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# Evaluation of the efficiency of the reverse osmosis process on nitrate removing from Tehran drinking water

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**Abstract**. Currently, there are many places in the world, including Iran, that are faced with the problem of high nitrate levels in their drinking water. Historically, the presence of high levels of nitrate in drinking water has led to methemoglobinemia in infants. International standard limits on nitrate levels have been enforced as a result of this. The potential relationship between high levels of nitrate and a variety of cancers as well as the risk of nitrosamines serve as the reasons for the focusing of this paper on the reduction of nitrate from drinking water of Tehran. The proposed method for the reduction of nitrate is Reverse Osmosis (RO), which is considered one of the most useful techniques to remove nitrate from municipal water supplies. This study was carried out using samples taken from the inlet and outlet water RO pilot during a month-long period in the fall of 2013. A total number of 180 samples were analyzed for water nitrate levels and pH. The average concentration of nitrate in inlet water was 3.60 mg $L^{-1}$ and 0.77 mg $L^{-1}$ in treated water. Also, the average pH range in both the inlet and outlet water was 7.08 and 6.79 respectively. The overall results of this study indicated that RO has the potential to remove up to 78.4% of the nitrate present. Although the pH of outlet water relative to inlet water had decreased, it was nevertheless compatible with international drinking water standards.
**Key Words**: drinking water, household water treatment devices, nitrate, reverse osmosis, water purification.

**Introduction**. Recent research indicates that over a billion people globally lack access to purified drinking water (Shatat et al 2013). Water can be contaminated by physical, chemical, biological, or radiological substances or matter. Extensive research has focused on the removal of nitrate from water supplies due to its adverse health effects i.e. methemoglobinemia and possible formation of nitrosamines (Mirvish 1975; Panno et al 2008). Today, nitrate is a major water pollutant in many areas in the world (Jalali 2011). Nitrate pollution is caused by the intensive use of nitrogen fertilizers, crop irrigation with domestic wastewater, and the use of manure. Thus, nitrate usage is a concern of diffuse pollution (Della Rocca et al 2007). The maximum contamination level of nitrate permitted in the drinking water is 10 parts per million (ppm) by the United States Environmental Protection Agency (US EPA) (US EPA 2014). They believe this level of protection would not cause any of the potential health problems described above (US EPA 1993). If contaminant levels are found to be consistently above the maximum contaminant level, the water supplier must take steps to reduce the amount of nitrates so that they are consistently below that level. For the removal of nitrate, many different approaches and methods exist. These include approaches such as ion exchange, nanofiltration, electrodialysis, and reverse osmosis (Hell et al 1998; Choi et al 2009). Each of these technologies, however, has its own advantages and disadvantages. Reverse osmosis (RO) technology, however, has been selected for this study because the technology is well known in Iran as a treatment used for tap waters in homes and because it is a physical treatment that has been proven to be both effective and safe (Bodalo et al 2005). RO is a pressure-driven membrane application that is most commonly used in water treatment and desalination (Guo et al 2012). RO is a membrane technology that can be applied to the treatment of various water resources for the production of drinking water. RO systems use a process that reverses the flow of water in a natural process of osmosis so that water passes from a more concentrated solution to a more dilute solution through a semi-permeable membrane. Pre and post filters are often incorporated along with the reverse osmosis membrane itself. The main goal of the study is evaluation of RO efficiency on nitrate removing from Tehran drinking water.

**Material and Method**. The RO pilot plant (DOW Filmtec TW30-1812-50 TFM50 membrane) is shown in Figure 1. Tap water enters the reverse osmosis chamber. The feed water is then filtered through 3 filters prior to RO treatment to protect the membrane from clogging. Afterwards, a high pressure pump delivers the water for the RO module. After the RO portion is completed, the water will pass through a carbon filter. Finally, the filtered water exits the process. For the best possible outcome, the reverse osmosis pilot was active and running for 72 hours prior to the initiation of the analysis.

