INTERNATIONAL JOURNAL OF SCIENCE AND NATURE

www.scienceandnature.org

THE STUDY OF THE EFFICIENCY OF HOUSEHOLD REVERSE OSMOSIS SYSTEM TO REMOVE THE POLLUTANTS FROM DIFFERENT WATER SOURCES

Ayat Abd-Aljaleel Altekrety & Yaaroub Faleh AL-Fatlawy
Department of Biology, College of Science, University of Baghdad, Baghdad, Iraq

ABSTRACT
The ability of household Reverse Osmosis system to treat three different water sources has been tested within a period of time. Water samples were analyzed before and after treatment with the system for physical, chemical and heavy metals parameters. The results showed that the values of temperature after treatment by Ro household filter increased slightly (29.88 ºC, 29.78 ºC and 30.66 ºC) in tap water, river water and well water respectively. While the values of pH decreased after treatment (7.07, 7 and 6.82) tap water, river water and well water respectively. The removal efficiencies of different parameters that tested during this study in tap water, river water and well water were as following: electrical conductivity (95.2%, 95.4% and 92.9%), total hardness (94.6%, 95.4% and 96.8%), free residual chlorine (100%), calcium (94.1%, 95.4% and 97.1%), magnesium (94.2%, 97.0% and 96.4%), potassium (88.6%, 72.7% and 84.9%), phosphate (86.4%, 86.8% and 84.3%), nitrite (89.1%, 92.2% and 92.2%), carbonate (100%, 96.9% and 100%), copper (19%, 64.2% and 86.6%), nickel (73.7%, 29.7% and 100%), zinc (38.5%, 83% and 57.6%).

KEYWORDS: reverse osmosis, activated carbon, tap water, river water, well water.

INTRODUCTION
The development of civilization led to increase water consumption, which negatively affects the quality and quantity of water sources, therefore to resolve these problems advanced water treatment technology is needed such as Reverse osmosis (RO)[1]. In osmosis, water flows from the lower concentration side of solid to the higher concentration side through a selective membrane depending on the naturally occurring osmotic pressure. While in reverse osmosis an applied pressure force water to flow in opposite direction leaving behind a concentrated solution of dissolved solids[2]. The household reverse osmosis (RO) water treatment system has been spreading in Iraq, especially in recent years due to deterioration of water sources. Most RO systems consist of the following stages.

A. Sediment filter: Polypropylene wound cartridges with size being of 5µm[3]. It is used to remove fine particles such as clay, silt and suspended solids[4].

B. Granular activated carbon filter (GAC): Its particles have sizes ranging from 0.2 to 5 mm[5]. It is able to remove chlorine, chloramines, and organic chemicals of low molecular weight such as pesticides, herbicides, and industrial solvents[4, 6].

C. Block Activated Carbon filter (BAC): finely powdered (block) carbon that has been bound together into a rigid solid and it has a relatively smaller particle size range between 15–25 microns [6, 7]. It is used for taste and odor control and also effective in removing the organic precursors that react with chlorine to form harmful THM compounds after disinfection [8].

D. RO Membrane filter: The spiral wound composite polyamide membranes are the most widely used types of membranes for reverse osmosis. The surface morphology of a polyamide membrane is rough, allowing for many areas where foulants can be captured and held by the membrane [9].

E. Post Activated Carbon Filter: to remove compounds that cause unpleasant taste and odors, including those from the tank, plastic tubing or any leftover chemicals just before the water is distributed [10].

F. Grancal Post Filter: It is made from natural healthy source of granulate calcium, magnesium and carbon that's provide a balanced pH adjustment to prevent acid water corrosion and returning the beneficial minerals calcium and magnesium to the drinking water [11].

G. Ultra Violet Filter: it ensures product water free from microbial contamination.

MATERIALS & METHODS
Water samples collected from three different water sources include: tap water samples collected from the advanced ecology lap at biology department, river water samples collected from Tigris River and well water samples collected from home well at AL-Ghazalia city from about 9 meters below the earth surface. The study period extended from the beginning of November 2016 to the end of April 2017 in which 25 liters of each water sources were passed through the RO system and the water samples before and after treatment were analyzed using different physical, chemical and heavy metals tests.

Water samples before and after treatment with the RO system were analyzed for: temperature, pH, Ec, total hardness, free residual chlorine, Ca, Mg, K, Po_4, No_2, Co_3, Cu^{+2}, Ni^{+2}, Zn^{+2}. Temperature was measured by HANNA meter. PH was measured by PH-meter 315i/SET/WTW/ Germany. Electrical conductivity was measured by EC meter 330i/ST/ WTW/ Germany. Total hardness and Ca were measured by titration with 0.01N EDTA. Mg was measured by the difference between total hardness and calcium hardness. Free residual chlorine was measured by lovibond Comparator 2000+ portable meter. NO_3, NO_2 and PO_4 were measured by ultraviolet spectrophotometric screening method. CO_3 was measured by titration with H_2SO_4. K was measured by the flame photometric method. Heavy metals were measured by flame atomic absorption spectrometry (FAAS) [12].

