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Review Article

Nalgonda Technique is an Ideal Technique for Defluoridation of Water: its use can Prevent and Control Hydrofluorosis in Humans in India

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Abstract

India is one of the countries where water-borne fluorosis (Hydrofluorosis) disease is hyperendemic which develops from drinking fluoridated water. This disease is more prevalent especially in the rural areas of the country. > 90% of drinking groundwater sources, hand-pumps, bore-wells, etc. are naturally contaminated with varying amounts of fluoride. In the country, groundwater of 23 out of 37 states and union territories is found to be fluoridated and in most of the rural areas have fluoride above the acceptable limit of 1.0 ppm or 1.5 ppm. Consumption of such water for both drinking and cooking for prolonged time is not safe for human health and causes dental mottling (dental fluorosis), skeletal deformities (skeletal fluorosis), and adverse changes in soft organs (non-skeletal fluorosis). According to the National Programme for Prevention and Control of Fluorosis (NPPCF), the population at risk based on population in habitations with high fluoride in drinking water is > 11.7 million in the country. Therefore, providing fluoride-free drinking water is more important and necessary for the prevention and control of dreaded hydro fluorosis disease in the population. For this, Defluoridation technique has been developed by the National Environmental Engineering Research Institute (NEERI) in India, through which fluoride free water can be easily prepared. The name of this technique is "Nalgonda technique". This technique can be used at both household and community level. In this technique, three basic chemicals, namely aluminium salts, lime, and bleaching powder are used for removing fluoride and getting cleaned potable water. The quantities of these chemicals are used in a scientific way for getting water having acceptable limit of fluoride (1.0 mg F/l). In the present review, how this technology is ideal and efficient for water defluorination and its basic mechanisms and utility in the prevention and control of hydro fluorosis in India are briefly focused on.

Keywords: Defluoridation; Dental fluorosis; Fluoride; Hydrofluorosis; Nalgonda technique, non-skeletal fluorosis; Raw or potable water; Skeletal fluorosis

Introduction

Water-borne disease, namely Hydrofluorosis is a worldwide public health problem and is endemic in more 125 countries [1]. India is also one of the countries where the Hydrofluorosis disease is highly endemic and more prevalent especially in rural areas [2,3]. In fact, this dreaded disease in the rural communities is mainly due to drinking fluoride contaminated water. According to the survey, 42.9% of households in rural areas use water (groundwater) of hand- pumps and bore- wells as their main sources of drinking water, while 40.9% of households in urban areas use piped or surface water as their main source [4]. Interestingly, in rural areas of India,

> 90% of drinking groundwater sources are naturally contaminated with varying amounts of fluoride [5]. In the country, groundwater of rural areas of 23 out of 37 states and union territories is found to be contaminated with fluoride or fluoridated. Among these, 70-100% districts in the states of Andhra Pradesh, Gujarat, Rajasthan, and Telangana and 40-70% districts in the rest of the states have fluoride-contaminated groundwater and having fluoride above the maximum permissible or safe limit, > 1.0 ppm or 1.5 ppm [1,6,7]. Prolonged use of such water for drinking and cooking is not safe for human health [8] and causes the disease hydrologists [1,9-18]. If domestic animals drink such fluoride contaminated groundwater frequently for long time, then this disease also appeared in them [19-32]. Irrigation of fluoride containing water in agriculture is also harmful to agriculture crops [5].

It is well known, in the human body, ingested fluoride through drinking water is absorbed by digestive system and ultimately reaches various organs through blood circulatory system. More than 50% absorbed fluoride is excreted from the body through excretory products and perspiration, while the rest of fluoride is retained in the body where it accumulates gradually in the various organs. However, its maximum bioaccumulation occurred in the calcified tissues, bones and teeth as compared to their counter parts [1,33]. In people, chronic fluoride intoxication (fluorosis) causes weakening, discoloration, and light to dark brown staining of the teeth (dental fluorosis), while they also become crippled and bent (skeletal fluorosis) due to various bone changes [33]. Apart from these, many types of health problems (non-skeletal fluorosis) such as gastro-intestinal discomforts, anaemia, body weakness, polydipsia, polyuria, repeated abortion, impaired reproduction and endocrines, neurological disorders, etc. also develop in people of all age groups from drinking of fluoridated water [1,33]. Although these fluoride- induced health problems are temporary, these are significant and helpful in the diagnosis of chronic fluoride intoxication not only in humans [33] but also in domestic animals [34]. Interestingly, due to the easy availability of water from hand-pumps and borewells, the villagers or people also started feeding water from these water sources to their domesticated animals, due to which domesticated animals also started getting Hydrofluorosis disease in India [19-32]. However, the severity and prevalence of Hydrofluorosis depends on chemical constituents of water and many other factors other than the amount of fluoride in the drinking water [35-42].

