RESEARCH ARTICLE | JUNE 01 2023

Brackish water treatment in Sidoarjo area (East Java Indonesia) using Reverse Osmosis (RO)

Surya Hermawan; Angela Jasmine Tanya Tjahyana; Kiki Prio Utomo; ... et. al

AIP Conference Proceedings 2691, 030009 (2023)
https://doi.org/10.1063/5.0118443

Brackish Water Treatment in Sidoarjo Area (East Java Indonesia) Using Reverse Osmosis (RO)

Surya Hermawan[1, a)], Angela Jasmine Tanya Tjahyana[1, b)], Kiki Prio Utomo[2, c)], Nelly Wahyuni[3, d)], Peni Tiewanto[1, e)], Ivan Richardian Limantara[1, f)] and Dicky Huidiyanto[1, g)]

[1] Civil Engineering Department Petra Christian University, Surabaya, 60236, Indonesia
[2]Environmental Science Department, Tanjungpura University, Pontianak, 78124, Indonesia
[3]Chemistry Department, Tanjungpura University, Pontianak, 78124, Indonesia

[a)] Corresponding author: shermawan@petra.ac.id
[b)]angelaj@petra.ac.id
[c)]kikiutomo@teknik.untan.ac.id
[d)]nelly_kimiauntan@yahoo.co.id
[e)]21416024@john.petra.ac.id
[f)]21415105@john.petra.ac.id
[g)]21415213@john.petra.ac.id

Abstract. One of the resources that cannot be separated from human life is water. In 2020, the Central Bureau of Statistics revealed that Indonesia has access to clean water up to 90.21%. However, it is not enough to cover all areas in Indonesia, especially coastal or rural areas. This research focuses on the area of Tegal Sari Hamlet, Kupang Village, Jabon District, Sidoarjo Regency, East Java Province, where the area has problems with brackish well water. The purpose of this research is to find the changes that occur when using the Reverse Osmosis (RO) tool in this brackish water treatment. This research used an experimental method, to determine the effect of the treatment on the test object. The treatment is carried out by flowing water through the Reverse Osmosis (RO) tool to make the water meet the world health organization existing standards of pH, TDS, and EC, including 6.5-8.5 units, 500 mg/l and 400 µs/cm, respectively. Based on the results of the experiments conducted, it is known that the use of RO can reduce the pH, TDS, and EC of brackish water. The best outcomes from the experiments conducted were increasing the pH from 7.9 to 8.4, decreasing TDS from 5260 ppm to 433 ppm, and EC from 10,580 µs / cm to 864 µs/cm.

INTRODUCTION

One example of a natural resource that cannot be released from human life is water. We as humans always use it for our daily needs, both from washing clothes, bathing, cooking, even we also need to drink water. Water can be categorized into 2, namely fresh water and saltwater (seawater) which is the largest part of this earth. Seawater has a salinity level of 35 grams/liter. Brackish water has a salinity between 0.5 ppt to 17 ppt, while freshwater is water with a salt content below 0.5 ppt [1-3].

According to the Sustainable Development Goals (SDGs), all countries must be able to achieve 100% access to safe clean water by 2030. Meanwhile in 2020, according to data from the Central Bureau of Statistics Indonesia has only reached 90.21% for access to clean water, which means Indonesia still has not met the desired target. This needs to be taken into account, especially in coastal areas or rural areas which still frequently use water from natural sources.

The 6th Engineering Science and Technology International Conference (ESTIC 2021)
AIP Conf. Proc. 2691, 030009-1–030009-8; https://doi.org/10.1063/5.0118443
Published by AIP Publishing. 978-0-7354-4485-0/$30.00

However, natural water sources often experience a decrease in water quality due to changes in ecosystems and pollution in natural water sources. Where these conditions will make the community eventually forced to use water that has a quality that is not suitable for standard water for use in daily life. Of course, this can cause diseases such as diarrhea, vomiting, to skin diseases such as scabies and itching. A key solution to respond to such growing demands and avoid further deterioration of freshwater supplies is the exploitation of saline water resources. Brackish water is an attractive alternative to freshwater due to its low salinity and abundance in regions facing water scarcity [4].

