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ANALYSIS OF PERFORMANCE OF WATER PURIFICATION SYSTEM WITH RESPECT TOFLUORIDE CONTENT IN DRINKING WATER

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Abstract: Drinking water is a rare and precious resource and needs to be protected and kept free from any contamination. The availability of potable water is still a major problem in both rural and urban areas of developing countries. Fluoride in drinking water plays a key role in dental health. Therefore, it is necessary to study the fluoride content in drinking water. A reduced concentration of fluorides leads to an increased risk of tooth decay. Excess fluoride in drinking water above the maximum contaminant level (eg the World Health Organization (WHO) standard of 1.5 mg/l) also affects the skeletal and nervous systems of humans. In the last few decades, India has witnessed an increasing trend in the prevalence of dental caries. About 40%-45% of the population in India suffers from dental caries and the number is still increasing day by day. To overcome the dangerous impact of fluorosis on welfare, there are different approaches to defluoridation such as coagulation-precipitation, membrane separation processes, ion exchange, adsorption techniques and others (electro dialysis and electrochemical). The RO process is effective in filtering out contaminants such as fluoride, especially in areas where the water is heavily contaminated. The Indian commercial markets are equipped with a variety of RO filters that differ in the type of membrane used (cellulosic or thin film composite membrane) and stages of filtration (5 stages/6 stages/7 stages). These variations in RO filters can affect the quality of the filtrate. However, data regarding the effect of different types of RO filters on fluoride levels in drinking water for the Indian scenario is lacking.

Due to the increasing use of water purifiers, the influence of these devices on the concentration of fluorides in drinking water was evaluated. In this study, different RO water filters available in Amravati city, Maharashtra, India were tested. Drinking water samples were taken before and after passing through a home water purifier. All the samples taken for fluoride content analysis are using the SPADNS calorimetric method. The obtained values were subjected to statistical analysis using the Statistical Package for the Social Sciences software (SPSS, IBM Corporation, Armonk, NY, USA version 25). Mean fluoride concentration before and after filtration and mean difference in fluoride concentration were reported using descriptive statistics.

Additionally, Amravati city has suboptimal fluoride levels in its drinking water and subjecting the drinking water to additional RO filtration can reduce fluoride to unacceptable levels. Therefore, this study was designed to determine the extent to which home RO water filters remove fluoride from drinking water. This work is also carried out to contribute to the identification of changes in fluoride concentration before and after water treatment.

***Index Terms* – fluoride, dental caries, RO filters, SPADNS calorimetric method, SPSS software.**

INTRODUCTION

It is important to consider the well-being of people in towns, cities, and other areas. The assessment of the health risks associated with the drinking water's quality must be done correctly. Life on earth depends on water, which also provides minerals that are vital to human health. All humans on earth have a basic need for access to fresh, clean drinking water. It is well known that the fluoride ion in drinking water can have both positive and negative impacts on health. If a substitute source of drinking water is available, the Bureau of Indian Standard (BIS) proposed a maximum limit of 1.5 mg/L as a tolerable limit, which may be reduced to 1 mg/L. Water consumption is the body's main source of fluoride. In India, dental fluorosis and caries are serious public health issues. The prevalence of dental caries has been on the rise in India during the last few decades. In India, the prevalence of dental and skeletal fluorosis is endemic in 230 districts across 19 states, with an estimated 40%–45% of the population suffering from dental caries.

Fluoride salts are less hazardous than the elemental form. Because of implications for both health and pharmaceutical formulations, its determination is crucial. Water that contains a lot of fluoride ions is unsafe to consume. Although fluoride ions are an essential component of drinking water, exposure to levels above 1.5 mg/L may be hazardous to human health. By avoiding bacterial demineralization and encouraging remineralization of initial non-cavitated carious lesions, fluoride makes the tooth-enamel surface acid resistant. Additionally, it exhibits antibacterial properties; at low concentrations, it inhibits bacterial adherence to tooth structure, while at high concentrations, the fluoride ion is extremely harmful to several oral pathogens.

