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Health Effects Associated with Fluoridated Water Sources—A Review of Central Asia

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Abstract: Water fluoridation is a common practice in different parts of the world, mostly as a means of decontaminating water. It has been used in developed, as well as in developing countries. In recent years, however, other countries have minimized, even eliminated its use due to health issues. In Central Asia, usage of fluoride is profoundly extant, thus occasioning the citizens' exposure to various health risks. An excessive level of fluoride causes various health issues, mostly on dental and skeletal fluorosis which often leads to vulnerabilities in the bones and teeth. Studies also indicate that excessive levels of fluoride have been known to contribute to poor neurological development among children, hip fractures to older adults, as well as osterosclerosis. Moreover, the review has concluded that fluoride contamination in ground water is very high in India, Pakistan and Sri Lanka. In contrast, fluoride levels are below threshold value of 1.5 mg/L in Bangladesh. Fluorosis cases have been observed in Nepal but available data is quite unsystematic and incomplete, thus rendering them of no statistical significance. In India, districts such as Kerala, Gujrat, Bakresh (West Bengal), Khudra (Orissa), Manikaran (Himachal Pradesh), Unkeeher (Maharashtra) and Tattapani (Chattisgarh) are currently facing a high level of fluoride. In Pakistan, fluoride data of 29 major cities are reviewed and 34% of the cities show fluoride levels with mean value greater than 1.5 mg/L where Lahore and Quetta are having the maximum values of 23.60 mg/L and 24.48 mg/L, respectively. Sri Lankan dry zone is polluted with fluoride having maximum value of 8.00 mg/L. Considering these verities, health authorities urgently need to establish alternative means of water decontamination in order to prevent associated health problems.

Key words: Fluoride, fluorisis, health effects, bones deformation, adsorption.

Introduction

Fluoridation of water has been a common practice in various countries like Australia, Brazil, Malaysia, USA, India, and Vietnam. Most European countries do not fluoridate their water, but in different parts of the world which are subject to high risk of water contaminant, this technique is most likely the best option to be implemented. Questions concerning the health impact of fluoride have been raised by various experts, arguing that water fluoridation carries significant health risks which may not be easily managed in the long run.

In many countries world over, it has been observed that high concentrations of fluoride occur naturally in ground water, which is the main source of drinking water. Undeniably, fluoride is one of the most abundant elements in the earth and it generally infiltrates ground water by natural processes. Soil, a product of the physical disintegration and chemical decay of solid bedrocks that are high in fluoride, is mostly found to be naturally rich in fluoride.

When fluoride is absorbed into the bloodstream, it is transported to other parts of the body, most of it being retained in the calcium-rich areas of the body like bones

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and teeth. Once absorbed, it may eventually lead to various health effects. At low concentrations, fluoride is beneficial to the teeth, mostly in helping eliminate teeth decay; admittedly, it also does decontaminate water as it kills various bacteria which may be present there (Rwenyonyi et al., 2000). However, at excessive levels, fluoride can cause negative health effects. Such effects mainly include dental and skeletal fluorosis. Dental fluorosis, yellowish striations on the teeth enamel, is often the first evidence of high fluoride consumption; and high levels of fluoride have also been associated with the erosion of the enamel (Saparamadu and Dinesh, 2000).

Highlighted in Figure 1 is a case of dental fluorosis wherein the detrimental effects of fluoride is denoted. Slowly but surely, it wears off the enamel and in the process of time results in tooth loss. There is statistical evidence for the presence of dental fluorosis in countries like India, Pakistan, Sri Lanka and China with about 60 million individuals affected (Giordano, 2009). An excessive amount of fluoride in the water may also cause skeletal fluorosis. Endemic skeletal fluorosis has been found in India, Pakistan, China, and most of the African countries (Fawell et al., 2006). Importantly, when considering issues relating to poor nutrition and diet, Osteroscelorosis, tendonous calcification, bone deformity and other related defects can also be present among individuals with high levels of exposure to fluoride (Sethi and Nitin, 2012).