The area to be studied in this research is located in the area of Tegal Sari Hamlet, Kupang Village, Jabon District, Sidoarjo Regency, East Java Province. The Sidoarjo region is one of the areas prone to natural disasters such as floods, tornadoes as well as this is further exacerbated by the failure of the mudflow technology in the Sidoarjo area. Apart from natural disasters Sidoarjo also experiences problems from the industrial waste sector which can cause environmental pollution as well as problems with shortages of clean water for daily life such as farming.

REVERSE OSMOSIS

The tool used in the research of the brackish water treatment process is one of the most widely used membrane technologies, namely, Reverse Osmosis (RO). Reverse Osmosis membrane is defined as a semipermeable membrane capable of separating freshwater from a salt solution with a pressure higher than the osmotic pressure of a salt solution. Separation of solute components measuring 0.001 to 0.01 μm and low molecular weight particles can be carried out by Reverse Osmosis membranes.

Reverse osmosis is a highly effective separation technology used industrially in several areas, including desalination of seawater and brackish water and wastewater treatment [5]. Since its invention, RO has undergone significant developments in terms of material science, process, system optimization, methods of membrane synthesis, and modifications [6]. Improvement in RO technology including advanced membrane material, module and process design, and energy recovery has led to cost reduction which in turn gaining interest to its commercial applications. RO is now being used in various applications including selective separation, purification, and concentration processes [7]. Treatment by RO reduces high levels of dissolved salts but has certain limitations in the removal of organics from chemical industry effluents [8].

The most commonly used desalination technologies are reverse osmosis (RO) and thermal processes such as multi-stage flash (MSF) and multi-effect distillation (MED). In europe, reverse osmosis, due to its lower energy consumption has gained much wider acceptance than its thermal alternatives [9]. Reverse osmosis (RO) is currently the most important desalination technology and it is experiencing significant growth [10]. The use of reverse osmosis (RO) membranes is becoming increasingly common in desalination plants, though disposal of the highly concentrated brines poses significant environmental risks [11].

The performance of membrane processes during separation of salts and ions from water is determined based on pores size and physical structure of different kind of membranes. Reverse osmosis membrane contains the smallest membrane pores. This small size of pores and reserve driven pressure causes a separation of water-soluble molecules [12]. Two distinct branches of reverse osmosis desalination have emerged: seawater reverse osmosis and brackish water reverse osmosis . Differences between the two water sources, including foulants, salinity, waste brine (concentrate) disposal options, and plant location, have created significant differences in process development, implementation, and key technical problems 13].

According to the research of demin water, which is water made from the water purification process and free from minerals dissolved in water from AC waste using an RO device. The greater the pressure applied to the reverse osmosis TDS value, the smaller the conductivity obtained. The working principle of the RO device to produce pure water from brackish water is to push water contained in brackish water to freshwater through a semipermeable membrane. In China, a similar study has also been carried out, based on the preparation of an RO device for brackish water and selecting the right RO membrane, the RO system can be used for brackish water. The RO system for brackish water is above the better method considering price or quality [14].

INDICATORS

The indicators used as references in this research are Power of Hydrogen (pH), Total Dissolved Solids (TDS), and Electrical Conductivity (EC). The first indicator is pH or degree of acidity, pH is the level of acid or base of a solution. If the pH is less than 7 then the solution is acidic, while the pH is greater than 7 then the solution is alkaline, and if the neutral solution has a pH of 7. According to the Regulation of the Minister of Health of the Republic of Indonesia number 32 of 2017, the pH limit for drinking water is between 6.5 to 8.5. The second indicator is Total Dissolved Solids (TDS) which are solids that have a smaller size than suspended solids.

Changes in the TDS concentration can be dangerous because they will lead to changes in salinity, changes in ionic composition, and individual ion toxicity. According to the Regulation of the Minister of Health of the Republic of Indonesia number 32 of 2017, the TDS contained in drinking water is less than 1000 mg / l or 1000 ppm. The last indicator is Electrical Conductivity (EC) which is a measure of the solution's ability to conduct electric current. If water has a conductivity value that is too high, water can settle in the body and damage kidney stones, according to the World Health Organization (WHO) (2011) [15] which states that the conductivity of drinking water is less than 300 µs / cm.

RESEARCH METHODS

This research was conducted in the Petra Christian University water laboratory. The research began with sampling in Tegal Sari hamlet, Kupang village, Jabon sub-district, Sidoarjo regency, East Java province. Water is taken from one of the residents' houses (Figure 1). After the required sample water is ready, the RO equipment is prepared to be used (Figure 2). After the RO tool is ready, the tool can be arranged according to the predetermined design as in Figure 3. As can be seen in Figure 4, after the sample water and RO device are ready for use, the sample water is tested to obtain values for pH, TDS, and Ec.