The RO system was chosen for the current study due to its rising popularity in India and a number of advantages over other water purification techniques, including a TDS controller, consistent water quality assurance, long membrane life, and little to no interference from other ions. People are choosing to install purifying devices at home, like as storage filters and reverse osmosis RO systems. Regardless of fluoride concentration, these purification systems treat it as an impurity and remove it from water. Water purifiers are often utilized in domestic settings. The unfavorable water odor and germs are eliminated by carbon powder bed filters, and these purifiers reduce water hardness via reverse osmosis of water across an organic membrane or by employing ion exchange resins. Despite these advantages, it is important to look into how these systems affect beneficial substances like fluoride in drinking water. We can therefore draw the conclusion that it is essential to determine the fluoride level of water.

I. FLUORIDE

As a beneficial ion for human health, fluoride can cause health issues if there is an inadequate or excessive intake. Water consumption accounts for 70–90% of fluoride intake in humans.Fluoride in water has three effects: it can prevent dental caries, increase the incidence of dental caries, and produce fluorosis when it is present at high levels. Therefore, determining the precise fluoride concentration in drinking water is crucial for developing an efficient fluoride regimen for stopping dental caries. India has a large number of fluoride-bearing rocks, which causes fluoride to leak out and damage nearby water and soil resources. Along with the natural geological sources that enrich groundwater with fluoride, numerous businesses also significantly contribute to fluoride pollution. Fluoride's toxicological and physiological behavior depends on its level of oxidation. Fluoride salts are less hazardous than the elemental form. Because of implications for both health and pharmacological formulations, its determination is crucial .

Fluoride can enter the environment through a variety of processes, including:

• Natural processes, such as volcanic emissions, weathering of minerals, and dissolution, especially into groundwater and marine aerosols;

• Human processes, such as the manufacture and use of phosphate fertilizers, the production of aluminium, steel, and oil, the production of hydrofluoric acid, and the burning of fluoride-rich coal, particularly indoors;

• Reactivation of old sources, like water flow and sediment movement from aluminium manufacturing facilities

II. EFFECTS OF FLUORIDE ON HUMAN HEALTH

Worldwide, it is estimated that 2.4 billion people suffer from caries of permanent teeth and 486 million children suffer from caries of primary teeth. Nearly 90 million people including 6 million children in the country in 280 districts in about 17 states i.e. Andhra Pradesh, Bihar, Delhi, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu and Uttar Pradesh are most affected dental, skeletal and/or non-skeletal fluorosis. The intake of fluorides has both beneficial effects on reducing the incidence of dental caries and negative effects on the formation of tooth enamel and skeletal fluorosis after long-term exposure to high concentrations.

Fluoride intake that is adequate has a positive impact on both children's and adults' oral health. Fluoride prevents caries in a variety of ways. On carcinogenic and other types of bacteria, fluoride exerts a bactericidal effect. The enamel becomes more resistant to later acid attacks and the consequent onset of caries when fluoride is taken during the time of tooth formation. Due to increased fluoride intake throughout the period of dental development, enamel fluorosis can only occur in children. In the more severe form, decreased enamel mineralization causes teeth to become discoloured and pitted. In skeletal fluorosis, fluoride builds up gradually over a number of years in the bone. Joint stiffness and discomfort are among the early signs. Osteosclerosis, the calcification of tendons and ligaments, and bone abnormalities are all linked to incapacitating skeletal fluorosis.

III. DEFLUORIDATION TECHNIQUE

Fluoride ions in drinking water are removed during defluoridation. Drinking water defluoridation is a viable alternative for improving water quality. There are a variety of procedures that can be used, each with benefits and drawbacks. Defluoridating techniques can be broadly divided into two groups: additive techniques and adsorptive techniques. Reverse osmosis is a membrane separation technique that was used in this study for defluoridation. Using an incredibly well-designed semi-permeable membrane, particles are isolated in a membrane separation process based on the assumptions of their molecular size and form. Reverse osmosis, nano-filtration, Donnan-dialysis, and electrodialysis are the membrane separation techniques that are most frequently employed to remove fluoride.