RESULTS & DISCUSSION

Temperature: The average values of temperature in inlet water for tap water, river water and well water were 23.44 ºC, 16.5 ºC, and 17.66 ºC respectively and of outlet water 29.88 ºC, 29.78 ºC and 30.66 ºC respectively. The increase in water temperature may relate to the low-pressure mercury vapor lamp emits energy in the form of heat, and this energy cases warms the water up [14].

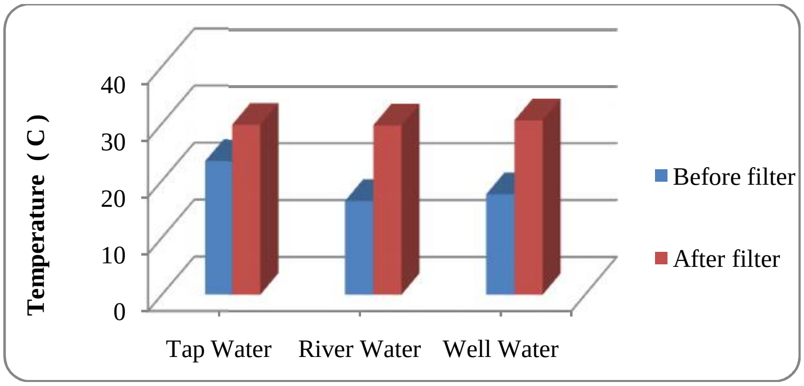

FIGURE 1: Mean Temperature Value (ºC) of Water Samples before/after Treatment

PH: The results showed that the average values of inlet water for tap water, river water and well water were 7.8, 7.7 and 7.74[13] respectively and of outlet water 7.07, 7 and 6.82 [13] respectively. The reduction of pH value due to the desalination process and the elements removal [15]. These results agreed with the studies of [15, 16].

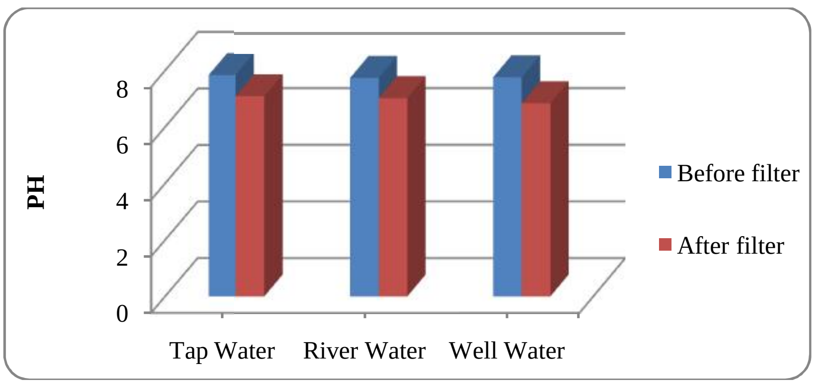

FIGURE 2: Mean pH Value of Water Samples before/after Treatment

Electrical conductivity: The removal efficiencies of (EC) in tap water, river water and well water were 95.2%, 95.4% and 92.9% [13] with average concentrations of inlet water 840.8 µs/cm, 921 µs/cm and 4526 µs/cm respectively and of outlet water 40.24 µs/cm, 42.02 µs/cm and 318.88 µs/cm[13] respectively. These results agreed with the studies of [16, 17].

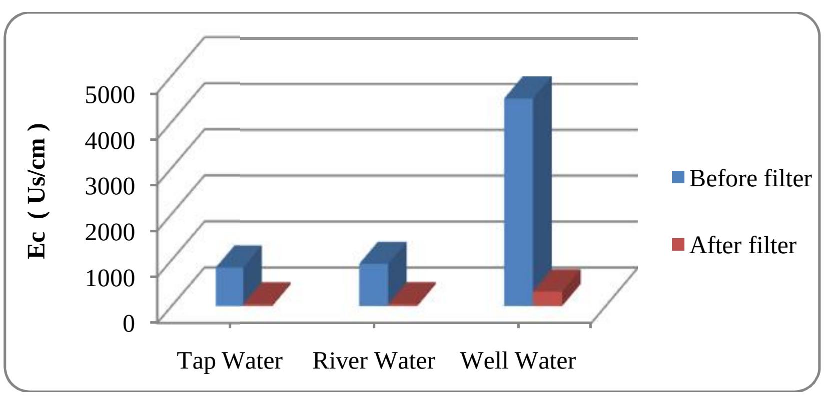

FIGURE 3: Mean Electrical Conductivity Value (µs/cm) of Water Samples before/after Treatment

Total hardness: The results showed that the Reverse Osmosis filter was able to remove (94.6%) of total hardness in tap water with average concentrations of inlet water (460.4 ppm) and of outlet water (24.8 ppm). Higher removal efficiency found in river water (95.4%) with average concentrations of inlet water (438 ppm) and of outlet water (20 ppm). The highest removal efficiency was in well water (96.8% [13]) with average concentrations of inlet water (1500 ppm) and of outlet water (48 ppm). Reverse Osmosis membrane is able to reduce water hardness, but the high level of hardness can adversely affect RO membrane and reduce its life as it is quickly fouled by hard water. Therefore, pre-filter must be used such as activated carbon filter to protect the RO membrane [18].