FIGURE 1. Brackish Water Sampling

FIGURE 2. Research Equipment

FIGURE 3. Arrangement of Tools

FIGURE 4. Testing of Sample Water

After the sample test results are known, the sample can be tested according to the Reverse Osmosis (RO) instrument procedure. The experiment was continued by preparing the pipe and laying clean water and dirty water from Reverse Osmosis to be produced (Figure 5). After the trials have been carried out and have results, the sample results will be tested (Figure 6). The examination is carried out to find out whether the results comply with the predetermined standards or not. If the test results are not meet the standard, the experiment will be repeated with a different number of independent variables and if it is according to the standard, the research is complete.

(a) (b)

FIGURE 5. (a) Placement of Clean Water and (b) Placing of Dirty Water

FIGURE 6. Testing and Testing Results

RESULTS AND DISCUSSION

There are several indicators examined in this research, including the pH, TDS, and EC values. Experiments were carried out several times to find out whether there was a difference between each experiment. As well as comparing the results of this experiment with suitable water standards. From Table 1, it can be seen that the results of the RO equipment sold in the market have been able to meet the pH and TDS standards of the world health organization (WHO) standard but still do not meet the EC standard. From experiments with the RO device in the laboratory, it is known that the time needed to fill 1 liter of water is 12 minutes 55 seconds so that the discharge from the RO device is 1.29×10^{-3} liter/second. In addition to knowing the discharge generated from the RO tool, from the RO tool experiment it is also known that it takes 25 minutes 57 seconds to get a constant pH, TDS, and EC.

TABLE 1. pH, EC and TDS Before and After The Treatment With Reverse Osmosis

Trials Number	pH (6.5 – 8.5)		TDS (500 – 1000 mg/l)		EC (400 μs/cm)	
	Before	**After**	**Before**	**After**	**Before**	**After**
1	7,9	8,4	5260	2340	10580	4670
2	7,9	8,4	5260	2170	10580	4370
3	7,9	8,4	5260	1509	10580	3020
4	7,9	8,4	5260	944	10580	1894
5	7,9	8,4	5260	718	10580	1441
6	7,9	8,4	5260	489	10580	979
7	7,9	8,4	5260	469	10580	939
8	7,9	8,4	5260	454	10580	909
9	7,9	8,4	5260	451	10580	904
10	7,9	8,4	5260	446	10580	893
11	7,9	8,4	5260	440	10580	880
12	7,9	8,4	5260	440	10580	880
13	7,9	8,4	5260	438	10580	877
14	7,9	8,4	5260	436	10580	872
15	7,9	8,4	5260	435	10580	872
16	7,9	8,4	5260	434	10580	869
17	7,9	8,4	5260	432	10580	865
18	7,9	8,4	5260	432	10580	864
19	7,9	8,4	5260	432	10580	864
20	7,9	8,4	5260	435	10580	870
21	7,9	8,4	5260	433	10580	867
22	7,9	8,4	5260	434	10580	866
23	7,9	8,4	5260	434	10580	867
24	7,9	8,4	5260	436	10580	872
25	7,9	8,4	5260	433	10580	867
26	7,9	8,4	5260	433	10580	867
27	7,9	8,4	5260	436	10580	872
28	7,9	8,4	5260	436	10580	872
29	7,9	8,4	5260	435	10580	870
30	7,9	8,4	5260	435	10580	870
31	7,9	8,4	5260	435	10580	870

Information:
pH = Power of hydrogen
TDS = Total Dissolved Solids
EC = Electrical Conductivity

To see the development of pH, TDS, and EC during the study, see Figure 7 for pH, Figure 8 for TDS, and Figure 9 for EC. To have a constant water yield it takes 25 minutes 57 seconds. The results will be compared with the standard for clean water. Where the best results obtained from the RO tool are a pH of 8.4, a TDS of 435 ppm, and an EC of 870 ms/cm. When compared with the existing standards where the pH must be between 6.5-8.5, TDS must be <1000 ppm, and EC must be <400 μs / cm, the research water has covered 2 parameters, namely pH and TDS. Meanwhile, the EC still does not cover the existing standards.

