions of the parameters: total dissolved solids 5,319 mg/l, turbidity of 6 NTU scales, color 0.634 units of PtCo, fluoride 0.5 mg/l F, total hardness of 1,573.2 mg/l CaCO3, chloride 2,049.8 mg/l Cl, manganese 1.4793 mg/l Mn, nitrate 7.98 mg/l NO3-N, nitrite 0.703 mg/l NO2-N, zinc 0.02 mg/l Zn, cyanide 0.001 mg/l CN, sulfate 459.58 mg/l SO4, organic substance 3.82 mg/l KMnO4, detergent 0.03 mg/l LAS, fecal (E. Coli) 900 MPN/100 ml, total coliform 5,166 MPN/100 ml.

Keywords: coagulation, filtration, deionization, ultraviolet water sterilizer

1. Introduction
To get clean water, one can use treatments such as coagulation, filtration, absorption, and ion exchange (Purwoto 2009), (Purwoto et al. 2015). Health risks relating to pollutants can generally be caused by, among other things, industrial and agricultural activities, whereas E. coli bacteria constitute a parameter in water use (Purwoto et al. 2019). The following combination of treatments: filtration using sediment polypropylene, absorption by carbon block and manganese zeolite, ion exchange using synthetic anion resin and cation resin by the depth of 70 cm, followed by reverse osmosis (RO), is a series of water treatment processes to reduce concentration of parameters for clean water (Purwoto et al. 2014). Water treatment can be done such as by filtration followed by reverse osmosis microfiltration using RO membrane followed by water sterilization under UV tubes. Removal of clean water parameters by a combination of coagulant aid treatment, polypropylene sediment filtration, and manganese greensand absorption, followed by ion exchanger resulted as follows; chloride 2,028 ppm,
iron 0.22 ppm, total dissolved solids 3,366 ppm, total hardness 621.43 mg/l, CaCO₃, organic substances 19.84 mg/l KMnO₄, zinc 0.08 ppm, sulfate 40.46 ppm, and detergent 0.12 mg/l LAS (Nurhayati et al. 2014). Treatment using ferrolite, manganese zeolite, and ion exchanger in the form of anion resin and cation resin in groundwater according to (Purwoto et al. 2016) was able to remedy the turbidity, color, and metals i.e. iron, chromium, and manganese according to the criteria for clean water parameters applicable in Indonesia. As an alternative disinfectant in the treatment of drinking water, the emission of ultraviolet (UV) light as a water sterilizer is one of the actions used to eliminate microorganisms in water including coliform. The contribution of previous research argues that pretreatment: filtration uses polypropylene sediment, absorption using ferrolite and manganese greensand, ion exchange using cation resin and anion resin, and reverse osmosis (RO) membranes when combined with disinfectant ultraviolet (UV) would kill all microorganisms in water including coliform. Some threshold limits of the standard parameters of drinking water according to Indonesian Regulation No. 492 of 2010 include: total dissolved solids 500 ppm, turbidity 5 NTU Scale, color 15 PtCo Units, iron 0.3 mg/l Fe, manganese 0.4 mg/l, chloride 250 mg/l, total hardness 500 mg/l CaCO₃, Zinc 3 mg/l Zn, organic matter 10 mg/l KMnO₄, detergent 0.05 mg/l LAS, total coliform (MPN) 0 amount per 100 ml sample. While according to WHO, several standard parameters for drinking water are as follows: total dissolved solids (no guidelines), iron 0.5 – 5.0 mg/l, manganese 0.5 mg/l, chloride 250 mg/l, hardness (CaCO₃) 500 mg/l, total coliform bacteria = zero per 100 ml sample. The use of UV light in drinking water treatment can be carried out in a series of treatment i.e. coagulation treatment, filtration treatment, absorption treatment, ion exchange treatment, reverse osmosis, and irradiation using UV light.

The process of drinking water treatment from groundwater raw materials includes the following steps: a. Deposition and coagulation of dissolved particles using coagulant affixing; b. Filtration using polypropylene sediment; c. Removal of iron and manganese using ferrolite; d. Decrease of hardness using manganese greensand; e. Decrease of cation using anion synthetic resin; f. Decrease of anions using synthetic cation resin; g. Decrease in the number of coliform bacteria using RO membrane; h. Removal of coliform bacteria using UV light

The problem questioned in this paper is the removal capacity of some drinking water parameters in water treatment using pretreatment followed by UV light. The research’s purpose is to process raw water into drinking water. Benefits of the research would be to overcome the inferior quality of water.