In 1984, the World Health Organisation published guidelines for drinking water where it was suggested that in optimal amount, fluoride is considered the effective agent for preventing dental caries. However, high exposure in daily intake must be sanctioned due to the differing dose-response rate of individuals in relation to their environment. In 1984, WHO thus set a guideline value of 1.5 to 2.0 mg/L for fluoride in drinking water depending on the climatic condition of the region (Fluorine and Fluoride, IPCS International Programme on Chemical Safety, WHO, 1984). Added to that, to maximize benefits and minimize toxic effects, the WHO has set a range between 0.7 and 1.2 mg/L. Usually, when it comes to water fluoridation, of the set range (0.7-1.2 mg/L), 1 mg/L should be the optimal concentration (Fawell and Niewenhuijsen, 2003). This article therefore reviews the health impacts and the current flaws in water fluoridation relative to Central Asian countries such as Pakistan, India, Sri Lanka, Bangladesh and Nepal. This analysis is carried out to establish in-depth understanding of the impact of fluoride on health, which can help health authorities in their policy-making activities concerning fluoridation of water in the future.

Information and Discussion

In general, fluoride is added to water as a decontamination agent to remove bacteria and other possible contaminants (Sharma and Soneja, 2003). In various countries, especially in developing countries, fluoridation is often embarked upon in order to improve the water supply. Water fluoridation is a comparatively cheaper and easier option for most parts in Central Asia, whose need for water decontamination is imperative. On the other hand, developed countries have better water decontamination options thus enabling them to dienlist the fluoridation of water in their water purification schemes. In Central Asia, fluoridation of water is extant despite the substantive evidence of high levels of water fluoridation in many regions of Pakistan, India and other countries. However, in recent years, various health issues related to the persistent introduction of fluoride in the water have

Figure 1: Teeth fluorisis.

been raised. Some of these health issues are discussed in the following section.

Based on the assessment conducted by the British Geological Survey (2012), fluoride build-up has become significantly apparent in the ground waters of countries that have been hardest hit including China, India, Sri Lanka, Pakistan, and other African and South American territories. Fluorosis arose in India and became major issue for its various territories, including Andhra Pradesh and Tamil Nadu. Fluorosis also emerged as a major issue in Sri Lanka and Bangladesh (Fawell et al., 2006). In Pakistan, fluorisis is also a major health issue, particularly in Lahore, Kusur and Sargodha districts (Tariq et al., 2012). In recent years, recommendations on the elimination, or at least the reduction, of fluoride in the water have been suggested as a healthier option for the decontamination of water. To some extent, reduction in fluoride usage has been implemented; however, undeniably, the health effects of fluoride in water are still persistent.

Results presented by Anita Joshi and Gita (2003) show that fluoride levels in district Jaipur, India ranges from 0.12 to 15.64 mg/L. Deepu and Shaji (2011) observed fluoride concentration ranges from 0.2 to 5.75 in Kerala**.** Brindha and Elango (2011) reviewed fluoride levels of different countries and reported that more than 70% of water sources contained fluoride concentrations above threshold value in India. Moreover, Sharma and Soneja (2003) analyzed 287 samples in areas of Ladakh, Manikaran (Himachal Pradesh), Bhilwara (Rajasthan), Sohna (Haryana), Tantoly (Bihar), Tattapani (Chattisgarh), Bakreshwar (West Bangal), Khudra (Orissa) and Unkesher (Maharashtra) and found that fluoride levels ranged from 0.2 to 18.0 mg/L. In all, the highest concentration was observed in Ladakh. According to him, nearly 66 million people face the risk of fluoride effect, 10% of the total being children. Smitha and Randy (2012) reported cases of groundwater quality scenarios in state of Gujarat where 18 districts of the state had fluoride content above the permissible limit. Fluoride concentration in water sources of 15 main districts of India are shown in Table 1.

Nepal's geography is similar to some parts of India and they are still culpable of excessive fluoridation of their water supply. Though some studies have shown some measure of excessive fluoridation in the territories of Nepal, the verity of these assertions have not been fully backed up by reliable evidence due to deficiencies in supportive data and research friendly aids available in these areas. Hence, further studies and research is thus necessary. Tariq et al. (2012) reported a similar scenario in Punjab, Pakistan, a country adjacent to India.

