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Research Article

An evaluation of chemical, physical and biological qualities of the inlet and outlet water of desalination plants by reverse osmosis and multistage flash processes in Qeshm Island during

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ABSTRACT

Background and aim: One of the most important components of community's health is providing clean drinking water. The aim of this study is the quality evaluation of inlet and outlet water of desalination plants in Qeshm by reverse osmosis (RO) and Multistage flash (MSF) processes and also to compare water quality of outlet from both of process with National and International standards of drinking water.
Methods: The cross-sectional descriptive study was carried out during 7 months from November 2011 to May 2012. Sampling was carried out once every two months from inlet and outlet water of desalination plants in Qeshm by RO and MSF processes. Parameters were studied included total hardness, electrical conductivity (EC), total dissolved solid (TDS), turbidity, temperature, pH, fluoride, nitrate, nitrite, chloride, sulfate and biological parameter (total coliform, fecal coliform). Finally, analytical analysis was performed by SPSS (version 16) using paired T- test.
Result: Although theresults of this study showed that total hardness and fluoride concentration in the effluent of the both of the processes (RO and MSF) were lower than desirable concentration and chloride concentration in RO process was higher than allowable concentration limit, the rest of parameters (chemical and physical) in both of processes were in the acceptable range. There was not observed any coliform contamination in the effluent from the both processes (RO and MSF).
Conclusion: Due to low fluoride and hardness concentration in the effluent of the both processes (RO and MSF), it should be compensated by adding fluoride and calcium or magnesium compounds. More importantly, the both processes have high capability in providing safe drinking water quality according to water quality standards.

Keywords: Water quality, Qeshm, Reverse osmosis process, Multistage flash process, Desalination

INTRODUCTION:

Water is essential for the survival; thus, supplying healthy water is one of the most important functions of governments. In addition to providing required water for vital activities of

body, drinking water, provides the body's essential minerals;however, the excessive amounts of minerals, lead to change water quality and in some cases to endanger human health (1). For example, in large amount of sulfate in the water impart undesirable taste (1and2). Methemoglobin (preventing oxygen transmission by HB), the formation of N-nitroso carcinogenic compounds, preventing from iodine absorption, are some of the adverse effects of excessive amounts of nitrate and nitrite in drinking water(2).Excessive TDS and chloride causes salinity of water and thereby reduces the consumer acceptance(1 and2). Hardness above 200 mg/l can precipitate in pipes and the distribution system, also it reduces the cleaning ability of water. The hardness of less than 100 mg/l and pH lower than 7, causes the corrosion in the pipes (1, 3). Turbidity of water is caused by mineral and organic particles and in most cases microorganisms(bacteria, viruses and protozoa) are also attached to the particles, so high turbidity results reduction of clear water and consumer dissatisfaction, as well as the increase in the intestinal infections(2). Lower levels of fluoride, damages tooth enamel and leads to its decay; however, higher levels of fluoride in drinking water causes sclerosis(1and4). The presence of pathogenic microorganisms in drinking water can seriously threaten consumer's health and lead to diseases such as cholera, typhoid, hepatitis, and severe bloody diarrhea(5). Therefore, continuous monitoring of chemical, physical and microbial parameters of drinking water is essential. Thus ,the World Health Organization published the first guideline for drinking water quality in years 1984,1985 and then published the second edition in 1993, the third edition in 2003; WHO in 2011 published the fourth edition and made it available for countries and organizations in charge(2). In Iran the first of standard of the chemical and physical properties of water published in 1966 under the Standard 1053 and its fifth revisions were approved and published in 2009 in the nine hundred nineteen the session of the National Standards Committee of Agriculture and Food(6).

Currently, all over the world, including the Middle East, using the Desalination Plants for the production of drinking water is very common and different forms of this technology are used including Multiple-effect distillation (MED), Multi-stage flash distillation (MSF), and the use of membrane with reverse osmosis process (RO); in terms of the production capability, RO, MSF and MED are used in Iran, respectively (7). During the past years, a few studies have been conducted on water quality of desalination plants and they were mainly based on reverse osmosis process.

