Development of Cost Effective Fluoride Removal Methods for Rural Water Supply Using Novel Adsorbents

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Abstract:
Occurrence of fluoride at excessive levels in drinking-water in developing countries is a serious problem. Its detection demands analytical grade chemicals and laboratory equipment and skills. Similarly, the prevention of Fluorosis through management of drinking-water is a difficult task, which requires favorable conditions combining knowledge, motivation, prioritization, discipline and technical and organizational support. Many filter media and several water treatment methods are known to remove fluoride from water. However, many initiatives on De-fluoridation of water have resulted in frustration and failure. Therefore, in any attempt to mitigate fluoride contamination for an affected community, the provision of safe, low fluoride water from alternative sources, either as an alternative source or for blending, should be investigated as the first option. In cases where alternative sources are not available, De-fluoridation of water is the only measure remaining to prevent Fluorosis. However, there are several different De-fluoridation methods. What may work in one community may not work in another. What may be appropriate at a certain time and stage of urbanization may not be at another. It is therefore most important to select an appropriate De-fluoridation method carefully if a sustainable solution to a Fluorosis problem is to be achieved.

Keywords: Fluorides, Fluorosis, Filter media, De-fluoridation.

Introduction:
Fluoride can enter in human body through drinking water, food, toothpaste, mouth rinses, other dental product, drugs and fluoride containing salts. About 95% of fluoride in the body is found in bone and teeth. Fluoride is a double-edged sword, ingestion of large amount of fluoride is as harmful as ingestion of its inadequate amount. Fluorosis is a disease caused by excessive intake of fluorides. It is a slow progressive, crippling malady. The tissues affected by fluoride are Dental, Skeletal, Non-skeletal. (Patil and Shivnikar , 2013).
Occurrence of fluoride at excessive level in drinking water in developing countries is a serious problem. Its detection demands laboratory equipment and skills. Similarly prevention of fluorosis through management of drinking water is a difficult task, which requires favorable conditions, combining knowledge, motivation, prioritization, discipline and technical and organizational support. (Aneeza et. al., 2013)

Nature of drinking water is a major task in advanced days because of expansion in pollution of water bodies. Fluoride is one of such pollutant that undermines living life forms, specifically peoples. Fluoride is vital in little amount for mineralization of bones and assurance against dental caries, higher intake reasons decay of teeth enamel called Fluorosis .The issue of fluoride in water bodies is serious for tropical nations such as, India, Kenya, Senegal and Tanzania (Waghmare and Arfin, 2015).

Near about 200 million people of 29 countries including India, are severely affected by fluoride pollution. In India near about 204 districts of 21 states and union territories are associated with fluoride problem. Most prominent states are Rajasthan, Punjab, Gujarat, Andhra Pradesh, Karnataka, Orissa, Maharashtra, Madhya Pradesh, Bihar, Uttar Pradesh, Tamil Nadu, and many more. Near about 62 million Indian population are at the risk of fluorosis, out of which, 6 million are children. (Shanmugam et. al.,2018).

Highly fluoride contaminated water in seven districts of Maharashtra is causing an increase in number of dental and skeletal fluorosis incidents. Nanded, Chandrapur, Latur, Washim, Yavatmal, Beed, and Nagpur districts have been found to have several cases of this chronic condition caused by excessive intake of fluoride. (Namrata Devikar, 2020).

Near about 53 villages in Nanded district where the groundwater is found to be contaminated with fluoride, rendering it poisonous for consumption by the people who are already grappling with acute water shortage, revealed a survey (UWSDA, 2018).

The basic characterization of the removal methods, followed by discussion of the most promising de-fluoridation methods are bone-charcoal, contact precipitation, Nalgonda technique, activated alumina and clay. Finally the methods discussed are compared using indicators which may be appropriate in developing countries.

Rationale:

Many filter media and several water treatment methods are known to remove fluoride from water to remove fluoride from water. However among these initiatives on de-fluoridation of water have resulted in frustration and failure (COWI, 1998). Therefore in any attempt to mitigate fluoride contamination for an affected community, the provision of safe, low fluoride water from alternative sources should be investigated as the first option. In case where alternative sources are not available, de-fluoridation of water is the only measure remaining to prevent fluorosis. However there are several different de-fluoridation methods what may work in one community, may be appropriate at a certain time and stage of urbanization, may not be at another. It is therefore most important to select an appropriate de-fluoridation method carefully if a sustainable solution to a fluorosis problem is to be achieved.