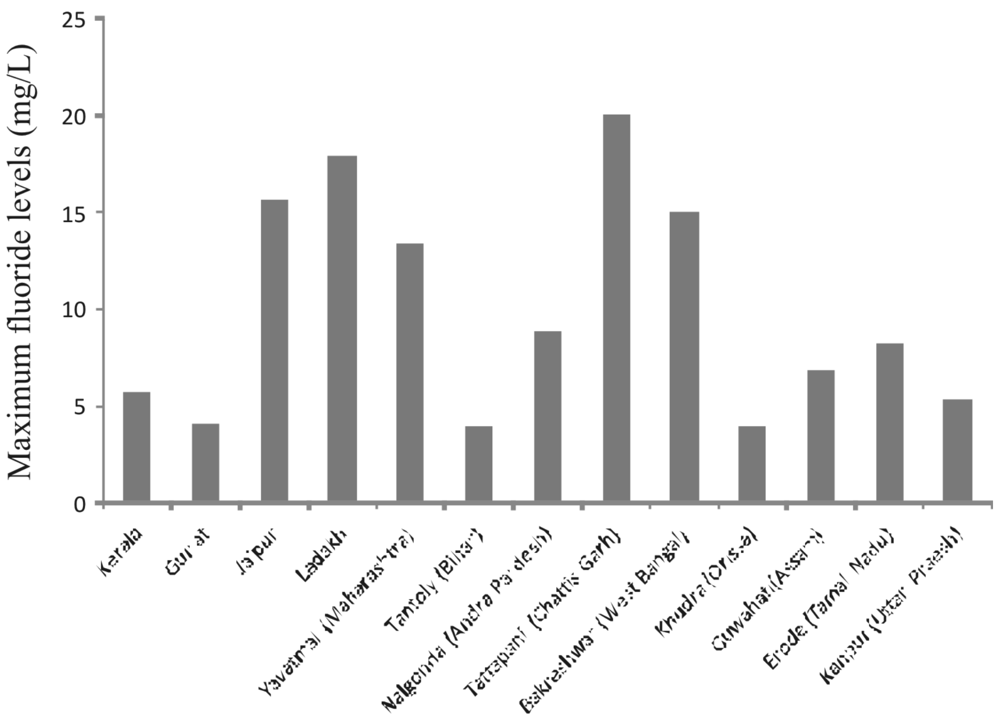

Figure 2: Maximum fluoride levels in polluted districts of India.

Source: Anita et al. (2003), Brindha et al. (2011), Deepu et al. (2011), Sharma et al. (2003) and Smitha et al. (2012).

Table 1: Fluoride concentrations in water of main districts of India

State	*Districts*	*Geogenic source*	*F^- Concentration (mg L^-)*	*Reference*
U.P.	Unnao, Agra, Varanasi, Mathura, Jhansi, Sonebhadra	Quaternary and Upper tertiary deposits	0.2-5.75	Nalini et al. (2008)
A.P.	Guntur, Anantapur, Hyderabad, Ranga Reddy, Nalagonda	Archean granite and gneissic complex	0.10-8.8	Brindha et al. (2011)
Gujarat	Almost all districts	Granite, gneissic complex, pegmatite and calcite deposits	0.94-2.81	Brindha et al. (2011)
Kerala	Muthalamada, Eruthenpathy, Athikodu, Vannamada, Nadupeni, Kulukkur, Chinnamoolathara, Vattalakki West, Kopanur, and Kodumthirapalli	Weathered and fractured crystalline and biotite gneissic complex	0.2-5.75	Shaji et al. (2007)
Jammu and Kashmir	Ladakh and Doda	Granite, gneisis complex, schist and lensoid of Protrozoic age	0.05-4.21	Meenakshi and Maheshwari (2006)
Rajasthan	All districts including Jaipur Nagaur and Bhilwara	Rocks containing fluorine and fluoride	0.12-15.64 0.64-14.62	Brindha et al. (2011) Radha et al. (2011)
Punjab	Amritsar, Ludhiana, Mansa, Faridkot, Jalandhar, Gurdaspur, Bhatinda, Muktsar, Moga, Sangrur and Patiala	Excessive use of phosphate fertilizers	0.44-6.0	Meenakshi and Maheshwari (2006)
Haryana	Rewari, Faridabad, Karnal, Sonipat, Jjind, Gurgaon, Mohindargarh, Rohtak, Kurukshetra, Sirsa, Hisar and Bhiwani	Rocks containing Fluorine and Fluoride	14-8.6	Susheela (1999)
Assam	Guwahati, Karbianglong and Nagaon	Granite	0.18-688	Brindha et al. (2011)
Delhi	Kanjhawala, Najafgarh and Alipur	Excessive irrigation and construction industry		Jacks et al. (2005)
T.N.	Dindgul, Salem, Periyar, Dharampuri, Coimbatore, Tiruchirapali, Vellore, Madurai, Virudinagar	Weathering of fluoride and rocks	0.5-8.2	Gopalan et al. (2009)
Bihar	Tantoly Palamu, Daltonganj, Giridih, Gaya, Rohtas, Gopalganj, Paschim and Champaran	Fluoride leaching from hornblende gneiss complex and granite rocks	0.35-4.00	Meenakshi and Maheshwari (2006)
W.B.	Bakreshwar, Birbhum, Bhardaman, Bankura	Over fertilization and fluoride leaching from hornblende gneiss	0.6-15.00	Kundu and Mandal (2009)

