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Fluoride Removal Efficiency of Commercially Available Reverse Osmosis Water Purifying Systems in Removing Fluoride Ions from Drinking Water in India

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Abstract : In recent years there has been extensive use of RO systems for water purification. Aim: To study the effectiveness of 3 commercially available RO systems in removing fluoride from water. Methodology: An observational study was undertaken, fluoridated water samples were prepared. After purification pH, TDS and fluoride concentration were analyzed. The same procedure was repeated after 1 week. Results: All RO systems showed no statistically significant difference in mean pH values. Kent RO system reduced TDS level at all water fluoride concentrations. Conclusion: All the RO systems were able to bring back the fluoride levels to the optimal range.

Keywords: Reverse osmosis, Defluoridation, water purifiers, pH, TDS, Fluorine.

Introduction

Endemic fluorosis is a public health problem in India. The WHO recommended optimal level of fluoride in drinking water is in the range of 0.5mg-1.0mg/liter[1]. Prolonged ingestion of fluoride through drinking water in excess of the daily requirement is associated with dental and skeletal Fluorosis. Dental fluorosis results when excessive amounts of fluoride are ingested during the years of tooth formation. Dental fluorosis is characterized by lusterless, opaque white patches in the enamel, which may become stained yellow to dark brown and in severe forms cause marked pitting and brittleness of teeth. The early symptoms of skeletal fluorosis include sporadic pain, back stiffness, burning sensation, pricking and tingling in the limbs, muscle weakness, chronic fatigue, abnormal calcium deposits in bones and ligaments. The advanced stage is osteoporosis in long bones and bony outgrowths may occur. Vertebrae may fuse together and eventually the victim may be crippled. It may even lead to a rare bone cancer; osteosarcoma and finally spine, major joints, muscles and nervous system get damaged[2-4].

Though changing the water source is the best method of having potable water for domestic purpose in endemic fluorosis regions. Defluoridation is the method of choice where other source of water is not available. The process of defluoridation can be accomplished with help of various techniques such as precipitation, adsorption, ion- exchange, electro dialysis, reverse osmosis etc. Many of these defluoridation techniques have limitations of being culturally unacceptable, expensive and difficulty in maintenance, so there has been constant search of new technique which can be adapted for household purpose and which can overcome the above mentioned limitations[5-7].

In recent years there has been an extensive use of reverse osmosis systems in household water purification. Many companies have come up with reverse osmosis water purifying systems claiming to reduce TDS, fluoride ion concentration and control pH of water. Thus increasing claims and usage of reverse osmosis water purifiers has made us study the effectiveness of reverse osmosis water purification system in removing fluoride ions. So, this study was planned to evaluate the effectiveness of commercially available reverse osmosis water purifying systems in removing fluoride ions from water.

I. Material and Methodology

Study design: An observational study was undertaken for assessing the effectiveness of 3 commercially available reverse osmosis water purifying systems in removing fluoride ions from water. The study was conducted in the respective sales outlets of reverse osmosis water purifying systems. The ethical clearance for the study was obtained from the Institutional review board. Based on the market share of water purifying units 3 different reverse osmosis water purifiers were selected for the study.

Study procedure: Three different concentrations of fluoridated water samples were prepared each containing 20 liters of water by dissolving sodium fluoride to obtain fluoridated water sample of 1.93ppm, 3.93ppm and 6.03ppm respectively. The prepared water samples were subjected to water analysis for assessing pH, TDS and fluoride ion concentration. After analysis the water samples were taken to respective outlet stores of the three reverse osmosis water purifying systems. Prior to the process of filtration the instrument was standardized and the water samples were subjected to purification in the three models of reverse osmosis water purifiers. Then 200ml of purified water sample was collected from each reverse osmosis system in plastic water bottles, which were washed with the sample water before collection of the sample and is taken to the water works department of Nellore district for water analysis to assess pH, TDS and concentration of fluoride ions in purified water. Again the same procedure was repeated after 1 week interval. The pH of the water was measured using digital pH meter. Calibration of the pH meter was carried out prior to the study using standard solutions. The pH was read after allowing the reading to stabilize for 30 seconds. Total dissolved solid concentration was estimated by electrical

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conductivity method. The relationship of TDS and specific conductance of ground water can be approximated by the following equation: TDS=KeEC. The fluoride ion concentration was assessed by adding alizarin red reagent to water sample and then analyzing by SPADNS method using a spectrophotometer. This method relies on the fact that when fluoride reacts with certain zirconium dyes, a colorless complex anion and a dye are formed. The resulting colored complex is measured in a spectrophotometer at 570nm.
Statistical analysis: The collected data was analyzed using SPSS version 20 statistical package. Mean and standard deviations were calculated. ANOVA was used for comparison of results among the three groups.

