Vicious cycle of fluoride in semi-arid India – a health concern

Excess fluoride in groundwater-based drinking water supply is a growing concern in semi-arid tropical (SAT) regions of India. More than 16 states in India are facing the fluorosis problem. Several southern-peninsular states are experiencing monsoon climate condition, where the rainwater is harvested through tanks and used for agriculture. Presence of millions of such tank systems in these regions and their interception in the fluoride cycle has been studied here on a pilot level in several tanks. The results show that these tanks are probably acting as sinks and cause the enrichment of fluoride in groundwater. The leachable fluoride level of tank silt is found to be several fold more than that of normal land soil of the area. With the aging of the system and increase in thickness of fluoride-laden tank silt, the rejuvenation of tank capacity through desilting and the practice of spreading silt in agricultural fields and further irrigating with fluoride-enriched groundwater, make fluoride enter in a vicious cycle in the environment and food chain thus causing great concern. Safe disposal mechanisms of fluoride-laden silt to end the cycle for safeguarding the groundwater used for drinking in the SAT regions are suggested here.

One of the environmental health issues connected with geogenic processes is excess fluoride in groundwater. Its ingestion through drinking and agricultural products leading to dental and skeletal fluorosis of hard-rock-covered SAT regions in India is severe, though the problem prevails in more than 25 countries of the world (Figure 1). A study conducted by the Central Ground Water Board, Government of India (Table 1) indicated that

Figure 1. Countries with endemic fluorosis due to excess fluoride in drinking water.

Table 1. State-wise population influenced by fluoride (F) content in groundwater

State	Population (millions)	Population influenced by *F* < 1.0 mg/l (millions)	Population influenced by *F* = 1.0–1.5 mg/l (millions)	Population influenced by *F* > 1.5 mg/l (millions)
Uttar Pradesh	139.11	110.28	17.18	11.63
Andhra Pradesh	66.50	63.62	1.60	1.27
Rajasthan	44.00	22.70	6.42	14.83
Maharashtra	78.93	76.41	–	2.44
Madhya Pradesh	66.18	61.48	3.04	1.52
Karnataka	44.97	36.88	5.26	2.78
Punjab	20.28	14.15	2.79	3.28
Haryana	16.46	7.19	2.57	6.67
Delhi	9.42	7.68	0.99	0.73
Orissa	31.66	26.31	1.90	3.41
Bihar	86.37	84.99	1.29	2.68
Tamil Nadu	55.85	47.87	6.36	1.56
Gujarat	41.31	38.83	1.03	1.40
West Bengal	67.98	67.98	–	–
Kerala	29.09	28.74	0.11	0.14
Jammu and Kashmir	7.71	7.71	–	–
Himachal Pradesh	5.17	4.71	0.25	0.06
North Eastern States	31.55	31.55	–	–
Total	842.54	739.08	50.79	54.39

Source: CGWB Report[1].

Table 2. Leachable soil fluoride analysis

Location (all tanks in Andhra Pradesh)	No. of tanks/sites studied	Average soil depth collected (cm)	Average leachable soil fluoride (ppm)								
			Soil analysis depth range (cm)								
			0–20	20–40	40–60	60–80	80–100	100–120	120–140	140–160	160–180
Irrigation tank	5	180	38.5	40.9	47.0	47.4	53.6	60.43	54.6	46.53	39.75
Percolation tank	3	160	2.33	4.9	5.07	5.87	9.03	7.87	12.6	14.2	
Irrigation tank feeder channel	2	140	12.35	15.1	24.85	26.35	28.5	22.5	23.2		
Agriculture field*	2	140	106.9	141.0	85.2	105.3	82	117.2	112.6		
Non-agriculture field (pastureland)	3	140	3.19	4.76	4.96	7.14	6.73	8.71	9.01		

*Fields spread with tank silt.

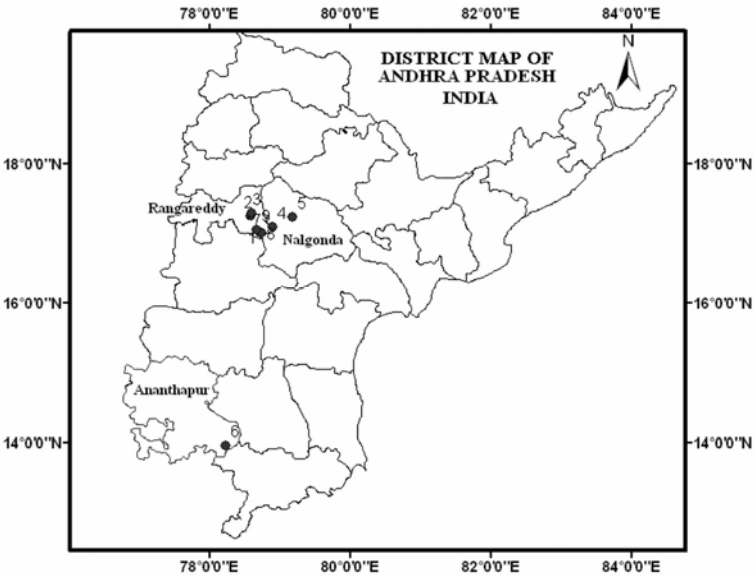

Figure 2. Locations of irrigation and percolation tanks studied.

more than 60 million people drink water having more than the permissible limit of 1.5 ppm of fluoride[1].

Out of several fluoride mineral-bearing rock formations, granites and alkaline rocks contain the highest percentage of fluoride and most parts of the SAT region are mainly covered with these rock types. During weathering of these rocks, the geochemical stage of fluorine controlled by a series of processes accumulates in the derivative product of weathering, namely the soil, and enters into the biotic system mainly through water. Thus the study of soil and water becomes critical in understanding the fluoride mobilization process and the interference of anthropogenic activities in the natural fluoride cycle.