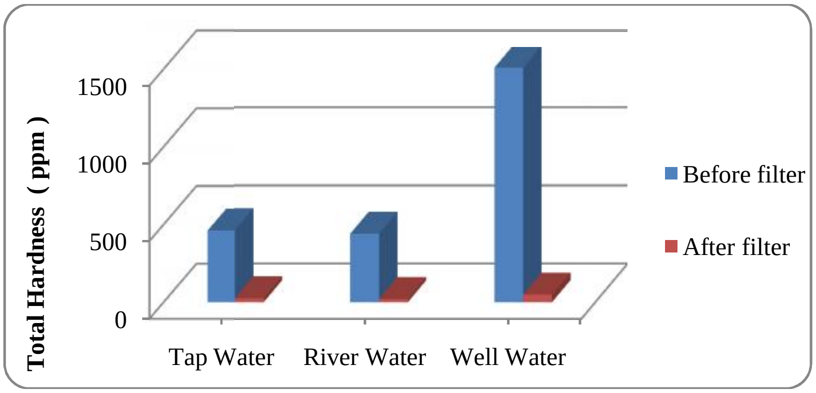

FIGURE 4: Mean Total Hardness Value (ppm) of Water Samples before/after Treatment

Free residual chlorine: The removal efficiency of chlorine by RO household filter in tap water was (100%) with average concentrations of inlet water (2.52 ppm) and of outlet water (zero ppm). In both river water and well water, there is no chlorine in inlet and outlet water. The study of [19] showed similar finding. The removal mechanism of AC involves a chemical reaction of the activated carbon's surface being oxidized by chlorine as shown below:

$HOCl + Carbon \rightarrow H+ + Cl– + CO$

$OCl– + Carbon \rightarrow Cl– + CO$

These reactions occur very quickly in which chlorine reduced to chloride ion and the site of (AC) after reacting with chlorine is CO [20].

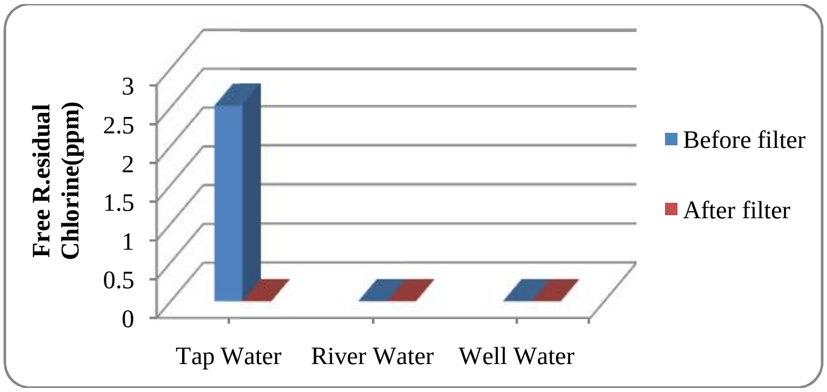

FIGURE 5: Mean Free Residual Chlorine Value (ppm) of Water Samples before/after Treatment

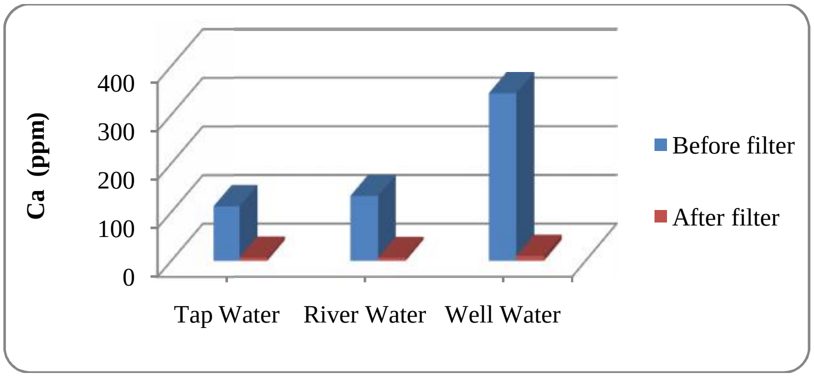

FIGURE 6: Mean Calcium Ions Value (ppm) of Water Samples before/after Treatment

Calcium (Ca^{+2}): The results of calcium removal in tap water by the RO household filter showed a high removal efficiency which reached to (94.1%) with average concentrations of inlet water (112.2 ppm) and of outlet water (6.6 ppm). While in river water the removal efficiency was (95.4%) with average concentrations of inlet water (133.2 ppm) and of outlet water (6.04 ppm). For well water the removal efficiency reached to (97.1% [13]) with average concentrations of inlet water (344 ppm) and of outlet water (9.96 ppm). These results agreed with the studies of [21, 22].