In India, according to the National Programme for Prevention and Control of Fluorosis (NPPCF), the population at risk based on population in habitations with high fluoride in drinking water is > 11.7 million in the country [43]. However, NGOs and scientists have warned that the threat is far more widespread, affecting more than 60 million people. Therefore, there is a great need to prevent and control Hydrofluorosis in rural areas of the country, which is possible only when people have regular access to fluoride-free water. For this, several techniques or methods such as chemical (precipitation processes, contact precipitation, coagulation techniques, and electrocoagulation), membrane (electrodialysis, reverse osmosis, and nanofiltration), distillation (solar and membrane distillation), adsorption (activated alumina, clay adsorbents, ion-exchange resins, metal: organic frameworks, carbonaceous adsorbents, biosorption, and layer double hydroxides), phytoremediation, etc. have been developed for Defluoridation (removal of fluoride) of raw or potable water [44-48]. These techniques are classified broadly as chemical, physical, and membrane-based or adsorptive. However, in India, the National Environmental Engineering Research Institute (NEERI), Nagpur, has developed and recommended a method referred to as the "Nalgonda technique" which is an ideal and efficient technique for water Defluoridation [49]. This technique is based on chemical methods and can be used at both the household and community level. In the present review, how this technology is ideal and efficient for water defluorination and its basic mechanisms and utility in the prevention and control of Hydrofluorosis in India are briefly focused on.

Nalgonda Technique

In simple terms, Defluoridation is the removal of excess fluorides from water which can be achieved by precipitation and complexation or fixed bed regenerative activated alumina process. In India, NEERI has developed a technique by which fluorides can be removed from water by precipitation and complexation method which is called or named as "Nalgonda technique" [50]. This technique is comparatively simple as well as economical.

In this technique, basically three chemicals, namely aluminium salts, lime, and bleaching powder are used and added to raw or fluoridated water followed by rapid mixing, flocculation, sedimentation, filtration, and disinfection processes. The aluminum salt (alum) may be added either in the form of aluminum sulphate [$Al_2(SO_4)_3$] or aluminum chloride ($AlCl_3$) or a combination of both. In the process of defluorination, only alum is responsible for removing fluoride from water. However, the selection of these salts depends upon the sulphate and chloride content of the raw water so as not to exceed their permissible limits. The amount or dose of aluminum salts increases with an increase in the fluoride and alkalinity levels of the raw water. The dose of lime ($CaCO_3$ or CaO) is empirically $1/20^{th}$ that of the dose of aluminium salt. In fact, lime facilitates the formation of dense floc for rapid settlement. Bleaching powder [$Ca(OCl)_2$] is added to the raw water at the rate of 3mg/l for disinfection. In this method, quantity of alum is added to the raw water in a certain proportion so that the fluoride level in this water comes down to an acceptable level (1.0 mg/l). It all depends on the fluoride and alkalinity level of this water which is shown in (Table 1).

Mechanism Involved in Defluoridation of Potable Water

This technique is very simple and can be easily understood and handled by a common man. This technique is a combination of several unit operations and processes involving rapid mixing, chemical interaction, flocculation, sedimentation, filtration, disinfection, and sludge concentration to recover both water and aluminum salts. All the basic operations of this technique are shown in (Figure 1).