Water management through tanks/ponds and harvesting the seasonal rainwater is a common practice followed in semi-arid regions of India. The presence of millions of tanks of various sizes in southern peninsular India, a semi-arid region, itself exemplifies the traditional wisdom nurtured in these regions. The number of irrigation tanks accounts for 1.2 million, irrigating 1.8 m ha (ref. 2). Silting of tanks has been one of the main causes for the decline in the effectiveness of this system over a period of time. A sample survey conducted in India indicated that out of 125 irrigation tanks, 16 tanks had silted more than 50%, 51 tanks between 25% and 50%, 50 tanks between 10% and 25%, and only 8 tanks less than 10% (ref. 2). As the tank silt is rich in organic nutrients, it is a general practice for farmers to remove silt from the tank during the dry season and spread it in their agricultural fields. In recent years, to control groundwater depletion, programmes were implemented to harvest rainwater by constructing new tanks for increasing recharge to the groundwater and reviving the old tanks through desilting operations. Farmers were encouraged to spread the excavated silt on a larger scale over their agricultural fields. Through this process, it was thought that the problem of disposing the large amount of silt coming out of the desilting operations could be solved and the agricultural production may increase.

We have conducted a study on leachable fluoride levels in silt/soil of five silted, minor irrigation tanks, three percolation tanks, two irrigation tank feeder channels and two agricultural fields spread with the tank silt and in pasturelands near three of the studied irrigation tanks in fluoride-affected regions of Andhra Pradesh, India (Figure 2). Soil core samples were collected in 20 cm depth sections to a maximum depth of silt/soil at several sites in each tank system studied and at several sites in other areas of study. These soil cores were subjected to leaching studies in the laboratory using deionized water and the fluoride content was measured using a spectrophotometer. Each soil core sample was subjected to leaching cycle till the fluoride content in the water was below detectable limit. The results of leachable fluoride experiment of all the sites are presented in Table 2.

The experimental study indicated that the irrigation tank silt is rich in fluoride and the leachable fluoride varies between 40 and 60 ppm. Studies in the agricultural fields using tank silt indicated that the soil had more than 100 ppm leachable fluoride content, whereas soil from new tanks and pasturelands had less than 10 ppm. Most of the foreshore areas of tanks are leased and cultivated with the help of groundwater. During the

Table 3. Fluoride content in various food items

Food item	Fluoride (mg/kg)	Food item	Fluoride (mg/kg)
Cereals		Fruits	
Wheat	4.6	Banana	2.9
Rice	5.9	Mango	3.2
Maize	5.6	Apple	5.7
Pulses		Guava	5.1
Gram	2.5	Beverages	
Soybean	4.0	Tea	60–112
Vegetables		Coconut water	0.32–0.6
Cabbage	3.3	Spices	
Tomato	3.4	Coriander	2.3
Cucumber	4.1	Garlic	5.0
Ladies finger	4.0	Ginger	2.0
Spinach	2.0	Turmeric	3.3
Mint	4.8	Food from animal sources	
Brinjal (egg plant)	1.2	Mutton	3.0–3.5
Potato	2.8	Beef	4.0–5.0
Carrot	4.1	Pork	3.0–0.5
		Fish	1.0–6.5

Source: A. K. Susheela[4].

southwest monsoon season (June–September), the tank feeder channel carries soil from these agricultural lands and deposits it in the bed of these tanks. The analysis of soil leachable fluoride of the tank feeder channel indicated a range of 12–28 ppm causing the mobilization of fluoride in the tank-water system. Crops like paddy, maize, etc. grown under such conditions are bound to pick up the fluoride from soil, which thus enters into the biotic chain. Further, the irrigation water would carry some of the fluoride from soil while percolating and add it to the groundwater. The average fluoride partition factor, which is a measure of specific fluoride adsorption of cereals and pulses, was found to be highest in red chillies (15.7), followed by sorghum (3.6), wheat (2.4) and rice (2.4)[3]. These are staple foods of people living in rural areas. The fluoride content in various food items analysed under the Fluoride Mission Programme of India is presented in Table 3.

In the case of newly constructed tanks for water-harvesting in fluoride-rich belts, it was found that fluoride was getting enriched at deeper levels. Leachable fluoride concentration was found to be less than 2 ppm at the surface to more than 10 ppm at 140–160 cm depth. This explains the process of fluoride migration through percolating waterfront in each cycle of tank-filling.

Spreading the silt as a good nutrient in fields is found to be adversely affecting the fluoride-rich belts. Creation of additional water resources through rainwater harvesting by new tanks induces fluoride enrichment in groundwater of high fluoride-affected areas. Thus, a paradoxical situation persists in the semi-arid belts.

Some corrective steps to be taken are as follows:

- Harvesting more rainwater in the upper reaches before the fluoride concentration increases in the surface water, and using it for drinking purposes by treating the surface water.
- Construction of tanks exclusively in the upper reaches for percolation of fluoride-free surface water to decrease fluoride concentration in groundwater of the downstream region. Such experiments conducted in hard-rock areas of southern India significantly reduced fluoride concentration in groundwater and sustained in meeting the demand.
- Using fluoride-laden tank silt for building materials such as bricks and arresting further degradation of the environment by tapping the fluoride.

The key to minimizing the risk is to incorporate hydrogeological, geochemical and microbiological expertise into the decision-making process in the rejuvenation of old irrigation tanks in fluoride-rich regions with the safe disposal methods. Planners, managers, pollution regulation specialists and the community have to work in tandem with earth scientists to save the environment for the future generation. It is also essential to demarcate the high-risk areas and provide them with alternative sources of drinking water as an immediate measure.

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