According to their analysis, fluoride level persists in range 0.15 to 23.6 mg/L in different cities of Punjab. The maximum value was observed in a well in Lahore, a location where public water supply is largely inexistent (Tariq et al., 2012). Azizullah et al. (2011) reviewed potable water problems in Pakistan. According to their report, typical fluoride level ranges from 0.38 to 26.8 mg/L. The maximum value was observed in city of Attock located in western part of Punjab, Pakistan (Azizullah et al., 2011).

Tahir and Rasheed (2012) analysed 747 water supply sources in 16 major cities of Pakistan and explored the fluoride toxicity. They observed around 16% of monitored sources having fluoride value above the permissible limit. They reported that Punjab and Baluchistan as having maximum fluoride levels with ranges less than 0.05 to 19.70 mg/L and 0.1 to 24.48 mg/L respectively. Fluoride levels in water sources of 29 cities of Pakistan are summarised in Table 2. Fazlul et al. (2003) reported that of all fluoride concentration levels in Bangladesh, groundwater sources had the lowest concentrations as they ranged from 0.22 to 2.32 mg/L with mean value of 0.56 mg/L.

Jayawardana et al. (2010) examined several water sources in Sri Lanka based on dry zone and wet zone and reported that the phenomenon of fluorosis and other fluoride effects were significantly seen in the dry zone. They analysed about 114 samples including 69 samples from the dry zone and 45 from the wet zone. They found that marked enrichment of fluoride in groundwater sources of the dry zone ranged from 0.2 to 8.0 mg/L. In a recent article by Sethi and Nitin (2012), the authors discussed the depleting ground waters in India relative to the persistent increase in its population, thus occasioning various public health issues, especially the contamination of their water supply. Unfortunately, fluoride was used to decontaminate these waters, an intervention which in turn has led to public health problems. The discovery of abundant levels of arsenic has also made matters worse particularly for groundwater resources in India. Adversely, the risk for Indians' health has been significant, especially among children. With excessive fluoride levels in their water, delays in their physical and mental development have been observed in addition to kidney problems among adults (Azizullah et al., 2011).

Similar situations have also been observed in Pakistan. Tahir and Rasheed (2012) highlighted that fluoride has been known to cause problems associated with the kidney, muscular system, as well as erythrocyte levels. They also added that with high levels of fluoride in Pakistan's drinking water, the occurrence of hip fractures has also increased. Fluoride has also been considered a carcinogenic, affecting mostly the bones. In Sri Lanka, aside from dental and skeletal fluorosis, chronic kidney disease has also emerged as one of the major health issues caused by fluoride. These health risks have also been seen in other Central Asian countries, including Nepal and Bangladesh. Along with other heavy metals like zinc and mercury,