Magnesium (Mg^{+2}): High concentrations of magnesium and sulfate in drinking water above 250 mg/l cause a laxative effect [23]. The current work showed high removal efficiency for magnesium in tap water, river water and well water as 94.2%, 97.0% and 96.4% [13] respectively. While the average concentrations of inlet water were (36.32 ppm, 26.8 ppm and 155.6 ppm) respectively; and the average concentrations of outlet water were (2.1 ppm, 0.78 ppm, and 5.56 ppm) respectively. The studies of [24, 25] showed similar results to this study. The low concentration of Ca+, Mg and total hardness in RO water attributed to the process of desalinization which removes the minerals from the raw water [26].

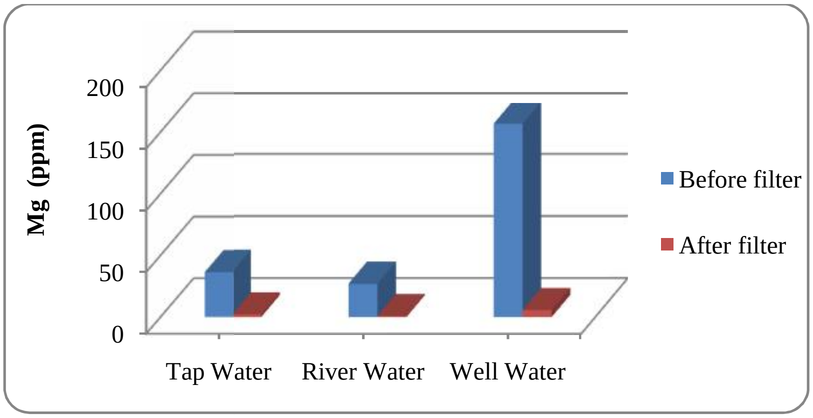

FIGURE 7: Mean Magnesium Ions Value (ppm) of Water Samples before/after Treatment

Potassium (K): Consuming drinking-water with unusually high levels of potassium may cause hyperkalaemia in individuals especially those in which excretion of potassium ions might be reduced or compromised, including those with kidney disease or renal insufficiency, older individuals and infants with immature kidney function [27]. Regarding water potassium content, the results showed that the percent of removal of potassium from tap water by the RO household filter reached to (88.6%) with average concentrations of inlet water (3.09 ppm) and of outlet water (0.35 ppm). Lower removal efficiency founded in river water (72.7%) with average concentrations of inlet water (2.02 ppm) and of outlet water (0.5 ppm). Finally, in well water the removal efficiency (84.9%) with average concentrations of inlet water (3.32 ppm) and of outlet water (0.5 ppm). Same results were found in the studies of [28, 29].

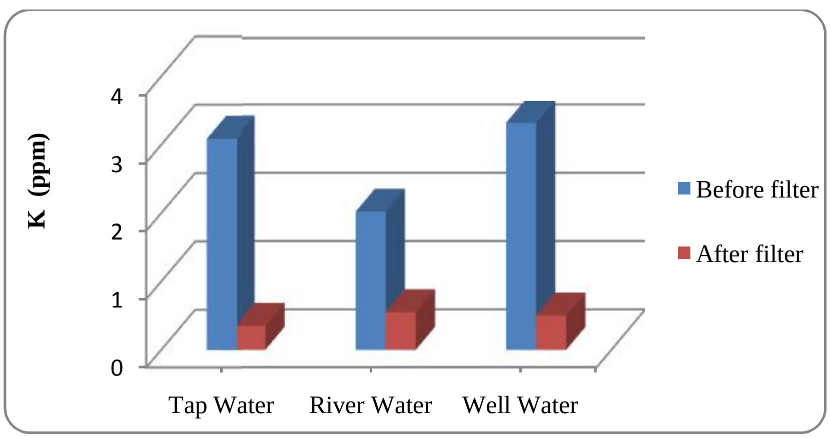

FIGURE 8: Mean Potassium Ions Value (ppm) of Water Samples before/after Treatment

Phosphate (Po_4): It has been found that the RO household filter was able to remove (86.4%) of phosphate from tap water with average concentrations of inlet water (1.14 ppm) and of outlet water (0.154 ppm). While in river water, the removal efficiency was (86.8%) with average concentrations of inlet water (1.22 ppm) and of outlet water (0.16 ppm). For well water, RO filter was able to remove (84.3%) with average concentrations of inlet water (3.96 ppm) and of outlet water (0.62 ppm). The results obtained in this study agreed with the studies of [24, 30].