II. Result s and Tables

The pH of water at baseline for all the three water fluoride concentration levels was below the acceptable range (pH 6.5-8.5). Aqua guard reverse osmosis water purifier was able to increase the pH to the acceptable ranges in all the three water fluoride concentrations. Whereas Kent reverse osmosis water purifier was not able to increase the pH to the acceptable levels at all the three water fluoride concentrations and Pure-It reverse osmosis water purifier was able to increase the pH to the acceptable range at low fluoride concentration, but was not able to increase the pH to acceptable level at high water fluoride concentrations from baseline after purification, but these differences were not statistically significant. The TDS level of water at baseline for 1.93ppm and 3.93ppm fluoride concentration levels was in the range of excellent (<300mg/lit). Water sample with 6.03ppm fluoride concentration had slightly higher TDS level (325.00). All the three RO systems, Aqua guard, Kent and Pure-It water purifiers significantly reduced the TDS level in all the three water fluoride concentration levels . Among the three RO systems Kent reverse osmosis water purifier showed highest drop in TDS level at all the three water fluoride concentration levels compared to Aqua guard and Pure-It reverse osmosis water purifiers (60.00 at 1.93ppm,
70.00 at 3.93ppm, 85.00 at 6.03ppm) after purification. The Fluoride level of water at baseline for all the water fluoride concentration levels was above the acceptable range. After purification Aqua guard, Kent and Pure-It reverse osmosis water purifiers were able to significantly decrease the Fluoride ion concentration to the optimal level (0.7 -1.2 ppm) in all the three water fluoride concentrations (Table 1).
Aqua guard reverse osmosis water purifier was able to increase the pH levels to the acceptable range (pH 6.5- 8.5) at all the three water fluoride concentrations, whereas Kent and Pure-It reverse osmosis water purifiers were not able to increase the pH to the acceptable levels at all the three water fluoride concentrations, but this difference was not statistically significant. Kent reverse osmosis water purifier showed highest decrease in TDS level at all the three water fluoride concentration levels compared to Aqua guard and Pure-It reverse osmosis water purifiers and this difference was statistically significant. All the three RO water purifying systems showed statistically significant decrease in Fluoride ion concentration and maintained the fluoride concentration at the optimal level (0.7 -1.2 ppm) for all the three water fluoride concentrations (Table 2).

III. Discussion

The WHO recommended optimal level of fluoride in drinking water is in the range of 0.7mg - 1.2mg/liter[1]. Prolonged ingestion of fluoride through drinking water in surplus of the daily requirement during tooth formation is allied with dental fluorosis. Though changing the water source is the best method of having potable water for domestic purpose in regions with high water fluoride concentrations. Defluoridation is the method of choice where other source of water is not available.
The majority of the household consumers seek to get better taste and quality of drinking water by using a moderately simple filter to remove unwanted impurities such as inorganic salts, heavy metals, and suspended and colloidal matter. Many companies have come up with reverse osmosis water purifying systems claiming to reduce the TDS level, fluoride ion concentration and control pH of water. Thus increasing claims in adjusting pH, TDS and fluoride ion concentration by RO water purifier companies, wide spread usage of RO systems in day to day life for domestic purposes and disadvantages of large scale water purifiers along with the other techniques of defluoridation has made us study the effectiveness of reverse osmosis water purification systems in removing fluoride ions.
The optimal range of pH for drinking water is between 6.5-8.5. If the pH is above the optimal range it does not pose health risk, but can cause alkali taste to the water[8]. If the pH of the water is below the optimal range, it causes demineralization of the enamel surface[9]. In present study there was no statistically significant increase in the mean pH values after purifying the water from all the RO water purifiers at all the water fluoride levels. A study done by Larsen MJ has shown that the mineral water erodes enamel to a limited extent as the pH of the mineral water was 5.60[10]. A study done by Adhani R et al., stated that decrease of one unit of pH, will increase calcium release rate by 19.5 times.
This means that decrease in the pH value increases the acidic media and calcium is released from the tooth enamel[11].
According to a committee report by Water quality association the consumption of low TDS water, naturally occurring or received from a treatment process, does not result in harmful effects to the human body. A study done in Australia by Meyers D says that mortality from all categories of ischemic heart disease and acute myocardial infarction was increased in a community with high levels of soluble solids such as calcium, magnesium, sulfate, chloride, fluoride[12]. TDS level below 300mg/lit is considered to be excellent[13]. All the three RO systems, Aqua guard, Kent and Pure-It water purifiers significantly reduced the TDS level in all the three water fluoride concentration levels. Among the three RO systems Kent reverse osmosis water purifier showed highest drop in TDS level at all the three water fluoride concentration levels compared to Aqua guard and Pure-It reverse osmosis water

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purifiers.

The optimal level for fluoride in water is between 0.7ppm -1.2 ppm. The consumption of fluoride above the optimal range causes dental fluorosis and skeletal fluorosis. Dental fluorosis results when excessive amounts of fluoride are ingested during the tooth formation. Dental fluorosis is characterized by lusterless, opaque white patches in the enamel, which may become stained yellow to dark brown and in severe cases cause marked pitting and brittleness of teeth. In skeletal fluorosis symptoms include sporadic pain, back stiffness, pricking and tingling in the limbs, muscle weakness, chronic fatigue, abnormal calcium deposits in bones and ligaments[2-4, 14]. Aqua guard, Kent and Pure-It reverse osmosis water purifiers showed statistically significant decrease in water fluoride concentrations and maintained the fluoride concentration of water at the optimal level (0.7 -1.2 ppm) for all the three water fluoride concentrations.

