Review Article

Endemic Hydrosis in Cattle (*Bos taurus*) in India: An Epitomised Review

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Abstract

In India, a slow progressing water-borne dreaded hydrofluorosis disease is endemic in rural areas where drinking groundwater contains fluoride >1.0 or 1.5 ppm. In the rural areas, most people feed their domesticated cattle (*Bos taurus*) water from hand-pumps and bore-wells, which usually contaminated with fluoride toxicant. Because these drinking water sources are easily available and accessible in rural areas. In the country, drinking groundwater of 23, out of 37 states and union territories is found to be contaminated with fluoride with varying amounts. When cattle exposed to fluoride for a long period of time through drinking groundwater of these sources then hydrofluorosis is developed in them. Thousands of cattle and their calves of rural areas of six states namely, Andhra Pradesh, Chhattisgarh, Karnataka, Madhya Pradesh, Odisha (Orissa), and Rajasthan of the country found to be victimised by this disease. Actually, in this disease, many types of incurable and irreversible deformities develop in the teeth and bones of animals. In general, in hydrofluorosis, teeth of cattle become weak and mottled (dental fluorosis) and animals walk with a limp (skeletal fluorosis). In the country, the highest prevalence, 89.6% of dental fluorosis and 42.7% of skeletal fluorosis at 1.3-6.7 ppm and 1.5-4.4 ppm fluoride concentration in drinking waters has been reported, respectively. In present communication, fluoride distribution in drinking groundwater, endemic hydrofluorosis in cattle and its determinants, economic implications, and prevention and control are briefly and critically reviewed. Along with this, research gaps have also been highlighted for researchers for further research work on chronic fluoride toxicosis in animals.

Keywords: Hydrofluorosis; Cattle (*Bos taurus*); Fluoride; Prevention and control; India

INTRODUCTION

India is the seventh largest country in the word and comprises 28 states and nine union territories. According to the 19th Livestock Census-2019, the total number of livestock in India is 512.1 million, out of which 119.9 million are cattle. Before the 80s, rivers, ponds, dams and dug open-wells were the main source of drinking water for these animals. At that time, dracunculiasis disease caused by human nematode round worm, dracunculus (*Dracunculus medinensis*) infection was more prevalent especially in the rural areas of India in the form of epidemic [1-3]. After 1986, thousands of hand- pumps and bore-wells were dug in villages and remote areas to provide clean water in rural areas for its eradication. Later, most of the herders started feeding the water of these water sources to their animals. Because these drinking water sources are easily available and highly approachable almost everywhere in the rural areas or villages. But the cattle rearers and the responsible people did not know that there is fluoride in the water of these drinking water sources, hand- pumps and bore-wells.

In the rural areas of the country, drinking groundwater of most of the hand-pumps and bore-wells of 23, out of 37 states and union territories contaminated with fluoride naturally or by geogenic processes [4-7]. Distribution of fluoride in groundwater in rural areas of different states and union territories has been shown in Figure 1. In the states of Andhra Pradesh, Gujarat, Rajasthan, and Telangana, where 70-100% of the districts are endemic for fluoride and the rest of the states have 40-70% of the districts. It is well known, an excess consumption or exposure to fluoride for prolonged period through drinking groundwater having fluoride more than 1.0 or 1.5 ppm [8-10] then it causes a serious disease known as hydrofluorosis. This disease has been reported in India in both human populations [11-20] and diverse domesticated animals such as bovines, flocks, equines, and dromedary camels [21-29]. In the country, fluoride emitted from various industrial activities is also causing a fluorosis disease (industrial fluorosis) in man and animals [30-33].

