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EXPERIMENTAL STUDY OF REMOVAL OF FLUORIDE IN WATER USING BIO MATERIAL

TAMIL SELVAN.N[1], SURAJ VENUGOPAL K.M.D[2], BALAJI.K[3]

[1,2,3]*Department of Civil Engineering, Sri Sairam Engineering College, Chennai, Tamilnadu, India.*

Abstract - *In this experimental study, we have characterised the water sample collected in northern districts of Tamil Nadu by following the standard procedure for fluoride. The results show us that the level of fluoride content in the obtained bore water sample is way beyond the permissible limit (Limit = 1.5 ppm) as stated by Indian Standards (IS).*

To make the water fit for consumption, we reduced the fluoride content in water by using Activated Coconut Shell Carbon, whose raw bio-material is readily available and easily manufactured. The process which underwent to reduce the levels were done with the help of batch studies and pilot studies.

As the bio-material is used, the disposal and the regeneration is possible by either thermal or chemical regeneration, thus making it highly sustainable in terms of cost, maintenance and reusability.

Key Words: Water, Bio-Material, Carbon, Environment.

1. INTRODUCTION

Domestic water demand is on the rise in all parts of the world due to modernization and industrialization in this 21st century. Hence, every drop of water is precious and shouldn't be wasted lethargically. Man has been in searching and researching for various methods to harness water according to his needs. Getting water from source, making the water fit for various demands, supplying it to the points of consumption has been under the environmental engineering. This plays a major role in converting the water of a surface or ground surface into the water need to perform a particular activity. As an environmental engineer, one needs to make sure, every human being is given a facility to have safe drinking water in this fast moving industrialized world.

On thorough study of various subjects and aspects related to environmental engineering, one can come across to a parameter called fluoride present in water. This parameter though seemed to be unevenly located and present makes an eye turning impact on human health. Fluoride has been 3rd biggest serious pollutant after oxides of sulphur and ozone. The main reason for getting big attention is it affects the human health badly when it is in excessive amounts in ground and surface water. Fluoride being a highly electronegative element reacts violently with all elements except helium, argon and radon. Its nature as a whole is corrosive. The excessive amount cause health issues on a big damaging scale.

1.1 OBJECTIVES

The aim of the experimental study is

1.To study the level of fluoride levels in districts of Tamil Nadu.

2.To identify the places of highest fluoride level in Tamil Nadu.

3.To assess the cause of increasing fluoride level.

4.To give a simple, easy, cost effective model in reducing the fluoride level within desirable limits.

5.To make the fluoride borne water made fit for consumption for humans and animals.

6.To use the bio material for the designed purpose.

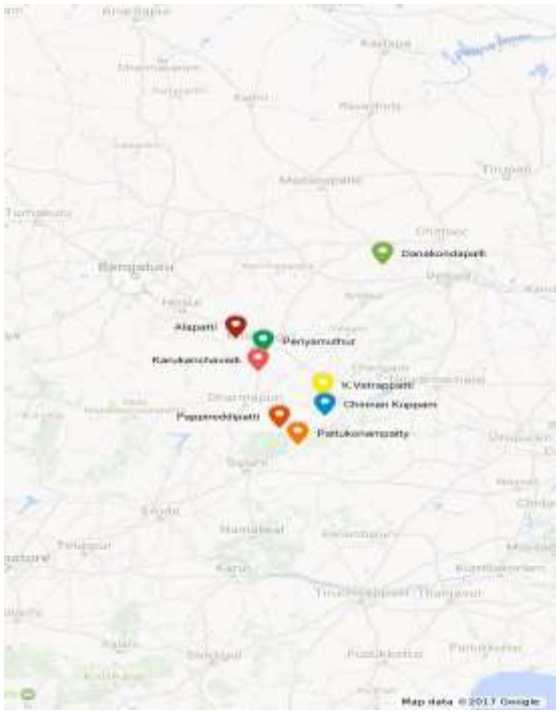
7.To prevent further cases of fluorosis in future.