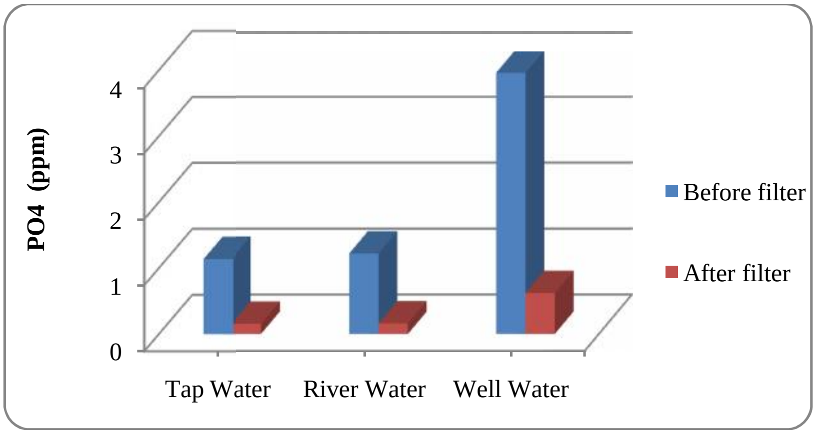

FIGURE 9: Mean Phosphate Ions Value (ppm) of Water Samples before/after Treatment

Nitrite (NO_2^-): The result showed that the removal efficiency of nitrite in tap water was (89.1%) with average concentrations of inlet water (3.06 ppm) and of outlet water (0.332 ppm). The removal efficiency of RO household filter in both river water and well water were (92.2%) with average concentrations of inlet water (3.52 ppm, 7.04 ppm) respectively, and of outlet water (0.274 ppm, 0.548 ppm) respectively. This result agreed with the result of [31].

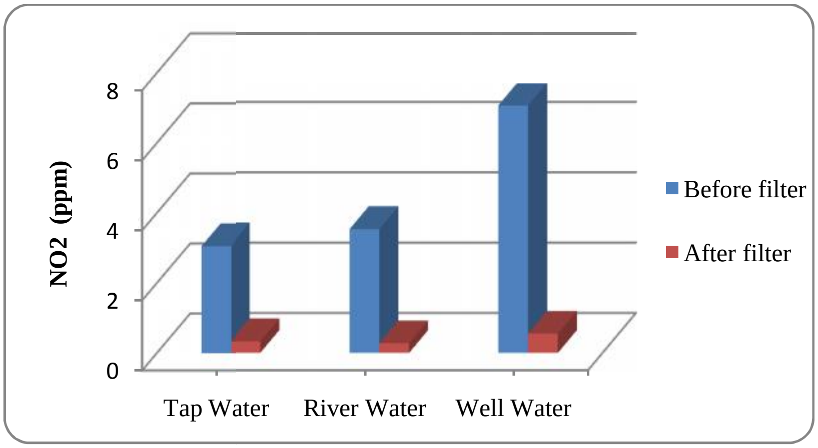

FIGURE 10: Mean Nitrite Ions Value (ppm) of Water Samples before/after Treatment

Carbonate (CO_3): The removal efficiency of carbonate in tap water was (100%) with average concentrations of inlet water (3.6 ppm) and of outlet water (zero ppm). While in river water the removal efficiency was (96.9%) with average concentrations of inlet water (7.2 ppm) and of outlet water (0.22 ppm). In well water the removal efficiency was (100%) with average concentrations of inlet water (7.2 ppm) and of outlet water (Zero ppm).

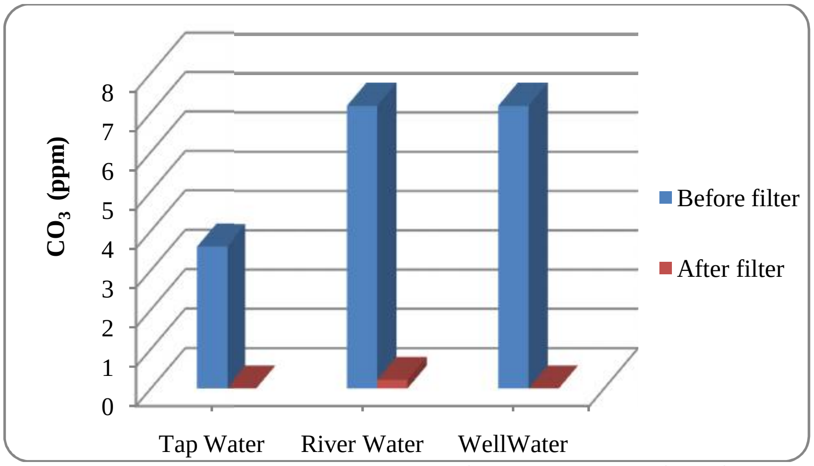

FIGURE 11: Mean Carbonate Ions Value (ppm) of Water Samples before/after Treatment