Though high level of fluoride in drinking groundwater in several states but studies on hydrofluorosis in domesticated cattle (*Bos taurus*) are still limited. However, few interesting and significant studies on hydrofluorosis in cattle in relation to different fluoride concentration have been conducted in different states of India which have been shown in Table 1. In present communication, endemic hydrofluorosis in cattle and its determinants, adverse economic consequences, and prevention and control are briefly and critically reviewed. Simultaneously, research gaps have also been highlighted which are useful for researchers to do some an advance research works on chronic fluoride intoxication in diverse species of domestic animals such as cattle (*Bos taurus*), water buffaloes (*Bubalus bubalis*), sheep (*Ovis aries*), goats (*Capra hircus*), horses (*Equus caballus*), donkeys (*Equus asinus*), and dromedary camels (*Camelus dromedarius*).

Table 1: State wise reports on prevalence (%) of dental fluorosis (DF) and skeletal fluorosis (SF) in domesticated cattle (Bos taurus) in relation to fluoride (F) concentration (ppm) in drinking water.

States	F range	Total number	DF	SF	References
1. Andhra Pradesh					
*Anantapur	1.0- >3.0	Cases	-	-	34
*Nalgonda	9.2-11.8	Cases	-	-	35
2. Chhattisgarh					
*Durg	0.2-13.2	Cases	-	-	36
*Rajnandgaon	2.6-12.7	Cases	-	-	37
3. Karnataka					
*Mysore	1.0- >3.0	Cases			34
4. Madhya Pradesh					
*Shivpuri	1.65-3.91	25	40.0	-	38
5. Odisha (Orissa)					
*Nayagarh	1.12-1.30	1117	18.09	-	39
6. Rajasthan					
*Banswara	0.2-5.5	22	13.6	-	40
		102	6.8	2.5	
	1.2-4.6	598	-	5.4	41
*Bikaner	1.5-2.5	24	41.7	-	42
		75	37.3	40.0	
	1.6-2.2	85	21.8	8.2	43
*Dungarpur	1.7-6.1	1521	66.2	35.8	44
	1.4-6.0	901	59.3	35.6	45
	1.1-4.1	538	-	9.6	41
	1.3-6.7	280	89.6	-	46
	0.8-7.6	326	67.7	-	47
		1127	2.6	36.0	
	1.5-4.4	836	50.0	42.7	48
*Sirohi	3.0-12.0	260	59.2	31.5	49
*Udaipur	0.3-7.0	143	39.1	-	50
	0.2-4.6	548	-	-7.4	41
	0.0-1.0	75	42.6	-	51
		175	30.8	-	

*, District.

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Fluoride in groundwater

Groundwater of almost all the rural areas of India contains an anomalously high amount of fluoride which has been shown in Figure 1. This is the natural and due to presence of heavy deposition of fluoride- bearing minerals in the host rocks and sediments. The most important and common rocks are basalt, granites and gneisses, shales and clays, limestone, sandstone, phosphorite, and coals (ash). In these rocks, fluoride is found in the range (ppm) of 20-1060, 20-2700, 10-7600, 0-1200, 10-880, 24,000-41,500, and 40-480, respectively. The average fluoride concentration (ppm) in these rocks is 360, 870, 800, 220, 180, 31,000 and 80, respectively. Some minerals of these rocks such as biotite, phlogophite, lepilodite, and muscovite contain a very high amount of fluoride (ppm), 970-3500, 3300-37,000, 19,00-68,000, and 170-14,800, respectively [6,52,53]. Other mineral deposits such as sallaite (MgF_2), villiaumite (NF), fluorspar (CaF_2), cryolite (Na_3 Al F_6), Bastnaesite (CeLaY) (CO_3)F, fluoroapatite [$Ca_5(PO_4)_3$ F] etc. also contain fluoride with concentration (%) of 61, 55, 49, 45, 9, 3.5, respectively [54]. Their chemical properties like decomposition, dissociation and dissolution, and interaction with water is considered to be the main cause of fluoride in groundwater. But distribution of fluoride in any region is under control of regional hydrogeological and climatic condition. Besides hydrogeological set up, the climate and physiography are other important factors that the areas of less rainfall have higher fluoride content as compared to groundwater in high rainfall areas despite having similar hydrogeological formation [55]. Nevertheless, level of fluoride concentration in groundwater is much more depends on the weathering and leaching process, chemical composition of parental rocks, the presence and accessibility of fluoride minerals to water, and the time contact between the source of minerals and water [55].