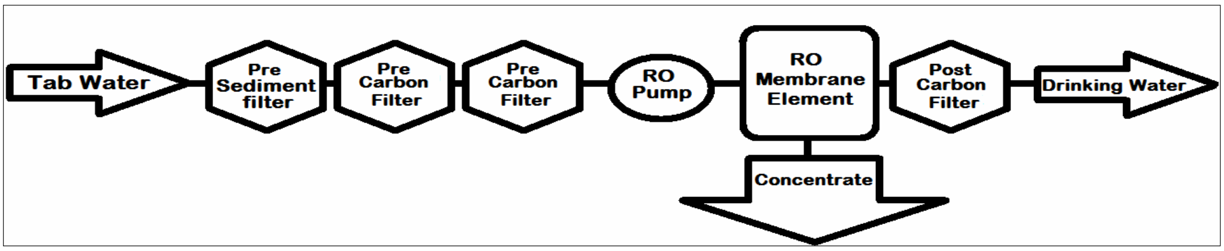


Figure 1. Flow diagram of the RO plant.

For the purpose of gaining standard samples from the tap water and domestic reverse osmosis pilot from the third municipal district of Tehran, after 3 to 5 minutes of water flow, these samples have been collected in 2-liter clean polyethylene containers. These samples have been held in the 3 to 4 degree environments and transferred to the laboratory. During a period of 30 consecutive days (December, 2013), these samples were tested on 3 occasions. The total number of samples was 180. They were analyzed for water nitrate levels and pH.

Firstly, the pH levels were measured. This was followed by the measuring of the nitrate content through the usage of a spectrophotometer. The data that was acquired through the experiments was obtained with the usage of the paired samples t-test in SPSS Statistics. The use of this program signified there is a statistically significant difference between nitrate level of samples before and after RO system.

**Results and Discussion**. The average pH level of water that entered and exited the reverse osmosis process was compared to the acceptable pH levels of drinking water (Table 1).

Table 1

The average pH range in both the inlet and outlet water compared to global standards

| *Index* | *Inlet water to pilot* | *Outlet water from pilot* | *Standard level* |
|---|---|---|---|
| pH | 7.08 | 6.79 | 6.5-6.8 |

The numbers of samples taken in a 30 day period were 180. This is equal to 3 samples a day from inlet and 3 samples from outlets of RO systems during this period. The average levels of nitrate were measured both before and after the RO process was applied. The data attained is displayed in Figure 2. Additionally, the efficiency of the nitrate removal is shown in Figure 3. Comparison of nitrate levels in inlet and outlets of reverse osmosis systems obtained through usage of paired sampled t-tests is shown in Table 2. The minimum, maximum, and median of nitrate level obtained through the sample collections were compared to the national and globally accepted levels. This is displayed in Table 3.

Table 2

Differences of nitrate between the inlet and outlet water compared

| | | *Paired differences* | | | | | *T* | *df* | *Sig.* |
|---|---|---|---|---|---|---|---|---|---|
| | | *Mean* | *Std. Deviation* | *Std. Error Mean* | *95% confidence interval of the difference* | | | | |
| | | | | | *Lower* | *Upper* | | | |
| Pair 1 | VAR00001 - VAR00002 | 2.83367 | 0.40287 | 0.07355 | 2.68323 | 2.9841 | 38.525 | 29 | 0.000 |

Table 3

The comparison of nitrate between inlet/outlet water and acceptable nitrate level (mg $L^{-1}$)

| *Nitrate* | *Inlet water* | *Outlet water* | *National standard* | *Global standard* |
|---|---|---|---|---|
| Mean | 3.61 | 0.77 | 45 | 50 |
| Maximum | 3.77 | 0.83 | 45 | 50 |
| Minimum | 3.43 | 0.70 | 45 | 50 |