Copper (Cu^{+2}): High levels of copper in drinking water can cause vomiting, abdominal pain, nausea; diarrhea and can cause death by nervous system, liver and kidney failure [23]. The obtained results showed that the Reverse Osmosis system was able to remove (19%, 64.2% and 86.6%) of (Cu) from tap water, river water and well water respectively. The average concentrations of inlet water were (0.02 ppm, 0.014 ppm and 0.03 ppm) respectively, and of outlet water (0.0162 ppm, 0.005 ppm and 0.004 ppm) respectively. These results were different from the study of [24] which found that the RO system was able to remove (97%) of copper solution.

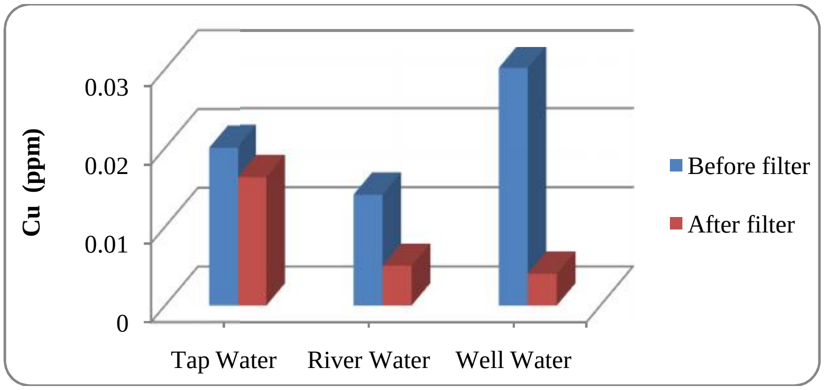

FIGURE 12: Mean Copper Value (ppm) of Water Samples before/after Treatment

Nickel (Ni^{+2}): In high quantities Ni can also cause cancer, respiratory failure, birth defects, allergies, dermatitis, eczema, nervous system and heart failure [33]. The results showed that the removal efficiency of RO system to remove (Ni) from tap water was (73.7%) with average concentrations of inlet water (0.016 ppm) and of outlet water (0.0042 ppm). In river water the removal efficiency was (29.7%) with average concentrations of inlet water (0.0074 ppm) and of outlet water (0.0052 ppm). In well water the removal efficiency was (100%) with average concentrations of inlet water (0.014 ppm) and of outlet water (Zero ppm). The results disagreed with the study of [34].