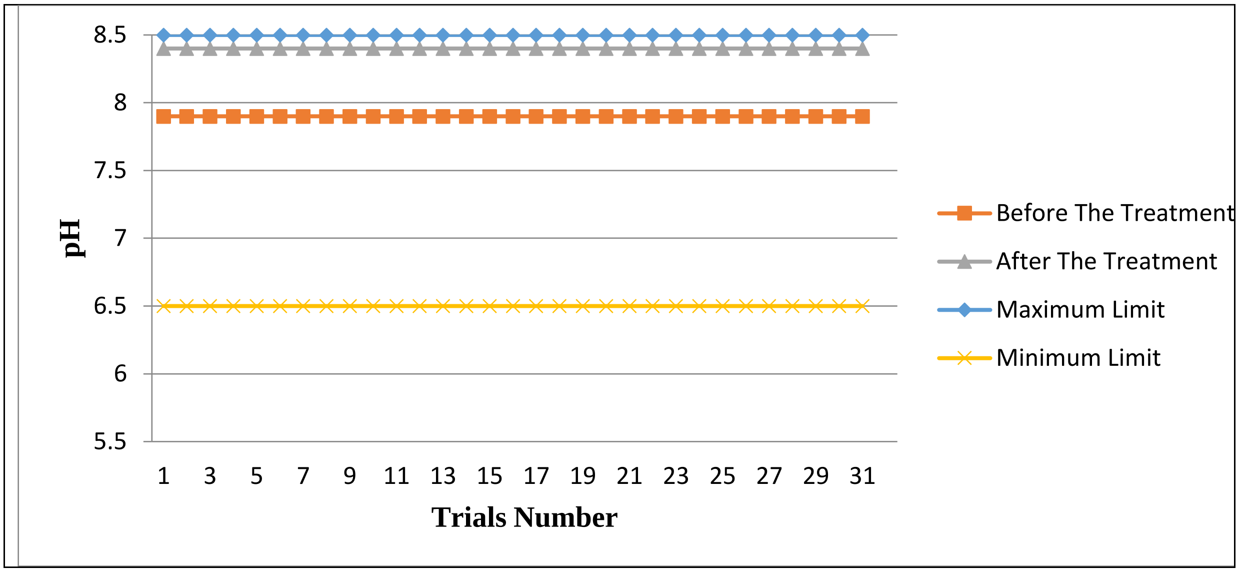

FIGURE 7. pH Treatment Before and After the Experiment (WHO Standard)