4.1 Reverse Osmosis Process

Using a semi-permeable membrane and the osmotic process, RO primarily separates solutes. When hydraulic pressure is applied to one side of a semi-permeable membrane in reverse osmosis, the water is forced through the membrane, leaving the salts behind. The water treatment process is now economically competitive and incredibly reliable because to advancements in the design and composition of the membranes. Therefore, with better management, this new technique for producing drinking water might be the best choice. Despite the advantages, it is important to look into how these systems affect beneficial substances like fluoride in drinking water.

There are primarily three different kinds of water purifiers. Reverse osmosis, ultra-violet, and ultra-filter water purifiers are what they are called. Common names for them include RO, UV, and UF, respectively.

1. Reverse osmosis water purifier RO is the most effective method for removing dissolved particles from water.
2. Water purifiers with ultraviolet (UV) rays

UV water sterilizers are made specifically to remove dangerous germs and viruses from water sources. You can drink the water with confidence knowing that it has been adequately disinfected thanks to a UV sterilizer.

3. Water filters based on membranes such tiny filters, with pores that are 0.01 micron in size, are Ultra Filtration UF membranes. The smallest virus and the tiniest germs are larger than 0.02 micron and are stopped by membranes with pores smaller than 0.01 micron.

Water purifiers cleanse water to make it pure and palatable using one or a combination of technologies. The type of filtration you choose should be based on the quality of the source water. Therefore, it's important to determine the degree and kind of water contamination in your location as well as its total dissolved solids (TDS) level. Knowing this will enable you to choose an appropriate brand based on the appropriate filtration procedure and price.

IV. METHOD TO DETERMINE THE FLUORIDE CONTENT IN DRINKING WATER BY USING SPANDS METHOD

The current project involves following steps for effective determination of the fluoride content in drinking water and to ensure whether the water is safe for drinking or not.

5.1 Water Sample Collection, Storage, and Transportation

The study used water samples collected from several homes with various RO systems that were supplied by a single municipal water supply and bore well. Only those RO filters that had been maintained in the previous three months were chosen in order to standardize the filtration capacity of all filters. Both water samples taken from residences before and after RO filtration were compared. The samples were taken in polyethylene plastic bottles that had been thrice cleaned with deionized water to get rid of any remaining fluoride.

5.2 Analysis of Fluoride Content

The spectrophotometric approach was used to calculate the concentration of fluoride ions. In this method, a red complex is created by zirconium oxychloride and an alizarin red dye derivative. With this combination, fluoride ion creates a colorless chemical. Using a visible light spectrophotometer, changes in the color of the solution relative to a reference fluoride ion solution are monitored. In a 1,000 ml volumetric flask, 0.75 g of alizarin red indicator was dissolved in distilled water. Additionally, 0.345 g of zirconyl chloride was dissolved in distilled water before being mixed with 33.3 ml of concentrated sulfuric acid and 101 ml of concentrated hydrochloric acid, respectively. By adding distilled water, the final volume of the solution was increased to 1,000 ml. 5 ml of prepared alizarin alizarin red and zirconyl chloride in acid solutions were added to 100 ml of each water sample. When chemical reaction was completed and the water samples were colored, the light absorbance of solutions was read at 520 nm with a spectrophotometer (Jasco, V-570). Fluoride concentration was determined by the light absorbance of each solution, compared to the standard fluoride solution (NH4 F.HF in distilled water)

5.3 Statistic Evaluation

The Statistical Package for the Social Sciences (SPSS, IBM Corporation, Armonk, NY, USA) version 25 software was used to conduct statistical analysis on the acquired results. Using descriptive statistics, the mean fluoride concentration before and after filtration as well as the mean difference in fluoride concentration were reported.

V. METHOD TO DETERMINE THE FLUORIDE CONTENT IN DRINKING WATER BY USING AQUA-XL WATER KIT

Salient features o AQUA-XL water kit:

- Analysis based on standard method
- Saves time
- Reliable and accurate
- Cost effective
- Portable and user friendly

6.1 Direction for Use

1. Take 10 ml of sample to be tested in the test jar.
2. Add reagent FL-1 and mix well. The solution will turn yellow
3. Now add FL-2 drop wise while mixing the solution, till the yellow colour disappears.
4. Further, add 5 drops more of FL-2, mix well.
5. Add 2 flat micro spoons full of FL-3, mix well.
6. Now drop wise add FL-4, counting the number of drops while mixing till pink colour appears.
7. Note down the ppm level of fluoride, from the chart given as below.