Table 2: Fluoride levels in drinking water sources of main cities in Pakistan

S.No	*Location*	*No of Sample*	*Minimum*	*Maximum*	*Mean*	*Reference*
1	Attock	30	3.1	26.8	10.35	Azizullah et al. (2011)
2	Nagar Parkar (Sindh)	32	1.13	7.85	3.33	Azizullah et al. (2011)
3	Naranji (Kp0t)	5	8.76	13.52	-	Azizullah et al. (2011)
4	Faisalabad	40	0.38	1.15	-	Azizullah et al. (2011)
5	Faisalabad	30	0.04	5.16	0.89	Tahir et al.(2012)
6	Karachi	60	0.5	2.77	0.48	Tahir et al. (2012)
7	Karachi	106	0.95	21.1	11	Azizullah et al. (2011)
8	Kalanwala	4	0.38	2.85	1.47	Azizullah et al. (2011)
9	Bahawalnagar	6	0.24	2.50	1.67	Tariq et al. (2012)
10	Gujranwala	16	0.22	1.90	1.58	Tariq et al. (2012)
11	Lahore	28	0.15	23.60	2.96	Tariq et al. (2012)
12	Lahore	79	0.05	19.70	2.62	Tahir et.al. (2012)
13	Rahim yar khan	6	0.5	2.00	2.00	Tariq et al. (2012)
14	Sargodha	20	0.18	2.80	1.62	Tariq et al. (2012)
15	Shaikhopura	13	0.27	5.80	3.58	Tariq et al. (2012)
16	Chakwal	51	0.00	2.63	1.02	Tahir et al. (2012)
17	Bahawalpur	60	0.15	4.58	0.67	Tahir et al. (2012)
18	Mirpur Khas	55	0.00	1.80	0.74	Tahir et al. (2012)
19	Khushab	50	0.04	4.78	1.09	Tahir et al. (2012)
20	Mianwali	30	0.08	2.14	1.37	Tahir et al. (2012)
21	Kasur	46	0.35	4.10	1.11	Tahir et al. (2012)
22	Kasur	12	0.37	6.60	4.38	Tariq et al. (2012)
23	Quetta	81	0.03	24.48	2.47	Tahir et al. (2012)
24	Ziarat	21	0.01	1.51	0.39	Tahir et al. (2012)
25	Loralai	21	0.08	1.86	1.08	Tahir et al. (2012)
26	Mastung	37	0.63	2.27	1.13	Tahir et al. (2012)
27	Jhelum	53	0.05	0.64	0.37	Tahir et al. (2012)
28	Peshawar	38	0.05	1.10	0.29	Tahir et al. (2012)
29	Risalpur	35	0.78	2.09	1.27	Tahir et al. (2012)

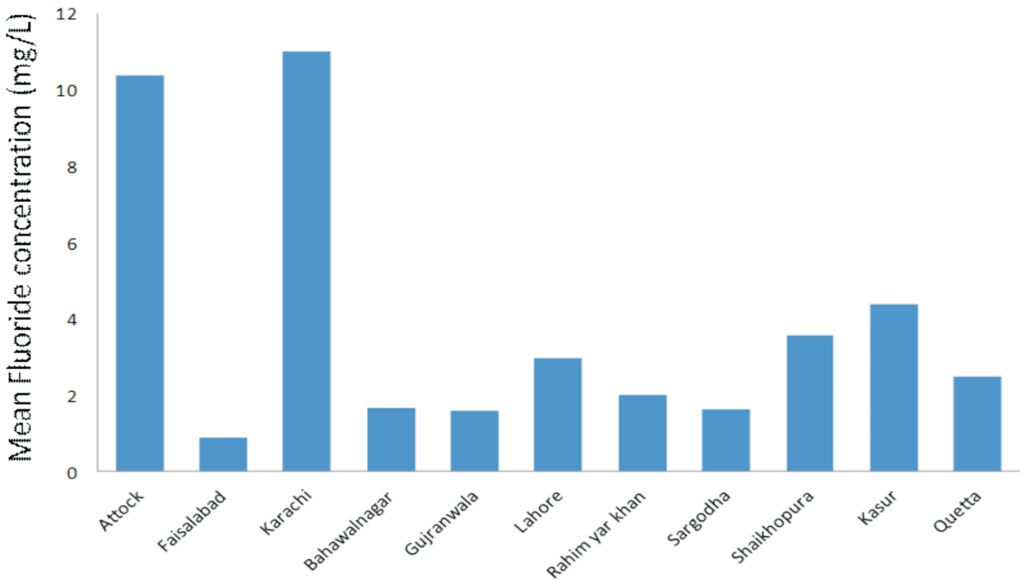

Figure 3: Statistical representation of fluoride concentration in cities of Pakistan.

Source: Azizullah et al. (2011), Tahir and Rasheed (2012), Tariq et al. (2012).

the concentration level of fluorine in ground water is high. Unfortunately, these are the heavy metals that have been known to cause most health risks to humans (Veressinina et al., 2001).