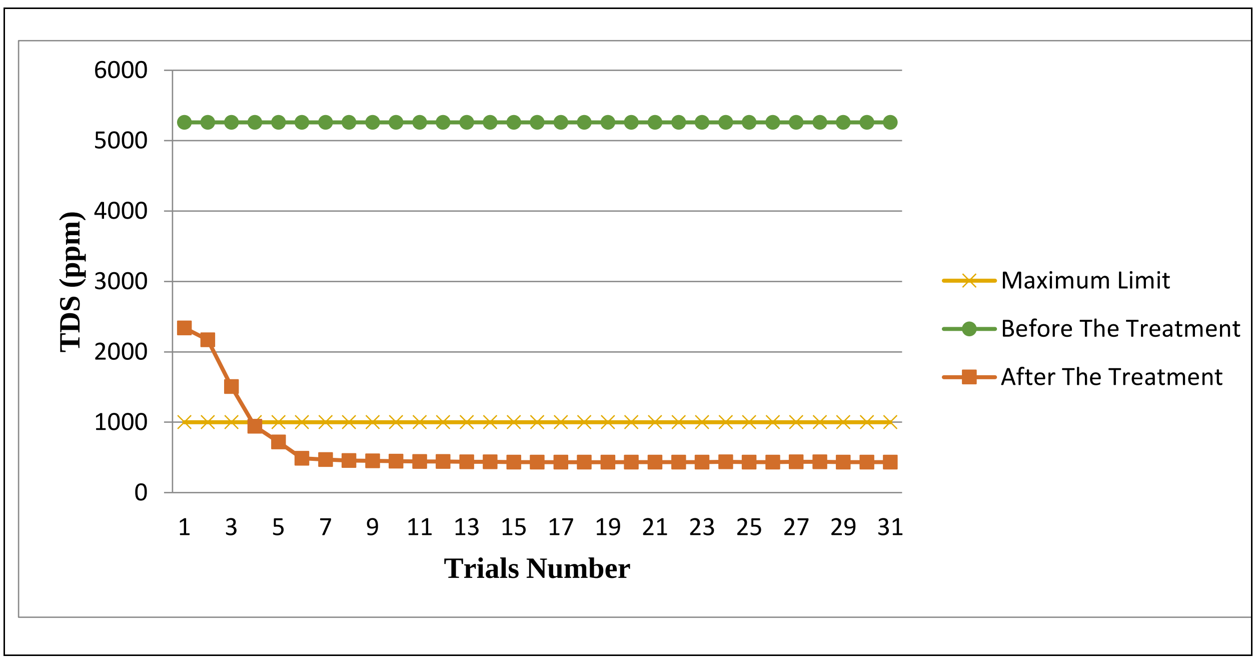

FIGURE 8. TDS Treatment Before and After the Experiment

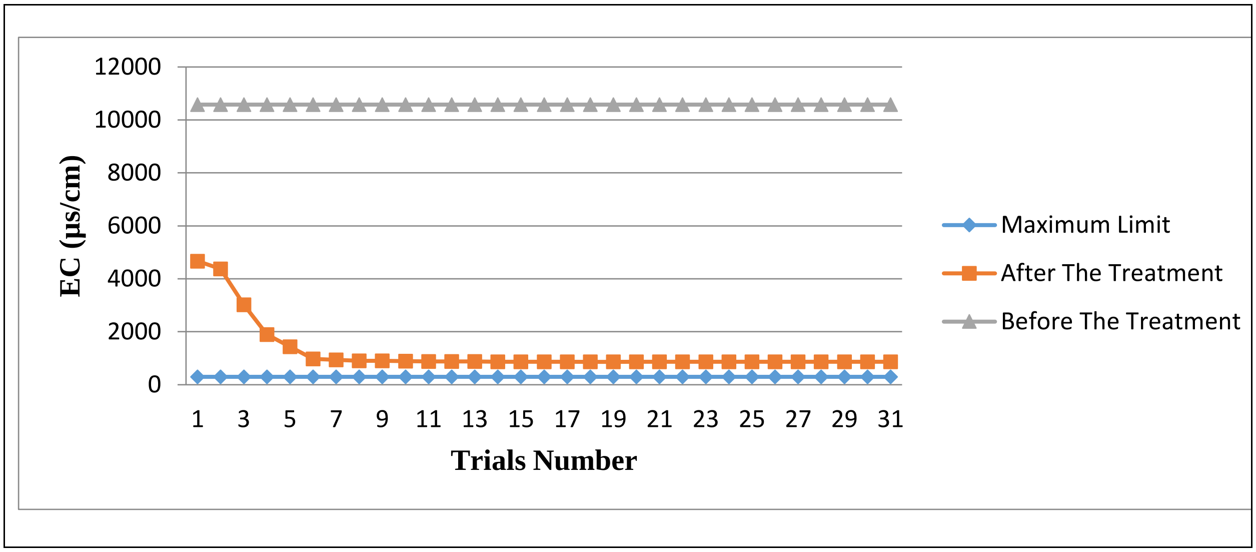

FIGURE 9. EC Treatment Before and After the Experiment

Meanwhile, here are some comparisons from various similar studies that have been done previously. The first research used a RO membrane, where the decrease in TDS by using the RO process is quite significant at the concentration of the solution NaCl feed 2000 mg/l and 2250 mg/l where the permeate produced already meets the quality standard of dissolved solids required for drinking water [31]. The second research used RO membrane too, where the research uses 2 types of water, seawater, and brackish water from coastal wells. Raw water for the RO process has several requirements, namely undetectable turbidity (zero), Fe content <0.1 mg/l, and maximum SDI of 5. The pH value must also be controlled to avoid movement of calcium which can from scale, while for coastal wells brackish water turbidity value is still below the standard, it is necessary to do pre-treatment to reduce the level of turbidity of brackish water [15]. The third research used Reverse Osmosis to purify seawater, In research with this experimental method, three experiments were carried out. Three samples were obtained, namely raw water samples, process water samples, and product water samples, and from the table of results of testing the RO product water sample above, it can be concluded that the water has met the standard maximum levels following the Regulation of the Minister of Health no. 416/PERMEKES/IX/1990.

