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Are Bovine Calves Ideal Bio-Indicators for Endemic Fluorosis?

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Editorial
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Abstract

Fluoride occurs naturally in water, rocks, and soils or from modern industrial processes, such as such as coal burning power generation stations, and manufacture of steel iron, aluminium, zinc, phosphorus, chemical fertilizers, bricks, glass, plastics, cement, hydrofluoric acid, etc. Long-term regular exposure to fluoride through fluoride-contaminated drinking water and air-borne fluoride can cause serious and disabling health effects in both humans and animals. However, in mammalian species, the skeleton in particular is relatively more sensitive or susceptible; growth on the bones and fusion of the joints cause lameness and lack of mobility at an early age. Teeth can become severely worn and damaged, often losing their enamel. Fluorosis has been well studied at different fluoride concentrations in drinking waters in different species of domestic animals, such as cattle (*Bos Taurus*), water buffalo (*Bubals bubalis*), sheep (*Ovis Aries*), goat (C*apra hircus*), camel (*Camelus dromedaries*), horse (*Equus caballus*), donkey (*E. asinus*), etc. Recent studies indicate that among these animals, bovines (cattle and buffalo) are found to be relatively less tolerant to fluoride toxicity and suffer from more severe fluorosis than other animal species. Their calves are also found to be relatively more sensitive to fluoride toxicity than immature animals or juveniles of other species. Cattle and buffalo calves were found to suffer from dental fluorosis even at fluoride concentrations less than 1.5 ppm in drinking water and a relatively high prevalence of 58.42% and 62.82%, respectively was observed. Therefore, bovine calves can be considered an ideal bio-indicator for endemic fluorosis as they show the earliest pathognomonic sign of chronic fluoride intoxication in the form of dental fluorosis compared to other animal species. Whether fluorosis is endemic in any geographical province or region can be interpreted from the evidence of dental fluorosis in bovine calves, which is highlighted and focused in the present editorial.

Keywords: Bio-Indicator; Bovine Calves; Dental Fluorosis; Drinking Water; Fluoride; Fluorosis; Industrial Fluoride Pollution; Skeletal Fluorosis

Introduction

In animals, three major sources of fluoride exposures are possible, fluoridated drinking water, industrial fluoride emission, and fluoride-rich feed phosphate supplements. However, the commonest source of fluoride exposure for animals is the fluoridated drinking water which is natural or geogenic in origin. Remaining two sources are anthropogenic and restricted to a specific area or region and are also potential sources for developing of fluorosis in man and animals [1-7]. In the rural areas, several coal- burning and industrial activities like electric generating processes and aluminium, iron, steel, zinc, chemical fertilizers, bricks and hydrofluoric acid production factories emit or release fluoride into surrounding environments [1]. This emitted fluoride contaminates diverse food chains, agriculture soil, Fresh water sources, air, vegetation, agriculture crops, and biotic communities around fluoride emitting industries, on which animals are generally dependant for foods and drinking water. Long-term fluoride exposure through any fluoride source causes diverse serious health hazards, including a serious disease called fluorosis, not only in humans [8-24] but also in various mammalian species of wild [25-32] and domestic [33-53] animals. Thousands of animals around the world suffer from chronic fluoride intoxication or endemic fluorosis due to drinking of fluoridated water and inhalation of air-borne fluoride. Is it possible to predict the endemicity of fluorosis in any area without fluoride testing of water, air, and biological and environmental samples? Yes, this could be possible with bovine calves as these are ideal bio-indicators for endemic fluorosis. Factual information about how this may be possible is described and focused on in this editorial.

Fluorosis

Regardless of the source of fluoride exposure, once fluoride enters the body, it is absorbed by the digestive and/or respiratory tract. Through these it reaches various organs or tissues of the body through blood. More than 50% of the absorbed fluoride is excreted from the body through excretory products, faeces and urine, and sweat, while the rest is retained in the body where it gradually accumulates in various organs. But its maximum bioaccumulation is found in calcified tissues, such as bones and teeth. Nevertheless, the bioaccumulation of fluoride in growing calves and juvenile animals is relatively higher than in adult animals [32,54,55]. Therefore, an early sign of chronic fluoride toxicity commonly appears in the form of dental fluorosis in calves and juveniles. This accumulation of fluoride causes toxic changes and interference in physiological and biochemical or metabolic processes that ultimately trigger the generation of adverse reversible and non-reversible toxic health effects in humans and animals. These fluoride-induced toxic or health changes are collectively known as fluorosis [1,5,6]. Various fluoride-induced anomalies or deformities in the teeth (dental fluorosis) and bones (skeletal fluorosis) are permanent, irreversible, not curable and are detected visually. If fluorosis develops from exposure to fluoride through fluoridated water and industrial fluoride pollution it is known as hydro fluorosis and industrial fluorosis, respectively [1,3,5].