Yari et al. (2002) studied the chemical, physical and microbial quality of desalinated water by desalination plants using the RO process in Qom, they found that the amount of total hardness, fluoride and pH in the outlet water of the systems were lower than optimal and 6% of the samples indicated bacterial contamination (8). Another study was carried out by Qannadi and Farhadpour in 2006 entitling 'the quality of water produced by desalination plants in cities and villages of Iran'. It was determined in their study that the outlet water's pH was getting acidic and the efficiency of desalination in the reduction of TDS is 98%(9). During 2007 and 2008, Miranzadeh and Rabbani conducted a research on RO Desalination Plants of Kashan city. They determined that with the exception of fluorine, other parameters have an acceptable limit, and none of the samples contain microbial contamination(4). Khodadadi et al.(2009) conducted a study in Birjand and indicated that the outlet water of Desalination Plants by RO process removes TDS and nitrite more than 90% and results of microbial tests showed that none of the samples had microbial contamination(5). Schoeman and Steyn in a study in South Africa proved that RO process is capable of reducing

nitrate from 42.5 to 0.9 mg per liter and TDS from 1292 to 24 mg per liter(10). Also Mohamed Belkacem et al. (2007) in Algeria showed that the RO process removes TDS of the inlet water up to 95% (11). Antonio Bodalo and et al carried out a study in Spain(2004) and confirmed the efficiency of RO process in removing sulfate; they indicated the ability of RO in reducing high concentrations of sulfate at a dose of 25 mg/l in treated water(12). Peter Sehn In another study in Finland(2008)investigated the effect of RO process in the removal of fluoride from water. The results showed that reverse osmosis process can reduce the concentration of fluorine from 1/7 to 0/3 mg/l (13).

Al-Odwani et al. conducted a study in Kuwait and realized that outlet water in MSF process indicated low pH and therefore is corrosive(14). Toufic M al. showed that the water of MSF process contained low levels of TDS and EC(15). Due to lack of fresh water in some parts of Iran, especially in the southern coast line, islands and desert areas, people had to use water with high minerals or salty water; however, in recent years these areas supply fresh water by the arrival and development of distillation plants. As mentioned above ,continuous monitoring of chemical, physical and microbial parameters of drinking water is essential, therefore, control of outlet water quality these plants is essential. According to the geographical location of Qeshm island and the necessity of supplying drinking water for residents through seawater desalination by RO and MSF processes, this study evaluated the chemical, physical and microbial quality of inlet and outlet water of desalination plants in Qeshm by reverse osmosis (RO) and Multistage flash (MSF) processes and also to compare water quality of outlet from both of process with National and International standards of drinking water.

METHOD:

a cross-sectional descriptive study considers two desalination plants in Qeshm(a desalination plant with RO process and the other one with MSF process). Each desalination plant had 2 points for sampling (inlet water of plants in the pipe of raw water and the other outlet water of plants in the tap of the treated water) and a total of 4 sampling points. Sampling was conducted over 4 times, from December 2011 to June2012 a two-month intervals. At each sampling, 3 samples were picked instantaneously and without prior notice during working hours, from each sampling point(the inlet(raw water) and the outlet of each desalination plant). So in total 48 samples were collected and transported to the laboratory in accordance with standard 2347 of Iran. (15)

All parameters studied in the laboratory and were tested with 3 repetitions for each sample. It is notable that for chemical sampling been used from 2 liters polyethylene containers and for microbial sampling from completely sterile and sanded lids glass containers . It Samples were transferred to the water laboratory of Hormozgan's health center for chemical and physical testing and for microbial culture, they were transferred to the water laboratory of Qeshm health center .All tests were carried out in accordance with the methods listed in the standard methods book -the twentieth edition (16).

The measured parameters are :total hardness by titration method using EDTA and based on Standard 2356 of the Institute of Standards and Industrial Research of Iran, Chloror by argentometric method using AgNO3 according to standard No.2350 procedure of the Institute of Standards and Industrial Research of Iran, Total dissolved solids(TDS) by heating method according to Regulation No.2540 of standard method's book, Turbidity measured by turbidity meter (model 2100Q, Hach)on the basis of Regulation No.2130 in standard method's book, temperature using Mercury thermometer and based on instruction No.2550 of standard method's book, Electrical conductivity using EC

meter (model CD20, AQUALYTIC) and based on instruction No. 2510 of standard method's book, Fluorine based on the standard NO.2351 Institute of Standards of Iran, Nitrate based on the standard NO.2352 Institute of Standards of Iran, sulfate based on the standard NO. 2353 Institute of Standards of Iran, Nitrate measured by spectrophotometer (mode l7000Palintest) and to measure the total coliforms (TC) based on to the instructions No. B-9221 of standard method and to measure fecal coliforms (FC)) based on the Regulation E-9221 of the standard method, so for total coliforms were used from BGB medium(Brilliant Green Lactose Bile broth)and the confirmatory test for the detection of fecal coliforms were used EC medium(Escherichia Coli broth) and Standard 9-tube method.

Eventually, the results were analyzed by paired t-test using SPSS version 16. The mean concentrations were compared with national standard of 1053 and some of the parameters that were not mentioned in standard1053 were compared with international standards such as the World Health Organization standards, and the Europe Union standards.