Tahir and Rasheed (2012) also pointed out, based on their study in Pakistan, that excessive levels of fluoride in water seems to have been a contributory element in the deaths of native people from unknown chronic diseases which share symptoms like bones and joints deformities. In India, tests undertaken by the government authorities revealed that about 70% districts in the country had fluoride levels in their ground waters where the level was above the permissible. The health authorities declared considering the safety levels of fluoride, serious health issues could arise, including weak bones and pain in joints (Brindha and Elango, 2011).

Scientists and other researchers have long established that excessive levels of fluoride in the water can be poisonous to the human body. Bryson et al. (2004) reported, based on studies on the enamel of children, that lines and spots were observed on the enamel indicating excessive fluoride exposure. Their studies revealed that high and persistent exposure to fluoride can block normal "breathing" for cells and can lead to the malformation of collagen (Bryson et al., 2004). The Environmental Protection Agency (EPA) in Washington also declares that there is a link between the fluoridation of water and the development of carpal tunnel syndrome

Figure 4: Skeletal fluorisis in Pakistan.

and arthritis (Aoki et al., 2007). *The Times of India* (2012) also reported that fluoride poisoning in untested wells was the cause of severe arthritis experienced by millions of people in Central India.

For older individuals, fluoridated water has also contributed to high risk of hip fractures and other bone impairments such as skeletal fluorisis. Figure 4 shows one of the adverse effects of fluoridation. This image report was the product of the studies indicating the detrimental effect of skeletal fluorosis in older people (Bryson et al., 2004).

The National Cancer Institute Toxicological Program (2012) also established that fluoride is a carcinogen. The US National Cancer Institute indicates that numerous cancer deaths have been attributed to fluoride. They also linked infertility with increased fluoridation. Scientists from the Food and Drug Administration report that there was a strong correlation between fertility rates in women and higher fluoride levels (Bryson et al., 2004). They also indicated that its impact on animal species in terms of fertility is actually even higher than in humans. Scientists also link high fluoride levels with brain damage or lower intelligence quotients (IQ). IQ levels of children with high exposure to fluoride were significantly lower. Shivarajashankara et al. (2001) presented a study on rats that also indicated neurotoxic effects being apparent when the subjects were exposed to high fluoride levels. The laboratory experiments also indicated that rats that were exposed to fluoride before birth were born hyperactive and retained this quality throughout their lives. However, those exposed as young animals indicated more depressed activity. The scientists established that brain cells exposed to fluoride might have mediated the depletion of some brain chemicals, thereby causing neurological issues (Shivarajashankara et al., 2001).

Fluoride Removal Techniques

Flocculation and adsorption are most common techniques used for removal of fluoride from drinking water sources (Tariq et al., 2012).

(a) Flocculation

The most common and pioneer method of removing fluoride is by flocculation where alum is used as a coagulant. Efficiency level of treatment is achieved under alkaline conditions, so lime is added during the process. Flocs are formed by chemical reaction with coagulant which settled down.

Presented in Figure 5 is the schematic process of water treatment by flocculation. It is a distinct three-step process. Firstly, the source water must be screened and passed through the optional steps of pre-chlorination and aeration, only then will it be set for flocculation. However, in the process of water treatment, flocculation entails two steps: water flows first into the flash mixer, and then enters the flocculation basin. Its chief aim is to clear out turbidity from the water. Flocculation also

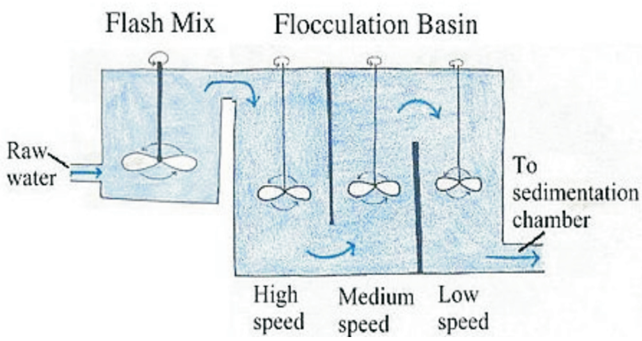

Figure 5: Flocculation process.

Source: Rosa, C. (2000).