No of drops of FL-4	1	2	3	4	5	6	7	8	9	10
Fluoride as F mg/L	0.05	0.1	0.3	0.5	0.75	1	1.25	1.5	2.0	2.5

Table 6.1 Chart to determine fluoride content by AQUA – XL kit

VI. RESULTS AND DISCUSSION

For the study, the water samples are collected from various water purifiers fitted on surface water and bore well water. Each sample was tested for 3 times to calculate the mean and standard deviation for getting the appropriate results. The mean and standard deviation is calculated in IBM SPSS Software. The steps for that are given as follows:

1] Enter data of respective readings in sheet. You can directly import the data from the excel sheet to SPSS. In variable view, select the type of data you want to enter in sheet then enter the readings

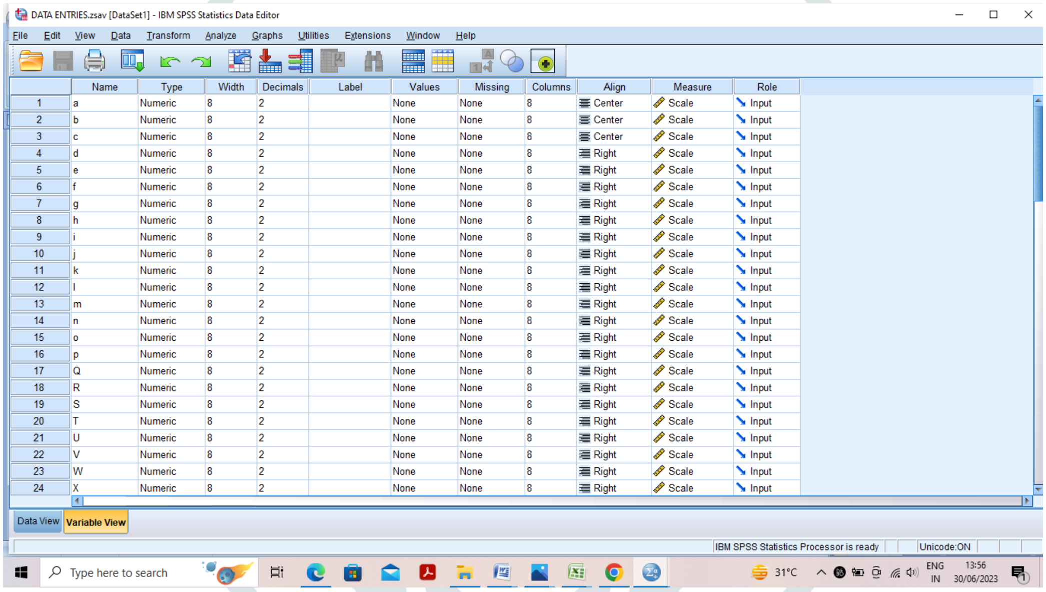

Fig 7.1 Variable view of SPSS sheet

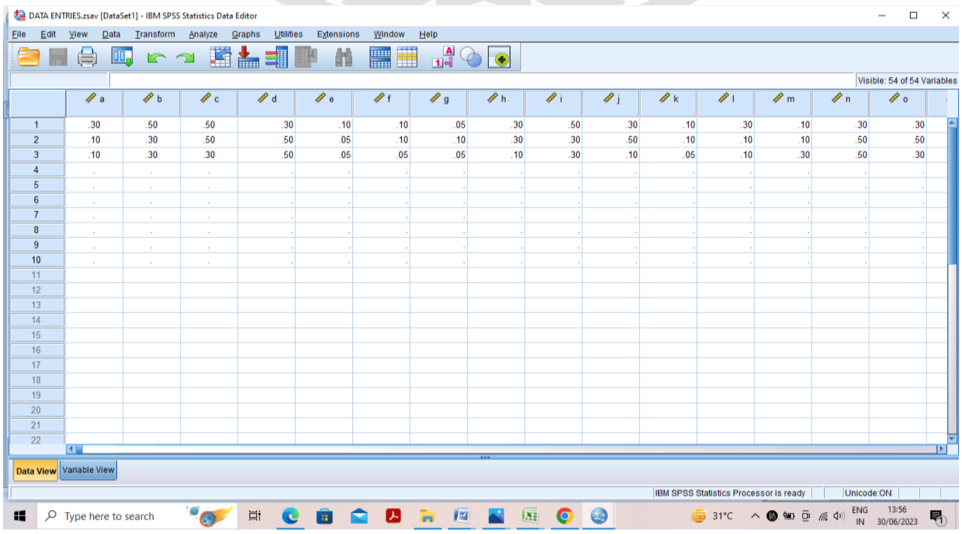

Fig 7.2 Data view of SPSS sheet

2] Select the option ‘analyze’ from the tool bar and then select descriptive analysis to calculate the mean.

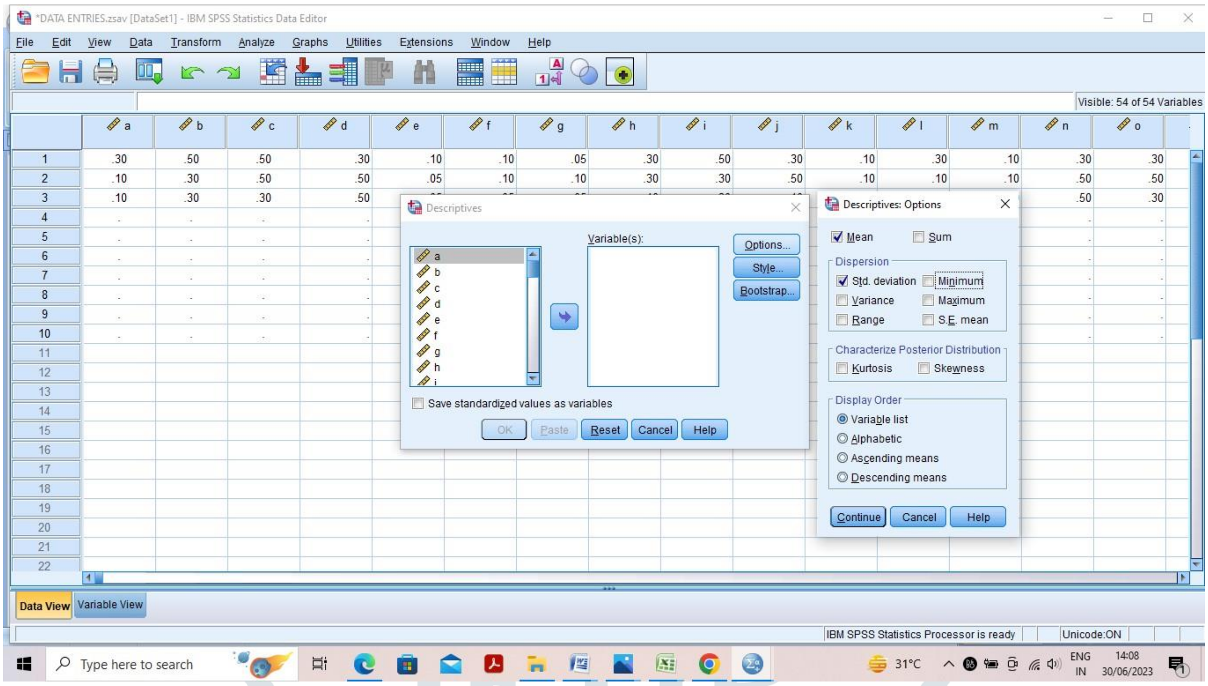

Fig 7.3 Descriptive analysis in SPSS

3] Calculate the required output.