RESULTS AND FINDINGS:

The mean concentration of chemical and physical parameters of the inlet and outlet water obtained from both the processes of reverse osmosis and Multi-stage flash distillation are presented in Table 1, the results of microbial culture of inlet and outlet water from both the process of RO and MSF are presented in Table 2; the percentage of removal efficiency of investigated parameters for both processes are presented in Figure1.

The water entering the RO process is obtained from a well drilled in 200 meters of shore and the water entering the MSF process is extracted from the sea. But the chemical and physical quality of the inlet water to both processes in this study is almost similar. In this regard, the results of the study are in line with the studies of Asadpour and Mir Hosseini entitling the environmental impacts of desalination plants of Qeshm Island(17). However ,this was not true concerning their microbial quality,because100% of samples selected from the sea (inlet water to the MSF process) indicated fecal coliform contaminations of Escherichia coli (E. coli), and all the samples from well (water entering the RO process)didn't indicate any microbial contamination. Statistical analysis shows that a significant relationship exists between inlet and outlet parameters ($P < 0.001$) also a there is a significant correlation between the measured parameters and the standards ($P < 0.001$).

CONCLUSION

Qeshm Island has not surface water or groundwater aquifers; thus, using desalination strategies and making use of desalination plants, are the most logical and economical ways of providing drinking water.

The inlet water to desalination plants is the water extracted from the Persian Gulf. The discharge of pollutants, including industrial wastewater, municipal waste, discharge of ballast water of ships ,oils pills caused by accidents of tankers and oil platforms, etc. day by day, pollute the water of Persian Gulf(19 and20). On the other hand, studies around the world have shown that desalination plants don't have the selective ability and remove all cations and anions, useful or harmful. This can lead to an imbalance in the level of minerals in outlet water and endanger consumer's health (4) Therefore, continuous monitoring of water quality is essential.

In this study, by measuring the chemical and physical parameters and as well as microbial culture were proved effectiveness of desalination plants to produce drinking water with both processes in accordance with existing standards; samples of the inlet water (inlet water to the RO process was obtained from the drilled well in200 meters of the shore and inlet water to the MSF

process was extracted from the ocean) and the outflow water were evaluated.

In this study, in both RO and MSF processes, the average concentration of fluorine in the outlet water was below the limit and is in accordance with the results of Yari et al. in Qom(8) and Miranzadeh and Rabbani in Kashan(4). However, these researches were mainly conducted on RO process. The amount of daily intake of fluoride depends on the geographical area. If the diet consists of fish, such as the case of Qeshm Island, the intake through food gets specifically high(1). However, considering the fact that the easiest and the best way to deliver fluoride to the body is through the drinking water, fluoridation of drinking water must be done, to prevent tooth decay, especially in children.

The results of this study showed that the pH of the outlet water in both processes is acidic and the acidification of water in MSF process is more than RO. This finding is consistent with the studies of Yari et al on desalination by RO process in Qom(8), Miranzadeh and Rabbani on desalination by RO process in Kashan(4) and Qannad and Farhadpour on desalination by the process of reverse osmosis in the cities and villages of Iran(9) and Al-Odwani et al. in Kuwait on the desalination by MSF process(11). Considering the fact that the optimal range of pH in the water at the fifth edition of national standards has decreased from 7to6.5(6), the pH of the outlet water of both processes is in the desirable range.

Total hardness of between 100 and200 mg/l is favorable for drinking water. Total hardness in both processes was lower than the desirable amount in this study; this result is also in accordance with the results of Yari et al. in Qom(8) and Khodadadi et al. in Birjand(5). In a study on RO desalination in cities and villages of Iran in 2006 proved the total hardness is not ideal(9), although the study of Miranzadeh and Rabbani in Kashan specifies that the mean of total hardness of the outlet water from RO desalination plants is 118mg/l and is favorable; and their result is inconsistent with the results of this study(4).

Since calcium and magnesium reduce the risk of cardiovascular disease and on the other hand, to prevent corrosion in water pipes to necessary hardness greater than100mg/l, so
by adding calcium and magnesium compounds these problems are overcome(1 and4).

Chloride of the inlet water to both desalination plants had a similar concentration but the chloride of the outflet water by MSF process is favorable and the chloride of the RO process is unfavorable. The bad taste in drinking water caused by chloride, should be controlled by the type of membranes used in RO process and continuous monitoring of chloridein the outlet water.