Hydrofluorosis in cattle (*Bos taurus*)

Ingestion of excess fluoride for a long-tenure is accumulated gradually in biological systems and develops diverse adverse toxic effects in the body. The condition is referred to as fluorosis or fluoride-induced toxicity [8,56]. If fluorosis is developed through drinking of fluoridated drinking water then it is called hydrofluorosis. Its clinical or pathognomonic signs or chronic fluoride toxicity generally appeared in teeth, bones, and soft organs are also referred to as dental fluorosis, skeletal fluorosis, and non-skeletal fluorosis [57,58].

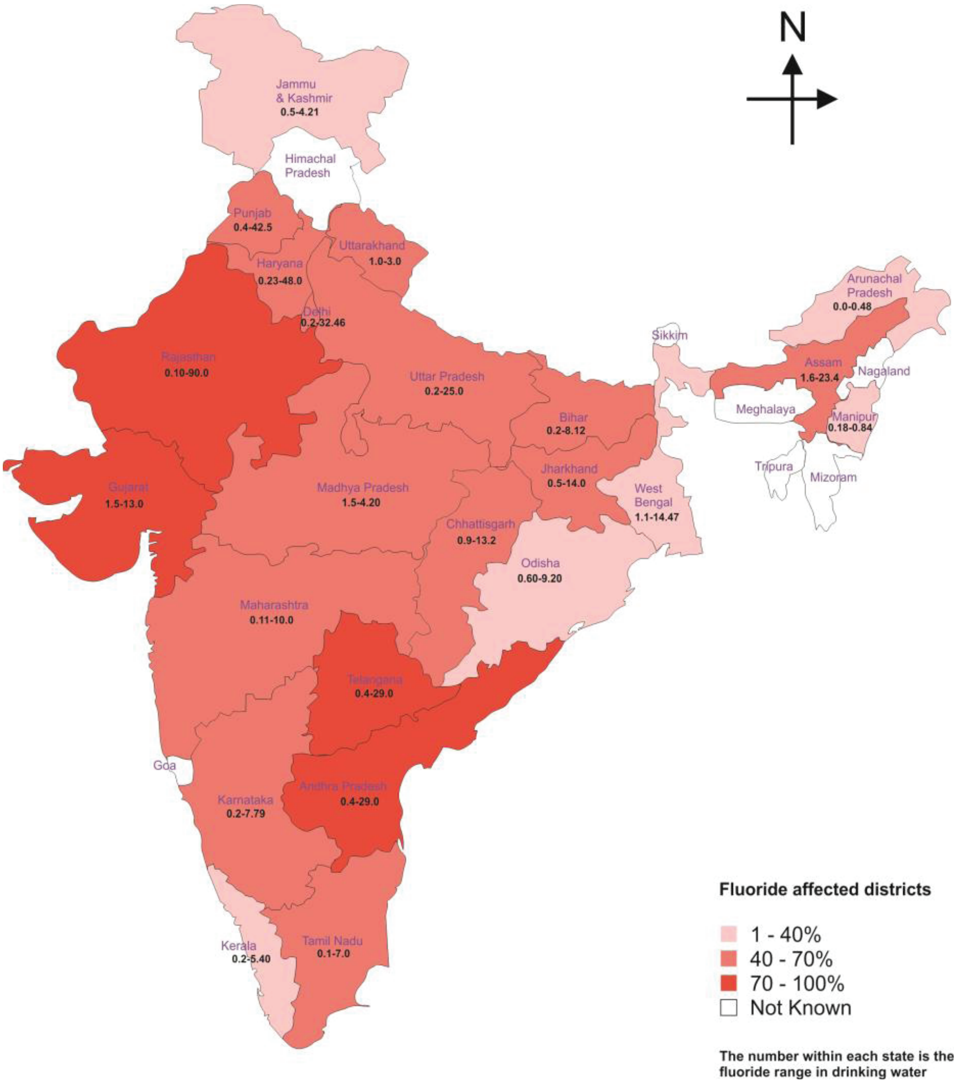

Figure 1: Map of India showing fluoride (in ppm) distribution in drinking groundwater in states and union territories [7].