2. Theoretical study

Water treatment process to obtain better water quality can be done in the following steps: a) Sedimentation and coagulation for discrete particle deposition using Surolite coagulant; b) Filtration of sludge and dissolved solids using silica sand; c) Decrease of iron (Fe) and manganese (Mn) using ferrolite; d) Hardness softening process and absorbent of iron (Fe) and manganese (Mn) binding using manganese green sand; e) Exchange of anions (decrease of cation in water) using anion resin; f) Exchange of cations (decrease of the anion in water) using cations resin (Montgomery 2005); g) Decrease of coliform bacteria using reverse osmosis process with RO membrane; h) Use of UV light.

One of the findings in terms of decreased parameters of clean water resulted by treatment using coagulant aid, silica sand, ferrolite, manganese greensand, synthetic resin (anion cation), and RO membrane were: turbidity 150.85 NTU Scale, color 148 PtCo units, iron 8.71 mg/l Fe, total hardness 71.43 mg/l CaCO₃, zinc 0.07 mg/l Zn, sulfate 24.08 mg/l SO₄, detergent 0.29 mg/l LAS. The decrease in total coliform was especially high by 600 MPN (Purwoto et al. 2017). Treatment using Surolite SP 211 as a coagulant in the form of colorless and odorless liquid; with pH 11-11.5 at 20°C;
specific gravity 1.35 gr/cm³; Al₂O₃ content 4.66%; pH of 2% 3.553 solution, 0.060% water-insoluble part (Purwoto et al. 2016). The use of polypropylene sediment as a water filter from the content of mud, sand, soil and other particles of water dissolved solids to produce clear, clean water free from contamination of dissolved solids. Ferrolite functioned to eliminate high levels of iron (Fe), stinging iron smell, manganese (Mn²⁺), and yellow color in groundwater. Treatment of iron and manganese can be done using manganese greensand absorbents, where the reactions of Fe²⁺ and Mn²⁺ in water with high manganese oxide produce a filtrate containing ferric oxides and manganese dioxide which are insoluble in water and can be separated by precipitation and filtration. Mn²⁺ removal can be carried out by adsorbing manganese oxide in manganese oxide coated zeolite (Taffarel, 2010). Resin works in a process of ion exchange between the anions in the resin with the anions contained in the solution being treated. In the demineralization process, for example; Na⁺ cations and Cl⁻ anions are removed from water and solid resin releases H⁺ ions to be exchanged with Na⁺ ions, and OH⁻ is exchanged with Cl⁻ from water so that the content of Na⁺ and Cl⁻ in water becomes reduced or lost (Montgomery, 2005). Whereas Purwoto, S. (2009) concluded that the desalination of brackish water can be carried out using ion exchange with the treatment of synthetic resin cations and anions pairing both separately and in a mixture of both. Turbid river water can be treated using coagulant followed by filtration, then zeolite and manganese greensand absorbents, silica sand filters and finally using cation synthetic resin and anion synthetic resin to produce clear water (Purwoto et al., 2015). Purwoto et al. (2014) stated that the treatment using sediment poly propylene, carbon block, manganese zeolite, ion exchange, and reverse osmosis (RO) can reduce the burden of several parameters, including total dissolved solids 2,686 ppm, total hardness 371.43 mg/l CaCO₃, chloride 1,144 ppm, coliform total 4 MPN/100 ml, 0.18 ppm iron, sodium 737.70 ppm, zinc 0.08 ppm, sulfate 24.56 ppm, organic substances 15.03 mg/l KMnO₄, and detergent 0.10 mg/l LAS.

3. Research methodology

3.1. Drinking water treatment methods
The series of processing of raw materials into drinking water used in this research as shown in Figure 1. begins with the application of Sucolite SP 211 as coagulant aid to be stirred in a coagulant tank (1), then followed by filtration using polypropylene sediment on the filter housing (2). Then the following treatment are next; ferrolite and manganese greensand on filter housing or FRP tubes (3) (4), cation reduction using anion synthetic resin on FRP tubes with upward flow type (5), and anion reduction using synthetic cation resin in FRP tubes where the flow of treated water is up (6). The decrease of coli bacteria uses RO membrane as a microfilter on the RO housing which is assembled with a buster pump as a pusher (7), and as a disinfectant to remove coliform bacteria using UV light as a water sterilizer on a UV tube (8). The results of the treatment process as drinking water in the reservoir (P).
Figure 1. UV rays and tools for processing raw materials into drinking water