One of the most important parameters of water quality that should be studied and controlled more carefully, is the water contamination by pathogenic microorganisms. This issue is considered by cultivation and identification o coliforms. In the outlet water from both process, no cases of microbial contamination was found and the results of this study match the results of Khodadadi et al. on the desalination plants of Birjandin 2009 (5) but were not in compatible with the outcomes of the study of Yari et al. in Qom(8). In the study of Yari et al. 6% of water samples indicated bacterial contamination. it might be resulted from not replacing the membrane and Biofilm formation, and secondary contamination during storage or maintenance and culture in the incubator. The interesting point is that the inlet water to the two processes of Ro and MSF was not similar from a microbial point of view. Sea water as the inlet water to MSF is microbial and contaminated with bacteria E. coli. But water of the well as inlet toRO process is free from microbial contamination; it indicates that the use of groundwater plays the role of the sand filter.

Conclusion: Due to the geographical location of Qeshm Island and residents' need to supply drinking water through desalination and the comparisons of qualitative parameters of chemical, physical and microbial processes of MSF and RO in Qeshm with national and international standards, it was found that both processes has a tremendous potential to provide clean drinking water. As shown in Figure1, most of the quality parameters in the outlet water of both processes, have reduced about 99%, although the reduction should be compensated in some parameters such as total hardness and fluoride.

The only parameter n Figure1, which has a low removal efficiency is the Turbidity of water; the turbidity of the inlet water in MSF (sea water) was 0.4 NTU and turbidity of the inlet water in RO (well's water) only 0.17 NTU, both processes were successful in reducing the amounts of turbidity to 0.1NTU which is highly desirable.

Due to the good quality of both processes in the production of drinking water, the next studies should be conducted on parameters such as physical space and human resources required for each process, the cost of each cubic meter of drinking water in each process based on the energy and chemicals required by the process, as well as the adverse effects the processes on the environment.

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Table 1: The mean concentration of chemical and physical parameters of inlet- outlet water to desalination plants of Qeshm using RO process and MSF

Parameters	MSF Process				RO Process				standard
	Inlet water	Outlet water	Compare between inlet and outlet water	Compare between outlet water and standard	Inlet water	Outlet water	Compare between inlet and outlet water	Compare between outlet water and standard	
TDS(mg/l)	45249/45	83/05	P<0.001	P<0.001	44746/3	702/1	P<0.001	P<0.001	1000
Total Hardness(mg/l)	4975/79	3/31	P<0.001	P<0.001	4472/7	17/95	P<0.001	P<0.001	200
EC (µS)	73472	29/17	P<0.001	P<0.001	74144	1441/8	P<0.001	P<0.001	2500*
Torbidity(NTU)	0/41	0/12	P<0.001	P<0.001	0/17	0/105	P<0.001	P<0.001	≤1
Sulfate(mg/l)	2491/4	0	P<0.001	P<0.001	3323/6	40/39	P<0.001	P<0.001	250
Nitrate(mg/l)	3/67	0/12	P<0.001	P<0.001	3/62	0/28	P<0.001	P<0.001	50
Nitrite(mg/l)	0/065	0/0004	P<0.001	P<0.001	0/06	0/012	P<0.001	P<0.001	3
Fluoride(mg/l)	10/97	0/075	P<0.001	P<0.001	10/89	0/072	P<0.001	P<0.001	0/5-1/5
Chloride(mg/l)	20109/5	7/78	P<0.001	P<0.001	20966/3	566/79	P<0.001	P<0.001	250
pH	8/31	6/51	P<0.001	P<0.001	7/77	6/63	P<0.001	P<0.001	6/5-8/5
Temperature(Celsius)	23/12	32	P<0.001	-	28	29/6	P<0.001	-	No standard

*Given that the standard 1053 is not specified allowed and desirable amount of Electrical conductivity, the standards of Union of Europe have been considered(18).

Table 2: the amount of fecal coliform contamination (E .Coli) in the inlet and outlet water using both MSF and RO processes and the percentage of removal efficiency in Desalination Plants of Qeshm

Parameter	MSF Process					RO Process					standard
	Inlet water	Outlet water	Efficiency	Test Results		Inlet water	Outlet water	Efficiency	Test Results		
				Inlet and outlet	Outlet and standard				Inlet and outlet	Outlet and standard	
Fecal Coliforms contamination	100%*	0	100%	P<0.001	P<0.001	0	0	-	P<0.001	P<0.001	lower than 2**

*inlet water to MSF process, 100% of samples were contaminated with E .coli.

**In the last edition of standard 1053(Fifth Edition) no standard is provided as the desirable amount of coliform contamination (6), so the standard 1053 -fourth edition-approved in 1997 was considered valid.

Figure1: removal efficiency percentage of chemical and physical parameters of inlet and outlet water of distillation plants using the processes of RO and MSF