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In India, for the first time in 1934-35, hydrofluorosis was detected in a pair of bullocks by farmers in Nalgonda district of state of Andhra Pradesh (now is Telangana state). In fact, these bulls were unable to walk due to painful and stiff gait. However, scientifically, hydrofluorosis in cattle as well as in other domestic animals was identified and reported for the first time from the Nellore district of Madras Presidency of south India [34]. Later on hydrofluorosis in cattle has also been reported from different states of India (Table1). However, this disease has not been extensively studied in highly economically important cattle animals. Though drinking groundwater of several states contaminated with fluoride and found beyond the maximum permissible level (> 1.0 or 1.5 ppm). Therefore, to know the exact status of chronic fluoride poisoning in cattle in the rural areas of the country more epidemiological studies on endemic hydrofluorosis in cattle is highly needed. In fact, the results or findings these survey studies are important and helpful in making of health policy to overcome this health problem in animals.

Dental fluorosis

The earliest visible pathognomonic or clinical sign of hydrofluorosis in man and animals is the dental mottling (dental fluorosis) [57,58]. This is the most recognizable, irreversible, sensitive, and indexive sign of chronic fluoride toxicosis. In India, dental fluorosis is rampant in cattle and is characterized with bilateral, striated, and light to deep brownish staining on teeth surface (Figures 2a-d) [41,59]. In some cases, unusual dental staining is also appears in the form of light to deep brownish spots, patches, and fine dots or granules on the surface of teeth. In severe dental fluorosis, pronounced loss of teeth supporting alveolar bone with recession and swelling of gingival and excessive wearing of teeth giving a wavy appearance have also been reported. In the study, performed in the Rajasthan state where drinking water contained fluoride in the range of 1.5-2.5 ppm teeth of cattle calves found to have well stratified blackish dental staining instead of brownish yellow (Figure 2d) [41]. Such blackish staining in buffalo calves had has also been reported [42]. However, the exact reason for this difference is not yet clear. Therefore, more studies are required to understand and confirm the exact cause of blackish staining.

In the country, the maximum prevalence (89.6%) of dental fluorosis in cattle was reported at the fluoride concentration 1.3-6.7 ppm in drinking waters [46]. At 4.7 ppm fluoride concentration 100 % prevalence of dental fluorosis in calves has been reported [50]. In fact, high prevalence of dental fluorosis in calves compared to adult animals at low level of fluoride indicates that calves are more susceptible and has low tolerance to fluoride toxicity [51]. Therefore, calves have been considered as ideal bio-indicators for endemic of fluoride and its intoxication, fluorosis [28,60,61,]

Dental fluorosis has the most negative aspect; it reduces the life-span of animals. In its severe state, teeth become weak and fall out in early age. This is enough to cause difficulty in grazing and mastication, the animals die at a young age from hunger and cachexia [10,62]. Nevertheless, the death of animals at an early age has economic consequences for herdsmen. But most animal reares are unaware of it.

Skeletal fluorosis

Fluoride-induced bony changes or anomalies are dangerous, more painful and highly significant since these diminish the mobility of animals in early age. The most common bony changes such as periosteal exostosis, osteosclerosis, osteoporosis and osteophytosis are found in the fluorotic subjects [17,63-65]. These changes appear clinically in the form of vague aches and pains in the body and joints which are associated with rigidity or stiffness and lameness, stunted growth, palpable bony lesions, and snapping sound in feet during walking in animals [41,42,57]. Simultaneously, these progressive and irreversible bony changes become more severe with increasing of fluoride concentration in drinking water and the advancing of age of animals. The excess accumulation of fluoride in muscles also diminishes or restricts the bone movement which leads to lameness in animals. Although intermittent lameness, enlarged joints, debility, mortality, hoof deformities, wasting of body muscles, and bony exostosis or lesions in the mandibles, ribs, metacarpus and metatarsus regions are well recognized in the fluorosed animals (Figures 3a,b). In advance skeletal fluorosis, ankylosis in animals is also seen in cattle afflicted with hydrofluorosis [34]. But this bony anomaly is rare in the cattle in India. The maximum prevalence (42.7%) of skeletal fluorosis in cattle was reported at the fluoride concentration 1.5-4.4 ppm in drinking waters [48]. This form fluorosis also found in calves (Figure 3).