RO membrane process is the reverse of natural osmosis as a consequence of applied hydraulic pressure from the high concentration side of the solution, it forces solvent filter through the membrane, against a pressure gradient into the lower-concentration solution leaving the salts behind. RO membrane rejects ions based on the size and electrical charge[5, 7, 13].

Fluoride removal efficiency is up to 98% by membrane processes have been documented by many researchers. No chemicals are required and very little maintenance is needed. The process works in a simple, reliable automated operating regime with minimal manpower using compact modular model.

Our study confirmed the findings of a study done by prabhakar et al., on the effect of water purification systems on fluoride content of drinking water, which proved that reverse osmosis water purifiers were effective in reducing the fluoride content of water for household purposes compared to other techniques used in the study such as distillation, activated carbon system and candle filters[15]. The results of our study were similar to a study conducted by Brown MD et al., showing a statistically significant reduction in fluoride content using reverse osmosis water purifying system[16].

As the general population is becoming increasingly concerned about the quality of drinking water, domestic water purification systems are becoming very popular and the reverse osmosis water purifiers works in a simple, reliable automated operating regime with minimal manpower, no chemicals, very little maintenance and can effectively maintain pH, TDS and Fluoride concentration in water. These can be recommended to use in water defluoridation for domestic purposes.

V. Conclusion

The Reverse osmosis water purifying systems tested were able to bring back the fluoride ion concentration to the optimal range from the higher level.

VI. Recommendations

It is suggested that a further study can be planned to evaluate fluoride removal effect of water purifiers in areas where drinking water includes high concentration of fluoride.

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Table 1:- Intra-group comparison of mean pH, mean TDS and mean Fluoride levels before and after purification of water with different fluoride concentrations using three commercially available reverse osmosis water purifiers

Water purifier		**Aqua guard**		**Kent**		**Pure-it**	
Fluoride level	Parameters	Mean ± SD	P- value	Mean ± SD	P- value	Mean ± SD	P- value
2ppm	**pH**	6.06±0.81	0.10(NS)	6.06±0.81	0.94(NS)	6.06±0.81	0.59(NS)
		7.13±0.87		6.12±0.80		6.81±2.62	
	TDS	115.00±12.91	0.001*	115.00±12.91	0.003*	115.00±12.91	0.03*
		75.00±7.07		60.00±10.80		80.00±7.07	
	Fluoride	1.93±0.01	<0.001*	1.93±0.01	<0.001*	1.93±0.01	<0.001*
		0.68±0.01		0.68±0.01		0.76±0.02	
4ppm	**pH**	6.01±0.81	0.29(NS)	6.01±0.81	0.91(NS)	6.01±0.81	0.65(NS)
		7.32±1.75		6.06±0.81		6.81±2.62	
	TDS	235.00±69.76	0.07(NS)	235.00±69.76	0.02*	235.00±69.76	0.25(NS)
		120.00±8.17		70.00±9.13		155.00±10.80	
	Fluoride	3.93±0.01	<0.001*	3.93±0.01	<0.001*	3.93±0.01	<0.001*
		0.79±0.05		0.73±0.03		0.88±0.03	
6ppm	**pH**	5.96±1.97	0.38(NS)	5.96±1.97	0.79(NS)	5.96±1.97	0.99(NS)
		7.35±1.72		6.27±1.26		5.97±1.00	
	TDS	325.00±12.25	<0.001*	325.00±12.25	<0.001*	325.00±12.25	<0.001*
		125.00±9.13		85.00±6.46		165.00±4.08	
	Fluoride	6.03±0.01	<0.001*	6.03±0.01	<0.001*	6.03±0.01	<0.001*
		0.96±0.04		0.88±0.03		0.98±0.01	

Paired t test *p<0.05 statistically significant p>0.05 Non significant, NS

Table 2:- Inter-group comparison of three commercially available reverse osmosis water purifiers at different water fluoride concentrations

Parameters	Group	1.93ppm		3.93ppm		6.03ppm	
		Mean ± SD	P-value	Mean ± SD	P-value	Mean ±SD	P-value
pH-after	Aqua guard	7.13±0.87	0.69(NS)	7.32±1.75	0.65(NS)	7.35±1.72	0.41(NS)
	Kent	6.12±0.80		6.06±0.81		6.27±1.26	
	Pure-it	6.81±2.62		6.81±2.62		5.97±1.00	
TDS-after	Aqua guard	75.00±7.07	0.02*	120.00±8.17	<0.001*	125.00±9.13	<0.001*
	Kent	60.00±10.80		70.00±9.13		85.00±6.46	
	Pure-it	80.00±7.07		155.00±10.80		165.00±4.08	
Fluoride-After	Aqua guard	0.68±0.01	0.04*	0.79±0.05	0.002*	0.96±0.04	0.003*
	Kent	0.68±0.01		0.73±0.03		0.88±0.03	
	Pure-it	0.76±0.02		0.83±0.01		0.98±0.01	

*p<0.05 statistically significant p>0.05 Non significant, NS