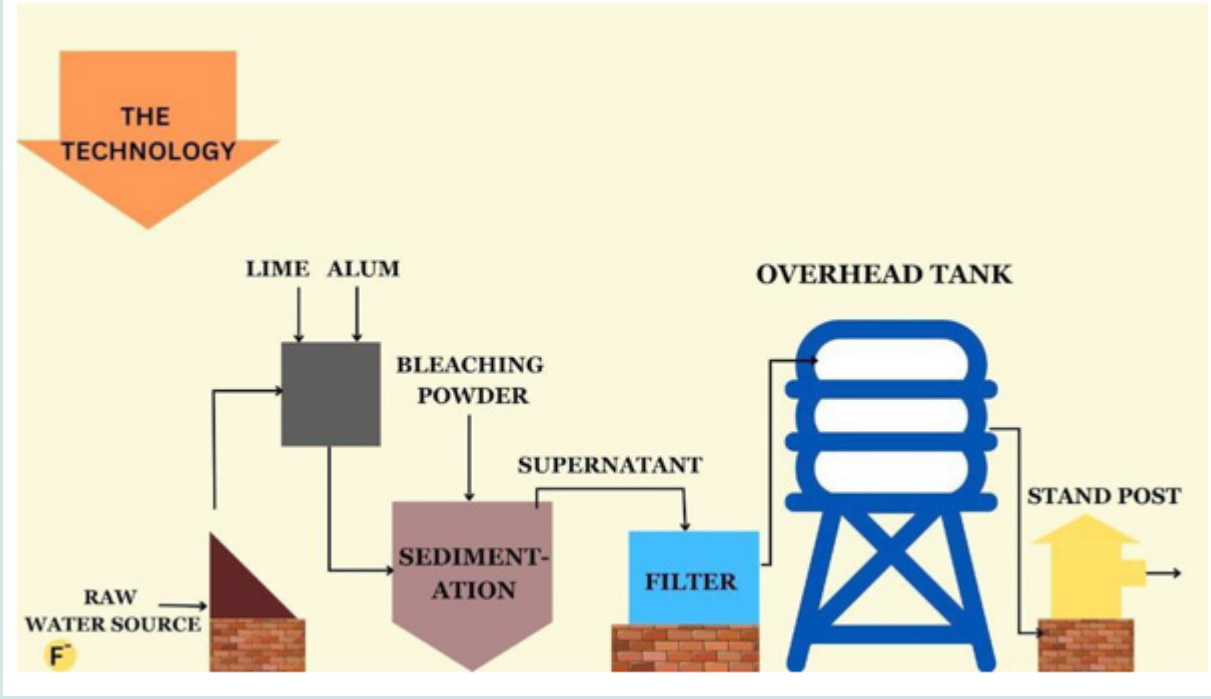

Figure 1: Layout plan of Nalgonda technique for potable water defluorination. Source: [49].

Table 1: Approximate alum dose (mg/l) required to obtain acceptable limit (1.0 mg F/l) of fluoride in test or potable water at various alkalinity and fluoride levels. Source: [49].

Fluoride (mg/l) In test water	Test or potable water alkalinity (mg $CaCO_3$/l)							
	125	200	300	400	500	600	800	1000
2	145	220	275	310	350	405	470	520
3	220	300	350	405	510	520	585	765
4	*	400	415	470	560	600	690	935
5	*	*	510	600	690	715	885	1010
6	*	*	610	715	780	935	1065	1210
8	*	*	*	*	990	1120	1300	1430
10	*	*	*	*	*	*	1510	1690

*To be treated after increasing the alkalinity with lime or sodium carbonate.

Rapid mixing:

It is the first step of Defluoridation of raw or fluoridated water. In this step, the basic chemicals, lime (alkaline), aluminum salt (alum) and bleaching powder are added when the potable or raw water enters the Defluoridation system or container.

Flocculation and chemical interaction:

Thereafter the water is thoroughly stirred by flocculators before entering the sedimentation tank. During flocculation, there is a close interaction between the fluoride in the water and the polyalanine species formed in the system and equilibrium is achieved. In fact, flocculation removes not only fluoride from potable or raw water but also turbidity, colour, odour, pesticides, and organic matter. During flocculation bacterial load is also reduced significantly due to presence of bleaching powder. All of these are caused by adsorption on the floc. Lime or sodium carbonate ensures sufficient alkalinity for effective hydrolysis of aluminum salts, so that residual aluminum does not remain in the treated water. Simultaneous disinfection is achieved with bleaching powder and keeps the system free from undesirable biological growth.