1.2 LOCATION AND STUDY AREA

Tamil Nadu has been chosen as the study area to analyse the areas of fluoride in excess limits and the places where the fluoride levels are highest.

We have chosen areas where fluoride levels in Tamil Nadu are highest. This will help us in designing the adsorption column to handle the highest possible fluoride content available in Tamil Nadu. We have taken the location as Dharmapuri, Krishnagiri and Vellore. Study area was conducted in 8 villages in these districts and were sampled.

Adsorption studies are performed regularly to check the removal of particular parameter within the desirable limits using the easily available raw bio materials. To support this, preliminary studies like batch studies and pilot studies are done to justify the experimental process.

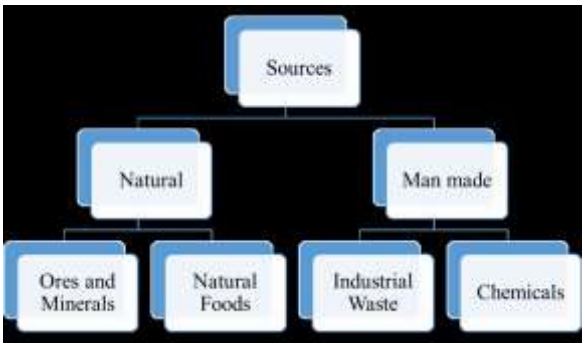


(Figure 1.1: Study area – Map)

1.3 SOURCES OF FLUORIDE

Fluoride is found in two ways. They are:

1. Natural
2. Man-made.



(Figure 1.2: Flow chart of sources of fluoride)

1.4 PROPERTIES OF FLUORIDE

The properties can be divided into two types namely

1. Physical properties
2. Chemical properties

1.5 USES OF FLUORIDE

- Fluoride can act as enzyme inhibitors.
- Hydrofluoric acid can dissolve glass.
- Sulphur hexafluoride can act as insulator.
- They help in manufacture of bio-compatible materials.
- Useful in nuclear reactors.
- Help in medical solutions.
- Raw material for phosphatic fertilizers.

1.6 APPLICATIONS OF FLUORIDE

- Used in medical industry to treat osteoporosis and bone loss.
- Oral hygiene products contain sodium fluoride or sodium monoflurophosphate to prevent tooth decay.
- Fluoride salts like beryllium fluoride and aluminium fluoride are use as inhibitors in chemical reactions.
- Hydrofluoric acid is used in production of fluorocarbons and aluminium fluorides.
- Fluoride-containing dyes and contrast mediums such as fluorodeoxyglucose are used in imaging studies such as positron emission tomography.
- They find application in surgical implants, cosmetic surgery and cookware.
- Uranium Hexafluoride helps to separate uranium isotopes in nuclear reactor fuel.

2. DEFLUROIDATION

Defluoridation is the removal of excess fluoride in water. It is also defined as the downward adjustment of level of fluoride in drinking water to the optimal level. Fluoride level in water in India ranges from 2 – 37.

2.1 CHARACTERISTICS OF DEFLUORIDATION

- Cost effective
- Easy to handle or operate by the people.
- Independent of input fluoride concentration, pH, temperature.
- Should not affect taste of water.
- Should not add other undesirable substances.