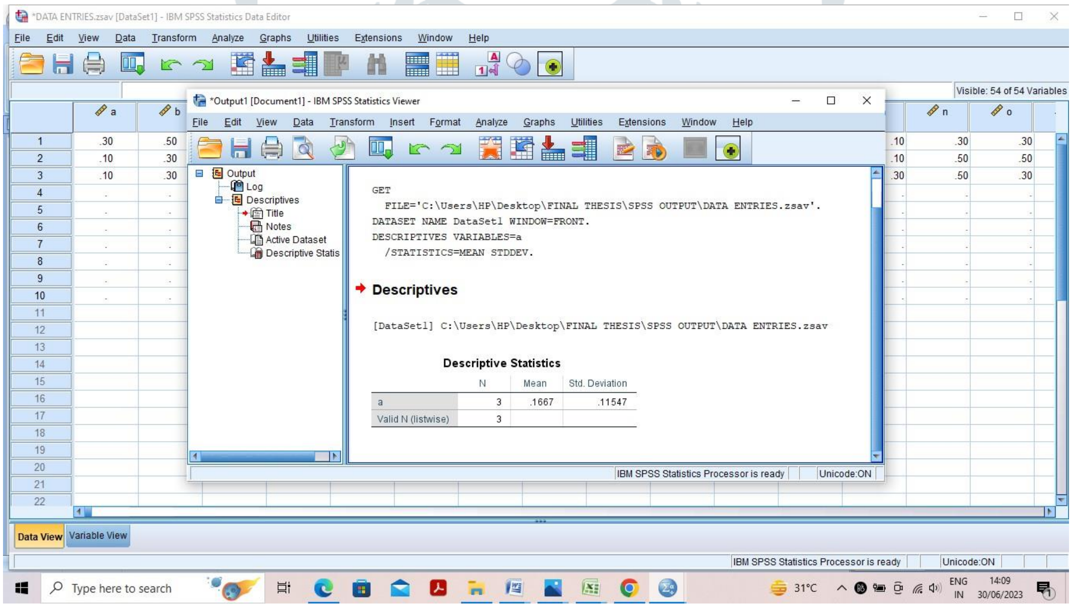

Fig 7.4 Output view

4] Copy the results as excel file and paste to the excel sheet.

7.1 Percentage Reduction of Fluoride Concentration Before and After Filtration for various filters on Surface Water

Variation of mean reduction of fluoride concentration before and after filtration according to different filters on Surface water is given in table 7.1.1

Table 7.1.1 Mean reduction of fluoride concentration before and after filtration on surface water

Type of Filter	Mean ± SD fluoride concentration (mg/L)		Mean Reduction (mg/L) (Percentage Reduction)
	Before Filtration	After Filtration	
RO+UV+UF+TDS	0.233± 0.12	0.067± 0.03	0.166 (71.24)
RO+UV+UF+TDS	0.367± 0.12	0.083± 0.03	0.284 (77.38)
RO+UV+UF+TDS	0.433± 0.12	0.067± 0.03	0.366 (84.52)
RO+UV+TDS	0.233± 0.12	0.067± 0.03	0.166 (71.24)
RO+UV+TDS	0.433± 0.12	0.167± 0.12	0.266 (61.43)
RO+UV+TDS	0.3± 0.2	0.1± 0.00	0.200 (66.67)
RO+UV	0.433± 0.12	0.167± 0.12	0.266 (61.43)
RO+UV	0.367± 0.12	0.167± 0.12	0.200 (54.5)
RO+UV	0.433± 0.12	0.167± 0.12	0.266 (61.43)
RO	0.367± 0.12	0.167± 0.12	0.200 (54.5)
RO	0.433± 0.12	0.233± 0.12	0.200 (46.2)
RO	0.367± 0.12	0.167± 0.12	0.200 (54.5)