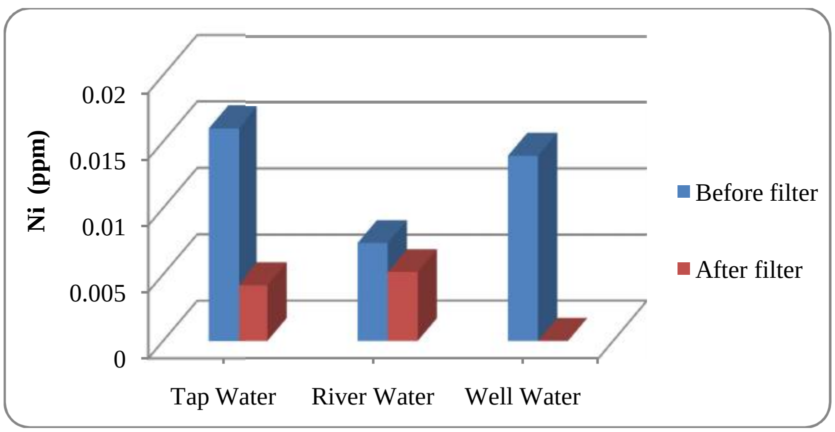

FIGURE 13: Mean Nickel Value (ppm) of Water Samples before/after Treatment

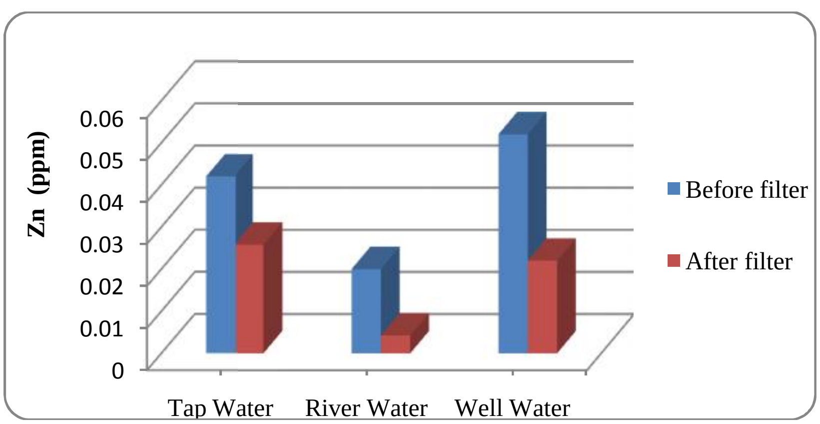

FIGURE 14: Mean Zinc Value (ppm) of Water Samples before/after Treatment

Zinc (Zn^{+2}): High concentration of zinc cause vomiting, lethargy abdominal pain, anemia, dizziness and nausea [35]. The removal efficiency of the Reverse Osmosis system in tap water was (38.5%) with average concentrations of inlet water (0.042 ppm) and of outlet water (0.0258 ppm). In river water the removal efficiency (83%) with average concentrations of inlet water (0.02 ppm) and of outlet water (0.0054 ppm). In well water the removal efficiency was (57.6%) with average concentrations of inlet water (0.052 ppm) and of outlet water (0.022 ppm). [36, 37] reached to the same results, but disagreed with [38] who found that the removal rate was 98.2%.

According to the negative charge of RO membrane and the Donnan potential, the positively charge ions (cations) such as calcium and magnesium had a higher removal efficiencies than the negatively charge ions (anions) such as, nitrite and phosphate [39]. Also, the surface of AC has a negative charged at high pH value because the numbers of the hydroxyl ions concentration increase and result in enhancing the adsorption of cationic contaminants [40]. According to this reason the removal efficiency of cations group was higher than of anions group except for potassium because of its low concentration.

CONCLUSION

The results of this study showed that the Reverse osmosis system was efficient in removing water contaminants with a high value. So this type of systems is recommended to treat water contamination.

ACKNOWLEDGEMENTS

The author would like to thank the staff of Ecology Science at Department of biology, College of Sciences, University Of Baghdad, Baghdad.

REFERENCES

[1]. Kieniewicz, A. (2006) A reverse osmosis (RO) plant for sewage treatment and nutrient recovery–the influence of pre-treatment methods. TRITA-LWR Degree Project, 06-08.

[2]. McMordie Stoughton, K., Duan, X., & Wendel, E.M. (2013) Reverse Osmosis Optimization (No. PNNL-22682) Pacific Northwest National Laboratory (PNNL), Richland, WA (US).

[3]. AWWA. American Water Works Association (2007) Reverse Osmosis and Nanofiltration: Manual of Water Supply Practices (M46).

[4]. Ingram, C. (2006) The Drinking Water Book: How to Eliminate the Most Harmful Toxins from Your Water. Random House Digital, Inc.

[5]. Poulopoulos, S.G., & Inglezakis, V.J. (2006) Adsorption, ion exchange and catalysis: design of operations and environmental applications. Elsevier Science & Technology.

[6]. Haas, E.M. (2006) Staying Healthy With Nutrition, 21st Century Edition: The Complete Guide to Diet & Nutritional Medicine. Random House Digital, Inc.

[7]. Degremont, S.A. (1979) Water treatment handbook. 5th ed, Halsted Press, New York.

[8]. Spellman, F.R. & Drinan, J. (2012) The drinking water handbook. CRC Press. Taylor & Francis Group.

[9]. Kucera, J. (2015) Reverse osmosis: design, processes, and applications for engineers. John Wiley & Sons.

[10]. Kneen, B., Lemley, A. & Wagenet, L. (2005) Reverse Osmosis Treatment of Drinking Water. Water Conditioning and Purification International, 50, 58.

[11]. Puricom Company Site. Available online at: http:// www. puricom.com/exec/ product.php? mod= show & cid= 69&pid= FT-0033-2&lg=E

[12]. APHA, AWWA and WEF (2012) Standard Methods for the Examination of Water and Wastewater. 22st edition. Washington, DC: American Public Health Association, American Water Works Association, Water Environment Federation.

[13]. Altekrety, A.A., AL-Fatlawy, Y.F. (2017) The Study of Groundwater Treatment by Household Reverse Osmosis System. International Journal of Science and Research, 6: 648-653. DOI: 10.21275/ART20176684.

[14]. Luminoruv, (2017). Available at: http://www. Lum inoruv. com/ qanda_uv.php

[15]. Aish, A.M. (2011) Water quality evaluation of small scale desalination plants in the Gaza Strip, Palestine. Desalination and Water Treatment, 29(1-3), 164-173.

[16]. Belkacem, M., Bekhti, S. & Bensadok, K. (2007) Groundwater treatment by reverse osmosis. Desalination, 206(1-3), 100-106.

[17]. Hamdy, S.M. (2016) Examination and Analysis of Water from Household Water Filter System (Kifllow). Eng. & Tech. Journal, Vol. 34, Part (B), No. 3, 2016.

[18]. Benham, B.L. & Ling, E. (2013) Virginia Household Water Quality Program: Household Water Treatment. Virginia Cooperative Extension, p. 442-670.