Picture 1 descriptions:
(1) = coagulant aid treatment in a coagulant tank
(2) = filtration using polypropylene sediment on the filter housing
(3) = ferrolite treatment in FRP filter housings or tubes
(4) = treatment with manganese greensand in FRP filter or tube housing
(5) = treatment of anion resin on FRP tubes
(6) = treatment of cation resin in FRP tubes
(7) = treatment with reverse osmosis (RO) membrane
(8) = UV disinfection (ultraviolet water sterilizer) S = Submersible Pump, P = drinking water product
B = Booster pump RO

3.2. Results and Discussion
After the treatment as shown in the process flow above, the criteria that refer to drinking water were obtained, shown in Table 1. on data of UV treatment results on sampled water. The table below shows 38 parameters of drinking water based on the regulations of the Indonesian Ministry of Health no. 492/Menkes/Per/IV/2010.

Table 1. Data of UV treatment results on sampled water

| No | Parameter          | Unit   | Terms of Drinking Water *) | A Raw water | B Treatment UV | Removal A - B |
|----|--------------------|--------|-----------------------------|-------------|----------------|---------------|
| 1  | Odor               | -      | odorless                    | odorless    | odorless       |               |
| 2  | Total Dissolved Solids | mg/l   | 500                         | 6,520       | 1,201          | 5,319         |
| No | Parameter          | Unit             | Terms of Drinking Water *) | A (Raw water) | B (Treatment UV) | A - B | Removal      |
|----|-------------------|------------------|-----------------------------|--------------|-----------------|------|--------------|
| 3  | Turbidity         | NTU scale        | 5                           | 6.65         | 0.65            | 6    |             |
| 4  | Taste             | -                | tasteless                   | taste        | tasteless       |      |             |
| 5  | Temperature       | °C               | Air temperature            | 26.9         | 27.4            | -0.5 |             |
| 6  | Color             | PtCo Unit        | 15                          | 1.51         | 0.876           | 0.634|             |
| 7  | Electrical conductivity | mhos/cm | - | not measured |            |                |      |             |
| 8  | Mercury           | mg/l Hg          | 0.001                       | < 0.000198   | < 0.000198      |      |             |
| 9  | Arsenic           | mg/l As          | 0.01                        |              |                 |      |             |
| 10 | Iron              | mg/l Fe          | 0.3                         | < 0.0413     | < 0.0413        |      |             |
| 11 | Fluoride          | mg/l F           | 1.5                         | 0.671        | 0.17            | 0.5  |             |
| 12 | Cadmium           | mg/l Cd          | 0.003                       | < 0.00935    | < 0.00935       |      |             |
| 13 | Total Hardness    | mg/l CaCO₃       | 500                         | 1,632        | 58.8            | 1,573.2|             |
| 14 | Chloride          | mg/l Cl          | 250                         | 2,782        | 732.2           | 2,049.8|             |
| 15 | Chromium (VI)     | mg/l Cr⁶⁺        | 0.05                        |              |                 |      |             |
| 16 | Manganese         | mg/l Mn          | 0.4                         | 1.51         | 0.0307          | 1.4793|             |
| 17 | Nitrate           | mg/l NO₃-N       | 50                          | 17.5         | 9.52            | 7.98 |             |
| 18 | Nitrite           | mg/l NO₂-N       | 3                           | 0.918        | 0.215           | 0.703|             |
| 19 | pH                | -                | 6.5 – 8.5                   | 7.29         | 7.87            | -0.58|             |
| 20 | Selenium          | mg/l Se          | 0.01                        |              |                 |      |             |
| 21 | Zinc              | mg/l Zn          | 3                           | 0.029        | 0.009           | 0.02 |             |
| 22 | Cyanide           | mg/l CN⁻         | 0.07                        | 0.003        | 0.002           | 0.001|             |
| 23 | Sulfate           | mg/l SO₄         | 250                         | 465.3        | 5.72            | 459.58|             |
| 24 | Lead              | mg/l Pb          | 0.05                        | < 0.0547     | < 0.0547        |      |             |
| 25 | Aluminium         | mg/l Al         | 0.2                         |              |                 |      |             |
| 26 | Ammoniacal Nitrogen | mg/l NH₃-N | 1.5                      | < 0.0165     | 0.0254          |      |             |
| 27 | Barium            | mg/l Ba          | 0.7                         |              |                 |      |             |
| 28 | Boron             | mg/l B          | 0.5                         |              |                 |      |             |
| 29 | Sodium            | mg/l Na          | 200                         |              |                 |      |             |
| 30 | Nickel            | mg/l Ni          | 0.07                        | < 0.0132     | < 0.0132        |      |             |
| 31 | Silver            | mg/l Ag          | 0.001                       |              |                 |      |             |
| 32 | Sulfide           | mg/l H₂S         | 0.05                        |              |                 |      |             |
| 33 | Copper            | mg/l Cu          | 2                           | <0.0110      | <0.0110         |      |             |
| 34 | Remaining Chlorine | mg/l Cl₂    | 5                           |              |                 |      |             |
Referring to Table 1., it can be seen that the total dissolved solids was 6,520 mg/l and it is considered high, far greater than the standard quality of drinking water which is only 500 ppm. This condition indicates that the raw water is not as feasible as drinking water. Coli bacteria amounting to 5,200 MPN/100 ml in raw water is also a condition of the water that makes it not feasible as drinking water. This figure indicates that the water is very high risk in the case of coli bacteria so that to be used as drinking water treatment must be done so that the E. coli content becomes zero.