2.2 NEEDS AND ADVANTAGES

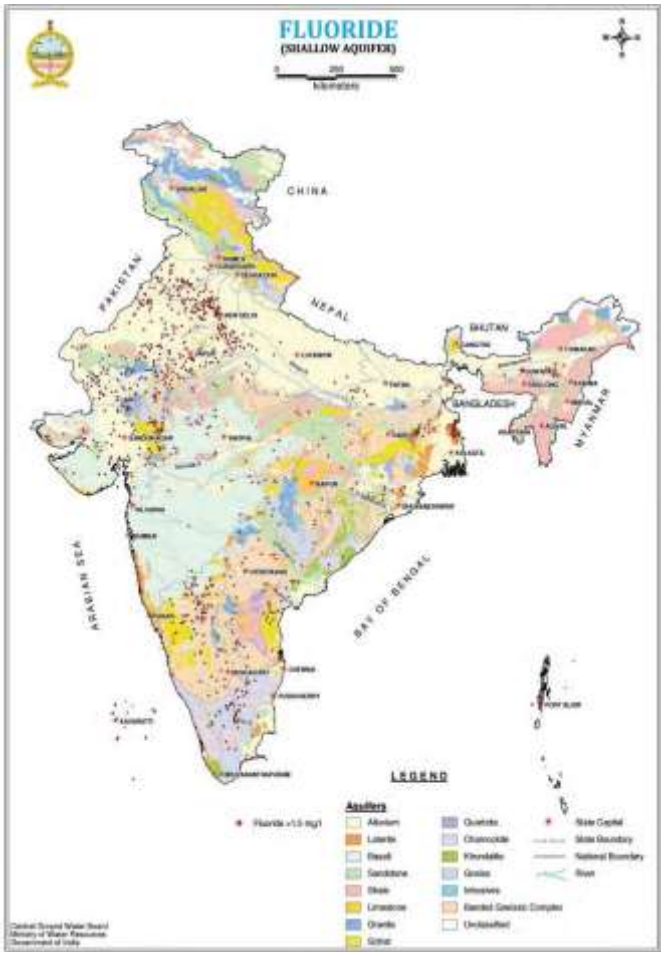
As stated earlier, to meet increasing domestic water demands in rural areas and also to feed animals, defluoridation of the ground water is needed to make the water safe for drinking. Defluoridation helps in retaining other minerals present in water by reducing the level of fluoride alone present in water. It is parameter specific process of solving the water crisis in fluoride excessive water areas. Defluoridation is have various advantages and it's given below:

- Can be attached as a small sub unit in any treatment plant.

- RMO (Running, Maintenance, Operation) costs are low.
- Does not add any changes to physical and chemical properties of water.
- Does not use any complicated or expensive materials.
- Process time is also less.

2.3 DATA COLLECTION – MAP

In India, Excessive fluoride has affected various states like Rajasthan, Gujarat, Karnataka, West Bengal, Uttar Pradesh and Tamil Nadu. The bad scenario is wide spread all over India. Hence, the problem is at national level. Data released by Central Water Resources Board is given below for visual representation.



(Figure 2.1: Central Ground Water Board data on fluoride)

2.4 EFFECT ON HUMAN HEALTH

The mere excess intake of fluoride over a period of time in a human body is called fluorosis. Fluorosis is a disease caused by deposition of fluorides in the hard and soft tissues of the body. It is endemic in 22 countries around the world. In Asia, India and China are worst affected.

There are 3 types of fluorosis. They are:
A. Dental Fluorosis
B. Skeletal Fluorosis
C. Non – Skeletal Fluorosis.

3. MATERIALS AND METHODS

3.1 SODIUM FLUORIDE

Sodium fluoride is manufactured from sodium hydroxide solution and hydrogen or hydrofluoric acid. Sodium Fluoride (NaF) is saturated by 4 to 50% by weight in the range of 20 to 80˚ C, preferably at 30 to 60˚C. Formation of sodium fluoride can be enchanced by adding alcohol (Ullmann's Encyclopaedia of Ind. Chem., 5th Ed., 1997, Wiley VCH, Weinheim). On introducing, hydrogen fluoride into dilute sodium hydroxide, NaF comes out as white precipitate. In some industries, it is performed using cryolite or hexafluorosilicic acid.