Sedimentation:

The treated water is transferred to a sedimentation tank where flocs containing fluoride, turbidity, bacteria, and other impurities are allowed to settle down. The supernatant water with a low concentration of suspended solids is transferred to the filter tank.

Filtration:

For proper filtration, rapid gravity sand filters are recommended by NEERI to get settled water. These filters usually contain unscented gelatinous flocs. Residual fluoride and microbes are adsorbed on the gelatinous flocs placed on the filter bed.

Disinfecting and distribution of water:

Finally, the filtered water is collected in a storage water tank. Before distributing this water, it is re-chlorinated so that there is no infection in it.

How is This Technique an Ideal and Efficient Technique?

There is no doubt that this "Nalgonda technique" is an ideal and efficient technique for Defluoridation of fluoridated or potable/raw water. Although this technique has many merits, but the main merits are as follows, which confirm it to be ideal, efficient, and effective: this technique is highly efficient removal of fluorides from water having 1.5 to 20 mg F/l up to desirable levels (1.0 or 1.5 mg F/ l), chemicals used in this technique are readily available in the market, adaptable both at the household and community levels, flexible up to several thousand m^3/d, having very simple design, construction, operation, and maintenance, it provides employment opportunities to the local people, at the same time, it also removes many undesirable impurities such as colour, odour, turbidity, bacteria, and organic contaminants from the water, alkalinity ensures the efficiency of fluoride removal, sludge generated can be converted into alum for use elsewhere, little wastage of water as well as having least disposal problem, no regeneration of media, needs of minimum mechanical and electrical equipment, no energy except muscle power for domestic equipment, and it costs comparatively less or it is economical.

When Can this Technique be Used?

This technique can be used only when the absence of an acceptable and alternative low fluoride drinking water source within transportable distance or the absence of an alternative source causes rejection limits such as total dissolved solids < 1500 mg/l and fluoride ranging from 1.5 to 20.0 mg/l.

Defluoridation at Domestic Level

Anyone can easily make raw or potable water free of fluoride by this technique at domestic level. In fact, its method is simple [50]. The method of how water is defluorinated has been shown in (Figure 2). An approximate volume of alum solution (milliliter) required to be added in 40 liters raw or fluoridated water to obtain acceptable limit of fluoride (1.0 mg F/l) in water at various alkalinity and fluoride levels has been depicted in (Table 2).