Non-skeletal fluorosis

Fluoride not only affects the teeth and bones but also affects the soft organs of the body. Fluoride-induced diverse health complaints due to changes in organs are referred to as non-skeletal fluorosis. In cattle, the most common health complications or complaints such as gastrointestinal discomforts (loss of appetite, bloating, colic pain, constipation, intermittent diarrhea etc.), frequent tendency to urinate (polyuria) / itching in the region, frequently intake of water (polydipsia), muscles/body weakness, allergic reactions, irregular reproductive cycles, abortion, still birth etc. are the resultant of chronic fluoride intoxication [41,42,57]. This is not necessary that all these

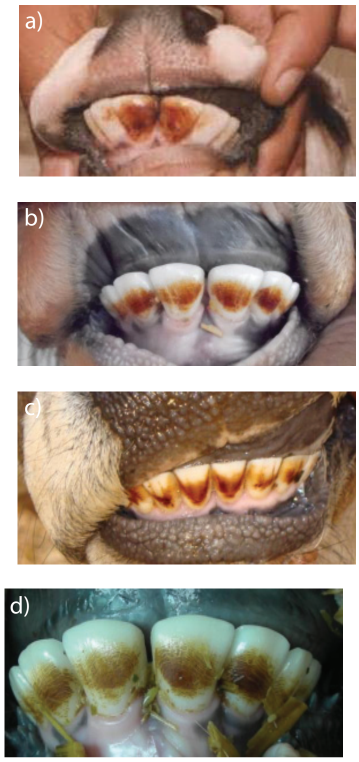

Figure 2a-d: Severe dental fluorosis in cattle calves (Figures 2a-c) and mature animal (Figure 2d) characterized with deep brownish staining and attrition of teeth [42,59].

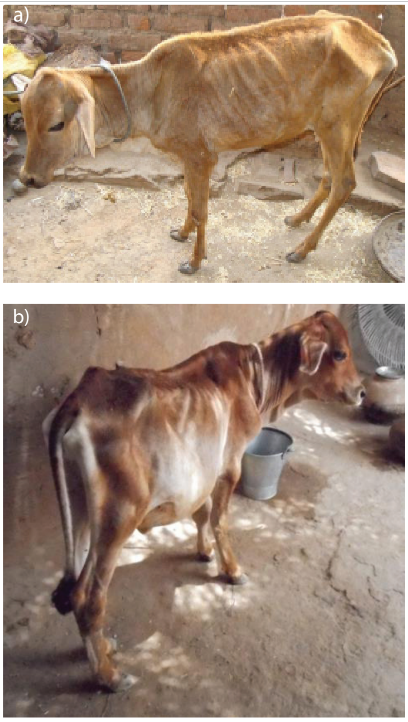

Figure 3(a,b): Severe skeletal fluorosis in calves and adult cattle characterized with lameness in hind legs, enlarged joints, debility, invalidism, wasting of body muscles, and bony lesions in ribs, metacarpus and metatarsus regions [27,41].

health issues are found in single animal and all these are reversible after withdrawal of fluoride exposure. However, works on fluoride toxicity in excretory, nervous and reproductive systems, endocrine glands, and embryogenesis in cattle are not adequate and well-studied yet. Therefore, understanding of the precise mechanisms involved in fluoride toxicity in these organ systems requires more research work at the molecular level.