3.2 ACTIVATED COCONUT SHELL CARBON

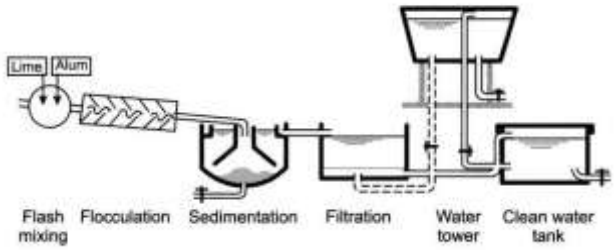
Activated carbon can be produced from different raw carbon resources like lignite, peat, coal, wood, bagasse, and coconut shells. However, the abundant supply of coconut shell is available as waste product from coconut oil. Making carbon from coconut shell is financially viable to any company manufacturing it compared to other materials. Being an amorphous form of carbon, it can absorb many gases, vapours and colloidal solids. Other factors which make coconut shell carbon superior are high density, high purity, virtually dust-free nature. They are resistant to attrition.

3.3 DEFLUORIDATION TECHNIQUES

There are 4 defluoridation techniques of water.
They are as:
1) Precipitation method
2) Ion exchange method
3) Reverse Osmosis method
4) Adsorption method

3.3.1 PRECIPITATION METHOD

Precipitation methods are based on the addition of chemicals (coagulants and coagulant aids) and the subsequent precipitation of a sparingly soluble fluoride salt as insoluble fluorapatite. The best example of precipitation method is the famous Nalgonda technique of defluoridation.



(Figure 3.3.1: Nalgonda Technique – process)

3.3.2 Ion Exchange Method

Synthetic chemicals, namely, anion and cation exchange resins are used for fluoride removal. It is almost similar to removing hardness in water. Here a strong base anion exchange resin in chloride form is used. It not only removes fluoride, but also arsenic, nitrates etc. present in water gets exchanged with the chloride ions of the resin.

3.3.3 REVERSE OSMOSIS

Reverse osmosis, or RO, is a common form of water purification. RO uses a semi-permeable membrane that has pores large enough to allow water molecules to pass through but small enough to block other types of molecules. When pressure is applied to water on one side of the membrane, water molecules are forced through to the other side of the membrane, producing pure water. Contaminants are essentially filtered out by the process.

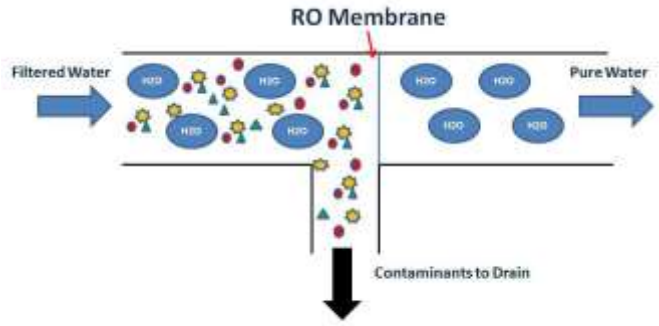


Figure 3.3.3: Reverse Osmosis

3.3.4 ADSORPTION PROCESS

Adsorption is a process where a solid is used for removing a soluble substance in water. In this process, various materials of active carbon is used. The reason for choosing active carbon is to achieve very big internal surface of 500- 1500 m2 per gram. This internal surface gives us the ideal condition for adsorption.

4. RESULTS AND DISCUSSION

Tamil Nadu, the study area covered 8 villages in 3 districts. The samples were tested as per the standard testing procedure. The results found were found to be above the permissible limit of 1.5 mg/l as per Indian Standards

EFFECT OF pH

The pH of the fluoride solution is varied from 2 to 12. The adsorbent is added and the effluent fluoride present is found for various pH. It is obtained that acidic range of 2 give the maximum efficiency and it goes on decreasing with increase in pH. pH 6.5 in order to be within the standard of supplying water (6.5-8 pH) is said to give maximum efficiency.

EFFECT OF DOSAGE

Various dosage of adsorbent of 1 mg, 2 mg, 3 mg, 4mg, 5 mg etc. were added and shaken with 1000ml of known concentration. The samples were collected after a particular time. The treated fluoride solution were tested to determine the amount of fluoride removed. With increase in dosage, the percentage removal increases till a particular point (4mg/L) and remains same. Hence, 4 mg/L is taken as optimum dosage.