4. Discussion
The process series of water treatment in a combination of coagulation, absorption and ion exchange as an initial treatment followed by microfiltration in the form of reverse osmosis (RO) and the use of ultraviolet water sterilizer was followed by the interpretation of laboratory test data on parameter criteria for drinking water compared to the water samples based on the decrease in parameters after treatment. Lisa et al. (2015) mentioned that all waterborne pathogens can be inactivated by ultraviolet light, provided a sufficient dose is administered. Combinations of water purification steps (oxidation, coagulation, settling, disinfection, and filtration) cause (drinking) water to be safe after production. As an extra measure, many countries apply a second disinfection step at the end of the water purification process, to protect the water from microbiological contamination in the water distribution system (Said, N.I. 2007). Parameters that have decreased significantly i.e. total dissolved solids (TDS), turbidity, total hardness, chloride, manganese, sulphate, fecal = E. coli, and total coliform are presented in Table 2.

Table 2. Significant allowance

| No | Parameter                 | Unit         | Threshold Limits for Drinking Water *) | Raw Water Levels | After UV Treatment | Allowance |
|----|---------------------------|--------------|----------------------------------------|-----------------|-------------------|-----------|
| 1. | Total Dissolved Solids    | mg/l         | 500                                    | 6,520           | 1,201             | 5,319     |
| 2. | Turbidity                | NTU scale    | 5                                      | 6.65            | 0.65              | 6         |
| 3. | Total Hardness           | mg/l \(\text{CaCO}_3\) | 500                                    | 1,632           | 58.8              | 1,573.2   |
| 4. | Chloride                 | mg/l Cl      | 250                                    | 2,782           | 732.2             | 2,049.8   |
| 5. | Manganese                | mg/l Mn      | 0.4                                    | 1.51            | 0.0307            | 1.4793    |
UV. Water purification can be done by UV irradiation in a common way to disinfect drinking water, but some viruses are very resistant to UV irradiation. For drinking water, the level of chlorine reduction was very significant, from 2,782 mg/l Cl down to 732.2 mg/l Cl. Chloride indicates the level of salinity or acidity of water. With the amount of chloride removal of 2,049.8 ppm, if the water being treated only contains 2,000 ppm chloride, it can be reduced to zero. Fecal bacteria = E. coli was able to be restored at 900 MPN/100 mL, while for the total coliform it was 5,166 MPN/100 ml. The raw water column shows a condition of the water that is not very feasible as drinking water. The figures shown indicate that the water was very high risk in the case of coli bacteria so that to be used as drinking water treatment must be done in order for the E. coli content to drop to zero. According to (Jati et al. 2017); potable drinking water treatment equipment uses zeolite filter media, zeolite manganese, activated carbon, sediment or cartridge filters, and to kill bacteria and viruses contained in water, UV radiation is used. For getting drinkable water from river water, biosand filter has been combined with a reverse osmosis system and ultraviolet disinfection. The system of reverse osmosis and ultraviolet disinfection are used to reduce any bacteria, viruses and total dissolved solids (TDS) from treated water which is resulted from the biosand filter process (Endarko et al. 2013). The process series of water treatment equipment in the form of a combination of coagulation, absorption and ion exchange as an initial treatment followed by microfiltration in the form of reverse osmosis (RO) and the use of ultraviolet water sterilizer is followed by the interpretation of laboratory test data on drinking water parameter criteria of water samples based on a decrease in parameters after treatment. Brackish water desalination can be done by ion exchange using synthetic resin treatment (Purwoto, S. 2009). Decreasing the content of water’s parameters in brackish water can be done by treatment with coagulant aid and ion exchanger that is followed serially by membrane technology reverse osmosis (RO). The combination of coagulant aid, ion exchanger, and reverse osmosis (RO) on brackish water treatment is mentioned in (Nurhayati et al. 2014). Zyara et al. (2016) also mentioned that ultraviolet (UV) irradiation is a common way to disinfect drinking water, but some viruses are very resistant to UV. Water purification can be done in a learning environment and to increase human resources in the application of appropriate technology (Purwoto et al. 2017).