Determinants

Interestingly, at approximately the same fluoride concentration in drinking water from different geographic provinces, the prevalence and severity of fluoride intoxication or hydrofluorosis in cattle are not found to be the same, but vary greatly (Table 1). This indicates that some determinants or factors are involved and responsible for controlling fluoride toxicity. These are well studied in both animals and human beings. The most important and common determinants are fluoride concentration in drinking water and its duration and frequency of exposure, density or rate of bio-accumulation of fluoride, chemical constituents in drinking water, age, sex, habits, food constituents, environmental factors, individual susceptibility and biological response or tolerance, health, and genetics of an individual [66-76]. However, further studies are still needed to understand the relationship of these determinants to chronic fluoride toxicity in different animals of different geographic regions where drinking water is contaminated with different fluoride concentrations. Finding of these studies will be useful in the prevention and control of endemic hydrofluorosis.

Possible adverse economic implications

The economy of rural India is mainly dependent on agriculture and animal husbandry. These two sectors are also complementary to each other. That is why people in villages still do animal husbandry along with agriculture. Due to getting milk, dung, leather, meat, bones etc. from the rearing of cows, the cattle rearers gets a very good income. But due to dental fluorosis, animals die at a young age, due to which the animal owner has an unintended economic loss. Second, fluorosis reduces milk production in cows, which also causes tremendous economic loss to animal husbandry. Male animals become lame due to skeletal fluorosis, which ends their usefulness in agriculture. Because of which the cattle rearer has to buy a new male animal for farming. This also causes financial loss to the cattle rearer. Selling lame animals in the market does not fetch the right price, which also has to be economical. Furthermore, chronic fluoride toxicity impairs reproductive function in animals, which ultimately affects animal productivity. The actual economic loss due to fluorosis in cattle or any domestic animal has not yet been estimated, which is more important. Therefore, there is a need for more and more scientific research studies on this subject so that the economic loss caused by fluoride can be assessed correctly.

Prevention and control

Hydroluorosis in cattle of any area can be prevented and controlled with a little effort. For this, it is most important that animals should not be fed hand-pump and bore-well water as far as possible. There is no possibility of fluorosis by providing clean water without fluoride. To prevent this disease, it is more important to give healthy food to the animal and bring awareness among the villagers or animal keepers. Defluoridation of fluoridated water at community level can be done by adopting Nalgonda defluoridation technique which is ideal and cost wise it is not much expensive. If this is not possible, rainwater harvesting and conservation is the most suitable and easiest way to get regular fluoride free drinking water for the animals. Another effective option is to provide fresh surface waters (ponds, reservoirs, dams etc.) instead of groundwater (hand- pump and bore-well water) to domesticated cattle which contain fluoride in the range of 0.01-0.3 ppm [8,77].

CONCLUSION

In India, 23, out of 37 states and union territories have fluoride in their drinking groundwater beyond the threshold level of 1.0 or 1.5 ppm. Drinking of such fluoridated water by domesticated cattle for long- tenure then it becomes highly toxic and injurious to their health and causes dreaded hydrofluorosis disease. Thousands of cattle are found to be afflicted with dental, skeletal, and non-skeletal fluorosis. This disease is endemic in cattle of rural areas of seven states, namely Andhra Pradesh, Chhattisgarh, Karnataka, Madhya Pradesh, Odisha (Orissa), and Rajasthan. To know the state wise status of hydrofluorosis in cattle, an epidemiological study in fluoride endemic state is highly needed. The data or findings of these studies will be useful not only in formulating animal health policy but also in the prevention and control of this disease. This disease can be prevented and controlled in animals by providing fluoride free drinking water and healthy food and the developing of awareness in animal reares or villagers. The significance of present review is not only to provide the scientific information of endemic hydrofluorosis in cattle to the potential researchers but will also be useful in the preparation of animal health plan for the mitigation of endemic hydrofluorosis in economically important cattle animals in India.

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Conflict of interest

The author declares no conflict of interest.

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