EFFECT OF CONTACT TIME

The adsorbent and fluoride solution are left to stagnate with the passage of time. The time taken are 10 minutes, 20 minutes, 30 minutes, 45 minutes, 60 minutes, and 120 minutes. With increase in contact time, the percentage removal increases till a particular time (45 minutes) and then remains same. Hence, 45 minutes is taken as optimum contact time.

REAL TIME RESULT

From the real time studies, the samples of the places collected were then tested in the fixed bed adsorption column to find the level of removal of fluoride.

DISCUSSIONS

Adsorbent Regeneration
Being a bio-material, it has the capacity to be reused after the saturated use during its lifetime. Regeneration is recommended for activated carbon is to maintain sustainable costs and recycle it to reduce the stress on materials. There are various methods to regenerate. The following methods are given below:

- Thermal Regeneration
- Chemical Regeneration
- Thermal Regeneration

Water content from the activated carbon is removed using slurry and the temperature of carbon is raised to 400- 600 ˚C, reversibly adsorbed substances are driven off while the impurities decompose and leave behind a char residue. After heating, it is cooled and washed it in water. The entire process will take about 30 minutes. One of the disadvantages of thermal regeneration is it will lead to loss of adsorption capacity due to changes in pore structure.

 Chemical Regeneration

Chemical regeneration is a process in which adsorbates are removed from carbon by reacting with suitable chemical reagents. The use of reagents depends on the type of activated carbon material. Chemical regeneration exhibits several advantages over thermal regeneration. Recovery is highly efficient also.

5. CONCLUSIONS

On the basis of the present experimental study, we can conclude the following:

1. Based on the study area tests, we are able to conclude that the 3 places of the study area were found to have fluoride content to be highest way beyond the permissible limits namely Pattukonam Patti at 3.389 mg/L, Alapatti at 2.048 mg/L and Dhanakondapalli at 2.091 mg/L.
2. The pH was fixed at 6.5 for maximum efficiency as the drinking water standards emphasise on 6.5 – 8 pH in water.
3. Based on batch studies, we have concluded that as the dosage goes on increasing the efficiency increases too till a certain point. It was 72.5% for 1 mg/L, 77.5% for 2 mg/L, 82.5% for 3mg/L, 85% for 4 mg/L, 85% for 5 mg/L, 85% for 6 mg/L. On the obtained results, we have fixed the optimum dosage as 4 mg/L for maximum efficiency.
4. Similarly, on batch studies, the maximum efficiency for an optimum contact time was 70%, 72.5%, 77.5%, 82.5%, 85%, 85%, 85% for 1mg/L, 2mg/L, 3mg/L, 4 mg/L, 5mg/L, 6mg/L respectively. Hence, the optimum contact time was fixed as 45 minutes.
5. The batch study results were best suited in Langmuir isothermthan Freundlich isotherm as R2 of Langmuir is 0.9967 and R2 of Freundlich is0.9898. The adsorption isotherms like Langmuir and Freundlich tells us that the adsorbent used is feasible and can withstand any changes in concentration.
6. Pilot studies shows us the Volume breakthrough occurs at 55 litres i.e. after the use of 55 litres, the adsorbent molecules are saturated with fluoride molecules and therefore need replacement. Volume exhaustion is 103 litres, where it the maximum limit of water adsorption to be taken. Beyond this, it acts like a normal fluid transporting pipe.
7. The design has been done based on batch and pilot studies. The dimensions found are 7.5 cm in diameter and 50 cm in height of the adsorption column.
8. The real time analysis gave an efficiency of about 73% for Pattukonam Patti, 63% for Alapatti and 61% for Dhanakondapalli which are within the designed limits of the design and also within the desirable and permissible limits of Indian Standards for Drinking Water which are 1.0 mg/L and 1.5 mg/L respectively.

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