Advanced treatment technologies e.g. reverse osmosis, Electro–dialysis and distillation methods based on patented media and natural media of restricted interest are largely excluded from the scope of this document. De-fluoridation of drinking water is technically feasible at the point of use for small communities of users and large drinking water supplies (WHO, 2006).

To overcome these limitations of the conventional and advanced de-fluoridation techniques and provide simple, suitable and affordable technique for the community there is a need of such research which develops a new de-fluoridation technique using cheap, locally available filter media.

Literature Review:-

Activated alumina after pretreatment with aluminium sulphate has given promising results for removal of fluoride from drinking water. An adsorption capacity of regenerated activated alumina was found to be 4.06 gm/kg at pH 7. It has been observed that the adsorption capacity of activated alumina is strongly dependent on the flow rate, inlet fluoride ion concentration and bed length and the fluoride removal is greater under condition of higher contact time and lower concentration of fluoride (Shrivastava and Sharma, 2012).

The fluoride removal efficiency varies according to many site specific chemical, geographical and economic conditions, so actual applications may vary from the generalizations made. Any particular process which is suitable at a particular region may not meet requirements of some other places (Razbe et.al., 2013).

Treated aluminium hydroxide has shown superior adsorption capacity for fluoride compare to commercially available activated alumina. The adsorbent can be regenerated easily and efficiently by treating with 1% NaOH and 0.1 m HCl (Mulugeta et. al., 2015).

The traditional system removing fluoride from drinking water is liming and the attending precipitation of fluoride. The weaknesses of these methods are high operational cost auxiliary contaminations for example generation of toxic sludge so on intricated process included in the treatment. Coagulation strategies have by and large be discovered compelling in defluoridation however they are to fancied concentration level (Waghmare and Arfin , 2015).

Materials And Methods:

De-fluoridation processes can be categorized into three main groups:

01. Bone charcoal, activated alumina and clay resemble sorption media, preferably to be packed in columns to be used for a period of operation. Sorption processes result in saturated columns to be renewed or regenerated.

02. Aluminium sulfate and lime in the Nalgonda technique, polyaluminium chloride, lime and similar compounds act as co-precipitation chemicals to be added daily and in batches. Precipitation techniques produce a certain amount of sludge every day.

03. Calcium and phosphate compounds are the so-called contact precipitation chemicals to be added to the water upstream of a catalytic filter bed. In contact precipitation there is no sludge and no saturation of the bed, only the accumulation of the precipitate in the bed.

In the present work the method of Adsorption and co-precipitation of chemicals in batches has been used. The adsorbents used in this research work are locally available,

1. Calcium Carbonate.
2. Shadu Soil. &
3. Fullers Earth,

These are used separately as well as in combination.

Adsorption and co-precipitation by Fullers earth, Calcium carbonate, and Shadu soil:

The Fuller’s earth, Calcium carbonate and Shadu soil (10 grams each) are added separately to 1 liter of raw water whose fluoride concentration is to be removed. They are mixed by stirring with a magnetic stirrer. The mixture is stirred gently for five minutes and slowly for one hour. The flocks formed are left to settle down for about one hour. The treated water is then filtered by Whatman filter paper No. 44. The fluoride content from treated water sample is then estimated by using FLUORIDE HIGH RANGE PORTABLE PHOTOMETER with CAL-CHECK (H197739, Fluoride HR), which determines fluoride concentration up to 20 mg/l.