CONCLUSION

From the research that has been done, several things can be concluded:

1. RO equipment that has been tested in the laboratory shows that it can reduce the TDS and EC of water by up to 91.7% and result in an increase in pH, but raise the pH to remain within the allowable limit. The experimental results of the RO tool show that the RO tools on the market can have a significant impact on the brackish water treatment process.
2. In this test, the RO tool took 25 minutes 57 seconds to be able to get relatively more constant pH, TDS, and EC values. The indicator values are pH of 8.4, TDS of 435 ppm, and EC of 870 ms/cm.

RECOMMENDATION

Based on the research that has been carried out, it can be suggested that for further research, it is better when doing testing, the membrane of the RO tool needs to be maintained or replaced when it is running and works more than 90%. If the RO membrane is forced to works more than 90%, it could cause the RO tool to be at a saturation point. For another suggestion is to use an RO tool with a larger capacity than the RO tool before.

ACKNOWLEDGMENTS

The authors would like to express appreciation for the support of the sponsors of Petra Christian University project number: **39/HB-Penelitian/LPPM-UKP/X/2020** and Directorate General of Higher Education Indonesia project number: **002/AMD-SP2H/LT-MULTI-TERAPAN/LL7/2021.**

REFERENCES

1. A.H. Baldwin, I.A. Mendelssohn. Effects of salinity and water level on coastal marshes: an experimental test of disturbance as a catalyst for vegetation change. Aquat Bot. (1998) 61:255–68.
2. N. Li, S. Phummisutthigoon, N. Charoenphandhu, Low salinity increases survival, body weight and development in tadpoles of the Chinese edible frog Hoplobatrachus rugulosus. Aquacult Res. (2015).
3. C. S. Wu, W. K. Yang, T. H. Lee, I. Gomez-Mestre, Y.C. Kam. Salinity acclimation enhances salinity tolerance in tadpoles living in brackish water through increased Na(+), K(+) -ATPase expression. J Exp Zool A Ecol Genet Physiol. (2014) 321:57–64.
4. S. Honarparvar, X. Zhang, T. Chen, A. Alborzi, K. Afroz and D. Reible, Frontiers of Membrane Desalination processes for Brackish Water Treatment: A Review, Membranes (2021).
5. D. Bhattacharyya, W. C. Mangum, M. E. Williams, Reverse Osmosis, Kirk-Othmer Encyclopedia of Chemical Technology (2000).
6. R. H. Hailemariam, Y. C. Woo, M. M. Damtie, B. C. Kim, K. D. Park and J. S. Choi, Reverse osmosis membrane fabrication and modification technologies and future trends: A review, Advanced in Colloid and Interface Science (2020).
7. I. G. Wenten and Khoiruddin, Reverse osmosis applications: Prospect and challenges, Desalination (2016).
8. A. B. Santoyo, J. L.G. Carrasco, E. G. Gómez, F. M. Martin and A. M. H. Montesinos, Application of reverse osmosis to reduce pollutants present in industrial wastewater, Desalination (2003).
9. C. Fritzmann, J. löwenberg, T. Wintgens, and T. Melin, State-of-the-art of reverse osmosis desalination, Desalination (2007).
10. K. P. Lee, T. C. Arnot and D. Mattia, A review of reverse osmosis membrane materials for desalination-Development to date and future potential, Journal of Membrane Science (2011).
11. T. Jeppesen, L. Shu, G. Keir, V. Jegatheesan, Metal recovery from reverse osmosis concentrate, Journal of Cleaner Production (2009).
12. M. Talaeipour, J. Nouri, A. H. Hassani and A. H. Mahvi, An Investigation of desalination by nanofiltration, reverse osmosis and integrated (hybrid NF/RO) membranes employed in brackish water treatment, Journal of Environmental Health Science and Engineering (2017).
13. L. F. Greenlee, D. F. Lawler, B. D. Freeman, B. Marrot, P. Moulin, Reverse osmosis desalination: Water sources, technology, and today's challenges, Water Research (2009).
14. P. Zhang, J. Hu, W. Li and H. Qi, *Research Progress Of Brackish Water Desalination By Reverse Osmosis. Journal of Water Resource and Protection*, 2013, 5, 304-309. North China Electric Power University, Beijing, China (2013).
15. World Health Organization (WHO), *Guidelines for drinking-water quality. 4th edn. Geneva, Switzerland: World Health Organization* (2011).