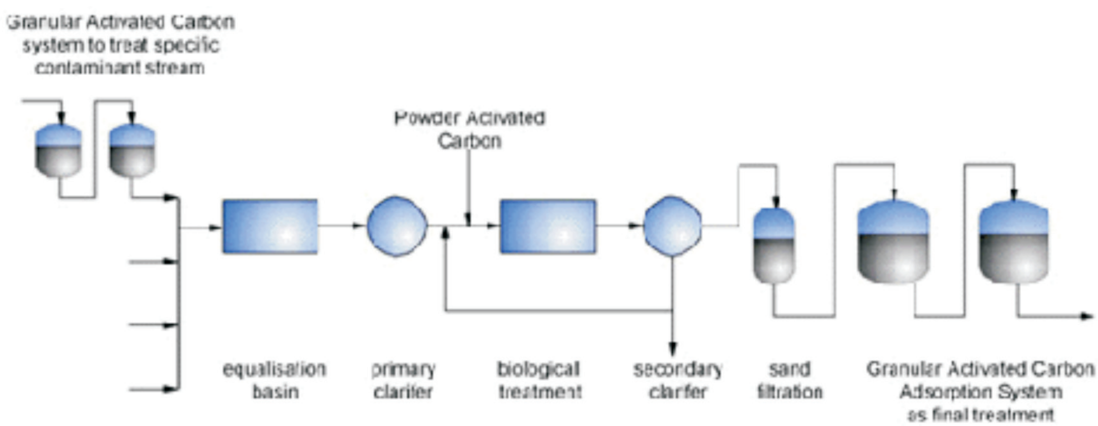

Figure 6: Typical water treatment using activated carbon.

Source: Chemviron Carbon (2012).

saves the water to be treated from bacteria and some harmful colouration. The first step centres upon water flowing into the flash mixer. The violent mixing effect and the application of a coagulant result in a coagulated water, which is a better presage for flocculation. The stage thus set, flocculation commences. Flocculation, through gentle mixing, compacts together some of the fine particles that were formed through coagulation. It typically lasts less than an hour. The end product of a well regimented coagulation/flocculation is a floc. A floc is a compacted impurity which forms a cluster. It settles out in the sedimentation basin as seen in Figure 5. The remaining flocs are filtered out by filtration.

(b) Adsorption

The second effective method is by adsorption where activated alumina (Al_2O_3) or activated charcoal is used as a strong absorbent. This technique is suitable for both community water supply and household use. The filter material needs to be backwashed when the adsorbent becomes saturated with fluoride ions. Weak acid or alkali solution can be used as a cleaning and regenerating agent. The effluent from backwashing is enriching with fluoride and disposal should be done carefully to avoid any further fluoride contamination.

Adsorption removes a soluble substance from the water. Active carbon is the main tool and it comes in two varieties—powdered and granulated form of active carbon.

Powdered Carbon: Some beaten form of carbon particles are employed for making powdered activated carbon. They are beaten to powdered form in order to allow an easy passage through a fine mesh sieve. Their extremely reduced size induces a large internal surface with small diffusion distance. It is majorly used as gravity filters, mix basins, etc.

Granulated Carbon: The large size of granulated activated carbon induces them to form smaller external surface because of their larger size in comparison with powdered active carbon. The main specialisation of granulated form is in water treatment. They are also capable of deodorising and separating flow system component.

Conclusion

Summarily, based on the discussion, it is safe to say that fluoridated water contributes to various health issues. In Central Asia, a high level of fluoride persists in various regions. In India and Pakistan, fluoride levels in drinking water sources range up to 18 mg/L and 26.8 mg/L respectively. Although the data for Nepal is unsystematic and incomplete, fluorosis is still a major challenge there. Sri Lanka's dry zone has also fluoride levels up to 8.00 mg/L. The problem of water fluoridation facing millions of people is usually in the form of dental and skeletal fluorosis, arthritis, high fracture rates, and similar bone-related affectations. Although permissible levels of fluoride may decontaminate waters, excessive and cumulative levels of fluoride contribute to serious health hazards, including those already mentioned, as well as cancer, carpal tunnel syndrome, and neurological issues. In the light of these premises, it is safe to conclude that it is high time the health authorities in Central Asia arose to establish alternatives to water decontamination.

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