5. Conclusion
The combination of coagulation, absorption, and ion exchange followed by ultraviolet water sterilization can reduce the following parameters: total dissolved solids 5,319 mg/l, turbidity of 6 scale NTU, color 0.634 PtCo units, fluoride 0.5 mg/l F, total hardness 1,573.2 mg/l CaCO₃, chloride 2,049.8 mg/l Cl, manganese 1.4793 mg/l Mn, nitrate 7.98 mg/l NO₃-N, nitrite 0.703 mg/l NO₂-N, zinc 0.02 mg/l Zn, cyanide 0.001 mg/l CN, sulphate 459.58 mg/l SO₄, organic substances 3.82 mg/l K₂MnO₄, detergent 0.03 mg/l LAS, fecal (E. coli) 900 MPN/100 mL, total coliform 5,166 MPN/100 mL.

| No | Parameter     | Unit   | Threshold Limit for Drinking Water *) | Raw Water Levels | After UV Treatment | Allowance |
|----|---------------|--------|---------------------------------------|-----------------|-------------------|-----------|
| 6. | Sulfate       | mg/l SO₄ | 250                                   | 465.3           | 5.72              | 459.58    |
| 7. | Fecal E. coli | MPN/100 ml | 0                                    | 900             | 0                 | 900       |
| 8. | Total Coliform | MPN/100 ml | 0                                    | 5,200           | 34                | 5,166     |

From Table it 2 appears that pre-treatment treatment of water if continued with UV light can eliminate the total hardness content of 1,573.2 mg/l CaCO₃ (from 1,632 to 58.8). This means that if the total water content of the total hardness level is only around 800 as it was found, it would generally be able to be reduced to zero (which means meeting the requirements of drinking water). Although the requirements for drinking water have not been met in the results of this treatment, the level of chloride reduction was very significant, from 2,782 mg/l Cl down to 732.2 mg/l Cl. Chloride indicates the level of salinity or acidity of water. With the amount of chloride removal of 2,049.8 ppm, if the water being treated only contains 2,000 ppm chloride, it can be reduced to zero. Fecal bacteria = E. coli was able to be restored at 900 MPN/100 mL, while for the total coliform it was 5,166 MPN/100 ml. The raw water column shows a condition of the water that is not very feasible as drinking water. The figures shown indicate that the water was very high risk in the case of coli bacteria so that to be used as drinking water treatment must be done in order for the E. coli content to drop to zero. According to (Jati et al. 2017); potable drinking water treatment equipment uses zeolite filter media, zeolite manganese, activated carbon, sediment or cartridge filters, and to kill bacteria and viruses contained in water, UV radiation is used. For getting drinkable water from river water, biosand filter has been combined with a reverse osmosis system and ultraviolet disinfection. The system of reverse osmosis and ultraviolet disinfection are used to reduce any bacteria, viruses and total dissolved solids (TDS) from treated water which is resulted from the biosand filter process (Endarko et al. 2013). The process series of water treatment equipment in the form of a combination of coagulation, absorption and ion exchange as an initial treatment followed by microfiltration in the form of reverse osmosis (RO) and the use of ultraviolet water sterilizer is followed by the interpretation of laboratory test data on drinking water parameter criteria of water samples based on a decrease in parameters after treatment. Brackish water desalination can be done by ion exchange using synthetic resin treatment (Purwoto, S. 2009). Decreasing the content of water’s parameters in brackish water can be done by treatment with coagulant aid and ion exchanger that is followed serially by membrane technology reverse osmosis (RO). The combination of coagulant aid, ion exchanger, and reverse osmosis (RO) on brackish water treatment is mentioned in (Nurhayati et al. 2014). Zyara et al. (2016) also mentioned that ultraviolet (UV) irradiation is a common way to disinfect drinking water, but some viruses are very resistant to UV. Water purification can be done in a learning environment and to increase human resources in the application of appropriate technology (Purwoto et al. 2017).
References