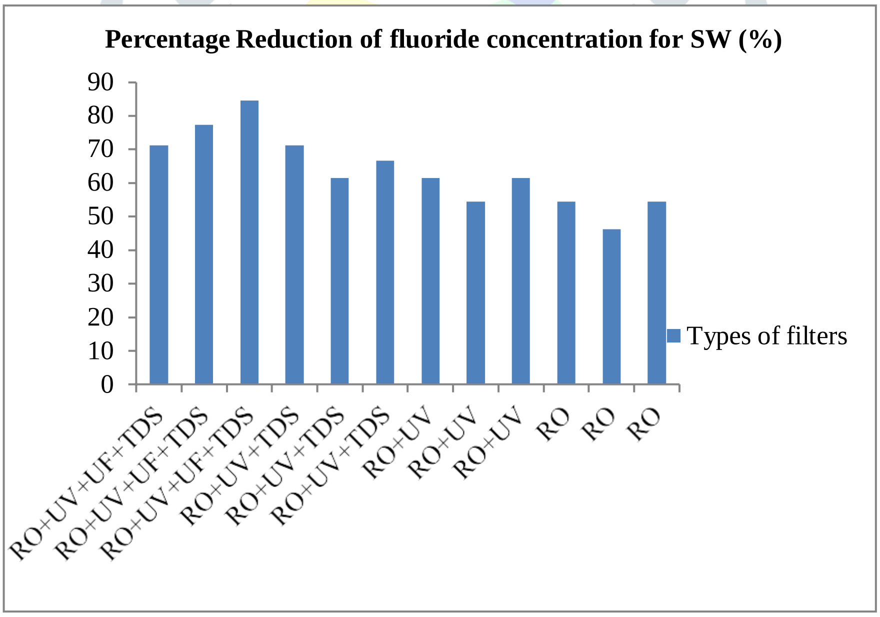

Fig 7.1.1 Variation of mean reduction in fluoride concentration for SW

7.2 Percentage Reduction of fluoride concentration before and after filtration for various filters on Bore well water

Variation of mean reduction of fluoride concentration before and after filtration according to different filters on Bore well water is given in table 7.2.1

Table 7.2.1 Mean reduction of fluoride concentration before and after filtration on Bore well water

Type of Filter	Mean ± SD fluoride concentration (mg/L)		Mean Reduction (mg/L) (Percentage Reduction)
	Before Filtration	After Filtration	
RO+UV+UF+TDS	0.583 ± 0.14	0.167 ± 0.12	0.417 (71.42)
RO+UV+UF+TDS	0.667± 0.14	0.167 ± 0.12	0.500 (75)
RO+UV+UF+TDS	0.583 ± 0.14	0.167 ± 0.12	0.417 (71.42)
RO+UV+UF+TDS	0.583 ± 0.14	0.083 ± 0.02	0.500 (85.71)
RO+UV+TDS	0.667± 0.14	0.233± 0.12	0.433 (65)
RO+UV+TDS	0.583 ± 0.14	0.167 ± 0.12	0.417 (71.42)
RO+UV	0.583 ± 0.14	0.233± 0.12	0.350 (60)
RO+UV	0.667 ± 0.14	0.3 ± 0.00	0.367 (55)
RO+UV	0.75± 0.25	0.3 ± 0.00	0.450 (60)
RO	0.667 ± 0.14	0.367 ± 0.12	0.300 (45)
RO	0.667 ± 0.14	0.433± 0.12	0.233 (35)