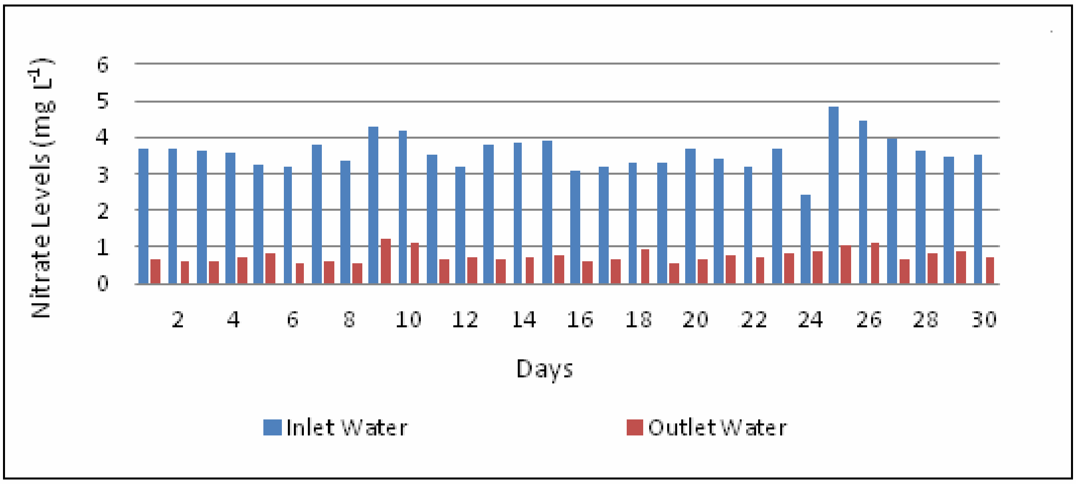


Figure 2. Daily level of nitrate in drinking water and the treated water.

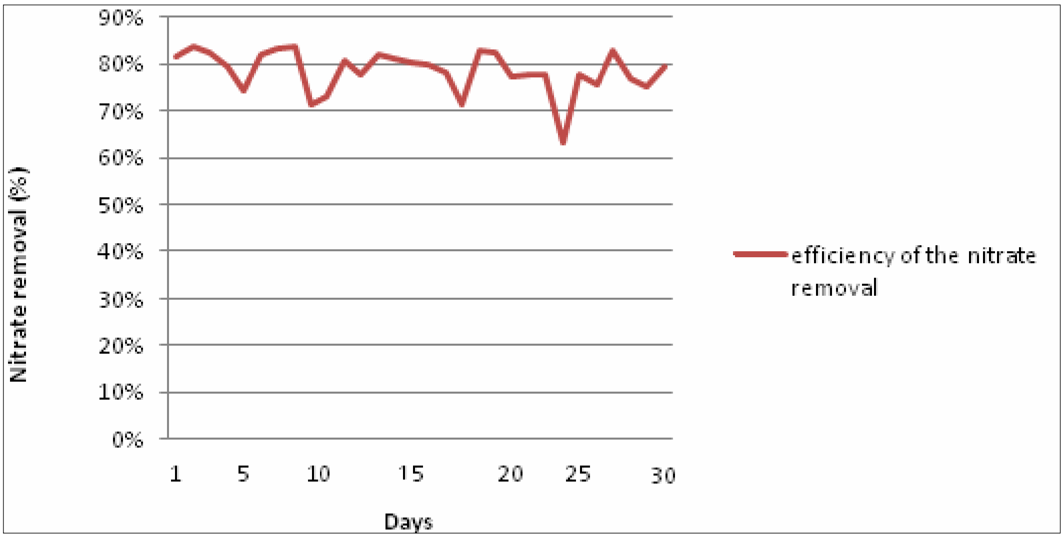


Figure 3. Efficiency of the nitrate removal after RO process in a 30 days period in Tehran.

**Conclusions**. The conclusions derived from this study in relation to pH show that the amount of pH in inlet water before treatment was between 7.0 and 7.4. This amount decreases to around 6.7 and 6.9 after treatment. This shows us that the process of reverse osmosis results in the decrease of pH and increase in acidity of the water.

In relation to nitrate levels, its average concentration in inlet water was 3.61 mg $L^{-1}$. This decreased to 0.77 mg $L^{-1}$ in the outlet water. Based on this, the average efficiency of the used domestic reverse osmosis process was 78%. The maximum nitrate content in inlet water was 6.14 mg $L^{-1}$. This is much less than the national and global standards for nitrate concentration in drinking water.

We can conclude that the amount of nitrate in Tehran's tap water is of acceptable amounts. Thus, the residents in areas using this water are not at risk for the negative aspects associated with high levels of nitrate.

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