[19]. Lim, M., Delehomme, C. & Capece, J. (2008) Removal of Residual Chlorine from Drinking-Water By Solar Radiation (UV) and Activated Carbon Filtration. Intelligentsia International, Inc.

[20]. Potwora, R. (2009). Chlorine and chloramine removal with activated carbon. Water Conditioning & Purification, 14-16.

[21]. Saad, N.A., Bashboosh, A.E., Abbass, T.S. (2012) Bacteriological and Chemical study on different types of Drinking Water. Kufa Med. Journal 2012. VOL. 15.No.1.

[22]. Abbas, A.H. (2015) RO softens brackish groundwater in Tikrit, Iraq. World Water: Water Reuse & Desalination.

[23]. WHO (World Health Organization) (2011) Guidelines for drinking-water quality - 4th ed. Geneva 27, Switzerland.

[24]. Schoeman, J.J. & Steyn, A. (2003) Nitrate removal with reverse osmosis in a rural area in South Africa. Desalination, 155(1), 15-26.

[25]. Pawlak, Z., Żak, S. & Zabłocki, L. (2006) Removal of Hazardous Metals from Groundwater by Reverse Osmosis. Polish Journal of Environmental Studies, 15(4) 21-29.

[26]. Moyel, M.S., Amteghy, A.H., Naseer, T.K., Mahdi, E.A., Younus, B.M. & Albadran, M.A. (2013) Comparison of total hardness, calcium and magnesium concentrations in drinking water (RO), and municipal water with WHO and local authorities at Basrah province, Iraq. Marsh Bulletin 8(1)65-75.

[27]. WHO. (World health organization) (2009) Guidelines for Drinking-water Quality, WHO/HSE/ WSH/ 09.01/7.

[28]. Garabedian, S.A. (2011) The Quality of Reverse Osmosis Water in Storage Tanks in Basrah city – Iraq. Marsh Bulletin 6(1)1-8.

[29]. Al-Bayati, M.A., Saleh, S.A. & Al-Abdraba, W.M. (2015) Evaluation of Efficiency of Groundwater Desalination Plants in Different Hydrogeological Conditions in Salahaddin Governorate/ Iraq. Tikrit Journal of Pure Science, 20(5).

[30]. Bodalo-Santoyo, A., Gómez-Carrasco, J. L., Gomez-Gomez, E., Maximo-Martin, F. & Hidalgo-Montesinos, A. M. (2003) Application of reverse osmosis to reduce pollutants present in industrial wastewater. Desalination, 155(2), 101-108.

[31]. Šír, M., Podhola, M., Patočka, T., Honzajková, Z. , Kocurek, P., Bystrianský, M., Vurm1, R. & Kubal, M. (2015) Removal of pesticides and inorganic pollutants by reverse osmosis. Environment Protection Engineering, 41(2).

[32]. Qdais, H.A. & Moussa, H. (2004) Removal of heavy metals from wastewater by membrane processes: a comparative study. Desalination, 164(2), 105-110.

[33]. Marfo, B.T. (2014) Heavy metals contaminations of soil and water at Agbogbloshie Scrap Market, Accra (Doctoral dissertation).

[34]. Rodrigues Pires da Silva, J., Merçon, F., Guimarães Costa, C.M. & Radoman Benjo, D. (2016) Application of reverse osmosis process associated with EDTA complexation for nickel and copper removal from wastewater. Desalination and Water Treatment, 57(41), 19466-19474.

[35]. Porea, T.J., Belmont, J.W. & Mahoney Jr, D.H. (2000) Zinc-induced anemia and neutropenia in an adolescent. The Journal of pediatrics, 136(5), 688-690.

[36]. Al-Jlil, S.A. & Alharbi, O.A. (2010) Comparative study on the use of reverse osmosis and adsorption process for heavy metals removal from wastewater in Saudi Arabia. Research Journal of Environmental Sciences, 4(4), 400-406.

[37]. Al-Alawy, F.A. and Salih, M.H. (2016) Experimental Study and Mathematical Modelling of Zinc Removal by Reverse Osmosis Membranes. Iraqi Journal of Chemical and Petroleum Engineering. Vol.17 No.3, 57- 73. ISSN: 1997-4884.

[38]. Aljendeel, H.A. (2011) Removal of heavy metals using reverse osmosis. Journal of Engineering, Volume 17 June 2011, Number 3.

[39]. Ong, S.L., Zhou, W., Song, L. & Ng, W.J. (2002) Evaluation of feed concentration effects on salt/ion transport through RO/NF membranes with the Nernst- Planck- Donnan model. Environmental engineering science, 19(6), 429-439.

[40]. Iqbal, M.J. & Ashiq, M.N. (2007) Adsorption of dyes from aqueous solutions on activated charcoal. Journal of Hazardous Materials, 139(1), 57-66.