[1] Endarko, Putro T, Nuzula N I, Armawati N, Wardana A, Agus Rubiyanto A, dan Muntini M S 2013 Rancang Bangun Sistem Penjernihan Dan Dekontaminasi Air Sungai Berbasis Biosand Filter Dan Lampu Ultraviolet *Berkala Fisika* 16 3 pp 75-84

[2] Indonesian Minister of Health Regulation 1990 *Number; 416/Menkes/Per/IX/1990. For clean water Requirements*

[3] Indonesian Minister of Health Regulation 2010 *Number; 492/Menkes/Per/IV/2010. For Drinking water Requirements*

[4] Jati D R, and Kadaria U 2017 Pengolahan Air Minum Portabel Dengan Sistem Filtrasi Dan UV Purifikasi *Seminar Nasional Penerapan Ilmu Pengetahuan Dan Teknologi* pp 63-67

[5] Lisa F, Timmermann L F, Ritter K, Hillebrandt D, Küpper T 2015 Drinking water treatment with ultraviolet light for travelers - Evaluation of a mobile lightweight system *Travel Medicine and Infectious Disease* 13 6 pp 466-474

[6] Montgomery J M 2005 Water Treatment Principles and Design *Johan Weley Inc. USA*

[7] Nurhayati I dan Purwoto S 2014 The Combination of Coagulant Aid, Ion Exchanger, and Reverse Osmosis (RO) on Brackish Water Treatment *Journal of Natural Sciences Research* 4 24 pp 26-30

[8] Purwoto S 2009 Desalinasi Air Payau Secara Ion Exchange dengan Treatmen Resin Sintetis *Waktu* 7 1 pp 52-59

[9] Purwoto S, Sopandi T, Kusuma P S W, Nurcahyanie Y D 2014 Removal Parameters of Clean Water using Treatment; Sediment Poly Propylene, Carbon Block, Manganese Zeolite, Ion Exchange, and Reverse Osmosis (RO) *Journal of Environment and Earth Science* 4 23 pp 72-77

[10] Purwoto S, Sopandi T, Nurcahyanie Y D 2014 Human Performance Learning Through Technology Brackish Water Treatment In ; Filtration, Ion Exchanger, and Reverse Osmosis *The 5th International Conference on Education of Adi Buana (ICETA-5) ISBN: 978-979-3870-58-8, Mei (2014) pp 350–359

[11] Purwoto S, Purwanto T, Hakim L 2015 Penjernihan Air Sungai Dengan Perlakuan Koagulasi, Filtrasi, Absorpsi dan Pertukaran Ion *WAKTU* 13 2 pp 45-53 ISSN: 1412-1867

[12] Purwoto S, Sutrisno J 2016 Pengolahan Air Tanah Berbasis Treatment Ferrolite, Manganese Zeolite, dan Ion Exchange *WAKTU* 14 2 pp 21-31 ISSN: 1412-1867

[13] Purwoto S, Sutrisno J 2017 Learning About Water Purification Using Filtration And Reverse Osmosis *The 9th International Conference on Educational Technology of Adi Buana (ICETA 9) pp 205-211, ISBN : 9789798559976, http://karyaimah.uncipusby.ac.id/2017/09/22/iceta-9/*

[14] Purwoto S, Rusdiyantoro, Sembodo B P 2019 Pre-Treatment of Raw Water Through the Coagulation Process, Filtration, Absorption, and Ion Exchange in Drinking Water *Water and Energy International* 62 4 pp 61-65

[15] Said N I 2007 Disinfeksi Untuk Proses Pengolahan Air Minum *JAI* 3 1 pp 15-28

[16] Taffarel S R, and Rubio J 2010 Removal of Mn^{2+} from aqueous solution by manganese oxide coated zeolite *Minerals Engineering* 23 14 pp 1131-1138

[17] Zyara A M, Torvinen E, Veijalainen A M, Helvi Heinonen-Tanski H H 2016 The Effect of UV and Combined Chlorine/UV Treatment on Coliphages in Drinking Water *Disinfection Water* 8 130
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