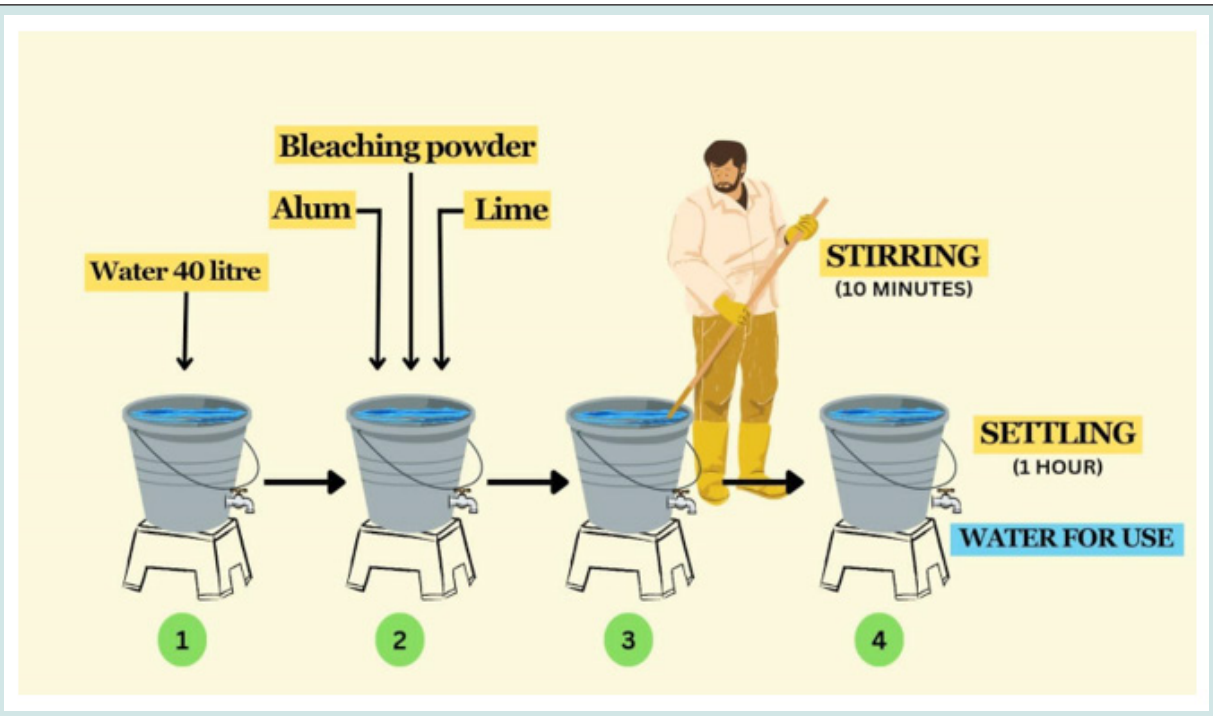

Figure 2: Defluorination at home or domestic level following the basic principle of Nalgonda technique. Source: [50,51].

Table 2: An approximate volume of alum solution (milliliter) required to be added in 40 liters test or potable water to obtain acceptable limit (1.0 mg F/l) of fluoride in water at various alkalinity and fluoride levels. Source: [49].

Fluoride (mg/l) In test water	Test or potable water alkalinity (mg $CaCO_3$/l)							
	125	200	300	400	500	600	800	1000
2	60	90	110	125	140	160	190	210
3	90	120	140	160	205	210	235	310
4	*	160	165	190	225	240	275	335
5	*	*	245	240	275	290	355	405
6	*	*	205	285	315	375	425	485
8	*	*	*	*	395	450	520	570
10	*	*	*	*	*	*	605	675

*To be treated after increasing the alkalinity with lime or sodium carbonate.

For the Prevention and Control of Hydrofluorosis

Hydrofluorosis disease is endemic in most rural areas of India due to presence of high amount of fluoride in drinking groundwater [2,3,5]. Thousands of children, young, and old men and women drink this water due to which these people are suffering from this disease. Due to this disease, people also become handicapped for life. If these people start getting fluoride-free water, then this disease can be prevented and controlled. Nalgonda technique can prove to be most suitable and effective for this. In fact, by this technique fluoride-free water can be prepared both at domestic and community level which can be used by people or villagers for drinking and cooking purposes. Through this way fluoride exposure can be checked in population. Due to which there is no possibility of hydro fluorosis in people. The special thing is that once this disease has happened or appeared in humans, there is no possibility of its recovery. In fact, there is no cure for this disease. This technique is more useful especially in tribal areas of Rajasthan where fluoride in drinking water sources is found in the range of 1.0 ppm - 21.6 ppm [2,51-61]. But this technique can also be used in any geographical area or country where fluorosis is endemic or the fluoride content in drinking water is found to be above the maximum permissible limit of 1.0 ppm or 1.5 ppm.

Conclusion

The groundwater of most parts of India is fluoride rich. Most of the rural people use this water for both drinking and cooking. Due to repeated long-term consumption of this water, a disease called Hydrofluorosis is prevalent in these people. This disease is usually seen only in rural areas of the country. This disease can be prevented and controlled by providing fluoride free drinking water to the population. The Nalgonda technique can be used in any area having fluorosis and fluoride in drinking water found beyond the permissible limit. By this technique, fluoride free drinking water can be prepared at both domestic and community level. This is a simple, ideal, efficient, and less expensive technique. Using this, clean and germ-free water can be obtained. However, the success of this technique at the community level requires proper monitoring, maintenance, and correct operation. Apart from India, this technique can be used in any country or geographic region where hydro fluorosis is endemic, and the drinking water contains fluoride above the permissible limit of 1.0 ppm.

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