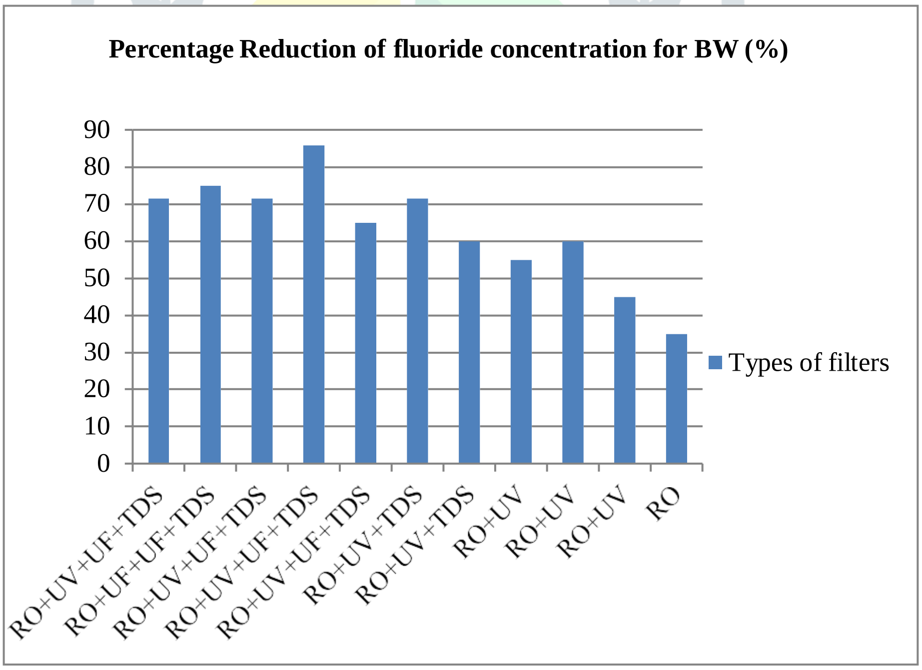

Fig 7.2.1Variation of mean reduction in fluoride concentration for BW

The mean fluoride concentration before and after RO filtration, mean difference in fluoride concentration, and percentage reduction were determined for each of the test groups. The baseline (before RO filtration) water fluoride concentration for surface water purification was in the range of 0.233 – 0.433 mg/L and 0.583 – 0.75 mg/L for bore well water purification. In the present study, all the water samples showed a reduction in fluoride content in the range of 0.166 – 0.366 after passing through various RO filters on surface water supplies[Table 1]. Also for RO filters on bore well water supplies, all the water samples showed a reduction in fluoride content in the range of 0.417 – 0.500 after passing through various RO filters.

VII. Conclusions

The current research work was undertaken to analyse the extent to which domestic RO water filters remove fluoride from drinking water. It was also done to determine the fluoride concentration changes before and after water purification. On the basis of the test results following conclusions can be drawn.

1. The fluoride concentration in the public drinking water supply was found to be in the range of 0.233 – 0.433 mg/L, which is far below the recommended levels of the Bureau of Indian Standard IS 10500:2012 (1–1.5 mg/L). Upstream policy actions are required to regulate fluoride concentration in drinking water, as the fluoride supply to body through water plays a pivotal role in controlling dental caries and bone ossification to all the populations.
2. The fluoride concentration in bore well water supplies was found to be in the range of 0.583 – 0.75 mg/L, which is below the recommended levels of the Bureau of Indian Standard IS 10500:2012 (1–1.5 mg/L). There is no way to add fluoride to bore well water.
3. Few of the RO water purifiers are equipped with TDS controller are selected for the study. The role of TDS controller is to maintain essential minerals in drinking water. Some difference was found in fluoride removal capacity of the RO filters with and without TDS controller.
4. The results of the present study showed variation in fluoride removal of different RO filters. RO filters with multiple stages (RO + ultraviolet + ultra filtration + TDS controller) removed more amount of fluoride as compared to RO filters with single stage filtration system. RO filter manufacturers can alter their technology for controlling the levels of essential elements in water according to the need of the specific area and manufacture the filters accordingly.
5. Fluoride concentration in bore well water supplies is more than surface water supplies.
6. The present study showed low levels of fluoride in drinking water and further reduction in this element after purification by RO filters. RO water filters are effective in reducing fluoride levels in drinking water, indicating their potential in fluoride endemic areas. However, considering the beneficial effect of fluorides in reducing dental caries, when drinking water is subjected to water purification systems that reduce fluoride significantly below the optimal level, fluoride supplementation may be necessary for prevention of dental caries.
7. Frequent monitoring of RO filters is needed to minimize the consequences of fluoride removal efficiency. Awareness about fluorosis and remedial methods need to be carried out.

VIII. Future Scope

Only surface water supplies and bore well water supplies were included. For future studies focus can be given on open well water supplies. In addition, pH and temperature of the water samples can also be taken into consideration.

IX. Acknowledgment

Any accomplishment requires work and efforts of many people. Thus I would like to acknowledge Principal of Government College of Engineering Amravati, Head of Civil Engineering Department and my guide Dr. M.N. Hedaoo, for their support.

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