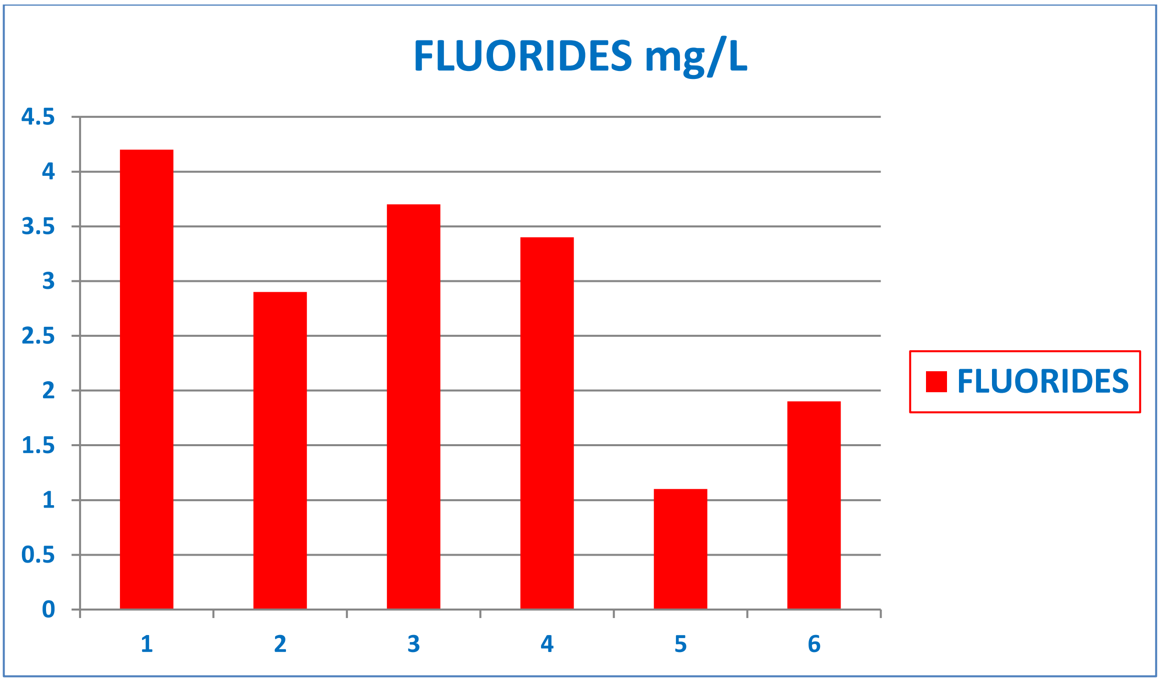
The same procedure has been repeated for the two separate combinations as,

1. Combination of Calcium carbonate and Fuller's earth (10 grams each), as well as
2. Combination of Shadu soil and Calcium carbonate.

Observation and Results:-

S. No	**Conc. of Adsorbent used per liter of water sample.**	**Fluoride conc. mg/L**	**% Fluoride removal**
01	Blank (Raw Water Sample)	4.2	----
02	Fullers earth 10 grams.	2.9	30.95
03	Calcium carbonates 10 grams.	3.7	11.90
04	Shadu Soil 10 grams.	3.4	19.04
05	Fullers earth 10gms + $CaCO_3$ 10gms	1.1	73.80
06	Shadu Soil 10gms + $CaCO_3$ 10gms	1.9	54.76

Graphical Representation:-



Discussion:

The table shows that, the removal of residual fluoride with 10gms. of Fuller's earth alone was from 4.2 mg/L to 2.9 mg/L. and the percentage of removal is 30.95%. The removal of residual fluoride with 10gms. of Calcium carbonate alone was from 4.2 mg/L to 3.7 mg/L. and the percentage of removal is 11.90%. Whereas the removal of residual fluoride with 10 gms. of Shadu soil alone was from 4.2 mg/L to 3.4 mg/L. and the percentage of removal is 19.04%.

The removal of residual fluoride with the combination of Fuller's earth and Calcium carbonate (10 gms each) was from 4.2 mg/L to 1.1 mg/L. and the percentage of removal is 73.80. The percentage removal of residual fluoride, when fuller's earth is combined with calcium carbonate was very high than the Fuller's earth and calcium carbonate alone.

The removal of residual fluoride with the combination of Shadu soil and Calcium carbonate (10 gms each) was from 4.2 mg/L to 1.9 mg/L. and the percentage of removal is 54.76. Here also as in the earlier case, the percentage removal of residual fluoride, when Shadu is combined with calcium carbonate was more than the Shadu soil and calcium carbonate alone.

Conclusion:

The removal of fluoride in drinking water is found to be more effective by using adsorption technique. The combination of Fuller's earth and calcium carbonate (10gm/L each) give the promising result with maximum reduction in terms of Fluorides as compared to any other individual adsorbent or combination with the highest percentage of removal i.e. 73.80%.

The removal of fluoride by the combination of Shadu soil and Calcium carbonate (10 gms each) give better results with the percentage of removal, 54.76%, than the individual one. More research is needed in this regard.

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