Dental Fluorosis

The first and most recognizable sign of chronic fluoride toxicity is lesions or spots on the teeth (dental fluorosis) that can be seen with necked eyes. Dental fluorosis is typically characterized by small brown spots, blotches, and dots on the tooth enamel and/or light to dark brown with bilateral, and horizontal striated stripes [1,35,56]. These pigmented or stained stripes appear more contrasting, regular, denser, and more intensely on the anterior teeth (incisors) in calves of bovine animals (Figure 1). In most calves, the pattern and appearance of dental fluorosis is approximately the same. But as they age, the patterns of dental fluorosis may change. The worst aspect of dental fluorosis is that it reduces the life span or longevity of animals. Its severe form causes severe problems in grazing and chewing food which can lead to death from hunger and weakness in animals [1,57].

Skeletal Fluorosis

Excessive accumulation of fluoride in the various bones of the skeleton and the attached muscles and ligaments causes mild to severe deformities that are dangerous and painful. These pathologies are collectively called skeletal or osteoporosis which ultimately restrict mobility due to various morphological changes in the bones, such as periosteal exostosis, osteosclerosis, osteoporosis, and osteophytosis [58-60]. Clinically, these changes manifest as vague aches and pains in the body and joints associated with stiffness, lameness, reduced body growth and detectable bone lesions in animals. These bone changes are progressive and irreversible and become severe as animals age and the duration of fluoride exposure increases. Intermittent lameness, enlarged joints, debility, invalidity, hoof deformities, wasting of body muscles, and bone lesions in the jaw, ribs, metacarpus, and metatarsus regions are well recognized in animals with severe fluorosis [37,56].

Non-Skeletal Fluorosis

This form of fluorosis is the result of various fluoride-induced histological, biochemical and physiological changes in the soft organs of animals [56] and is the initial stage of chronic fluoride toxicity in animals. In fact, many health complaints in animals such as gastrointestinal discomforts (intermittent diarrhea or constipation, abdominal pain, flatulence, etc.), urticaria, tendency to frequent urination (polyuria), excessive thirst (polydipsia), lethargy, muscle weakness, irregular reproductive cycles, reduce the reproductive performance, miscarriage, stillbirth, etc. [26] are the consequences of chronic fluoride toxicosis. These adverse health effects are temporary and may be reversed within a few days after removing the source of fluoride exposure. It is not necessary that all of these fluoride-induced health outcomes occur at the same time in the animal. Nevertheless, the severity of fluorosis is relatively high depending on the density and rate of bio-accumulation of fluoride [1,56] or the fluoride concentration and its duration and frequency of exposure. Apart from these factors the severity or magnitude of fluoride toxicity is also controlled by species, sex, nutrition, food nutrients, chemicals in drinking water, environmental factors, individual biological response and genetics, etc [61-71].

Are Bovine Calves' Ideal Bio-Indicators for Endemic Fluorosis?

It is well known that fluoride occurs naturally in water and soil or through modern industrial processes. If animals are exposed to fluoride over a long period of time through any of these potential sources, it can cause fluorosis or serious and disabling effects on the health of humans and animals. In vertebrate species, the skeleton is particularly relatively more sensitive; growths on the bones and fusion of the joints lead to lameness and lack of mobility. Teeth can become severely worn and damaged, often with their enamel destroyed. Whatever the case, the primary manifestations of excess fluoride exposure in herbivorous mammals are known as dental and skeletal fluorosis. In fluoride endemic India [47,72], fluorosis has been well studied in diverse species of domestic animals, such as cattle (*B. taurus*), water buffaloes (*B. bubalis*), sheep (*O. aries*), goats (*C. hircus*), camels (*C. dromedarius*), horses (*E. caballus*), donkeys (*E. asinus*), etc. [47]. Thousands of domestic animals of these species are found suffering from fluorosis in many countries due to exposure to fluoride through various fluoride sources.

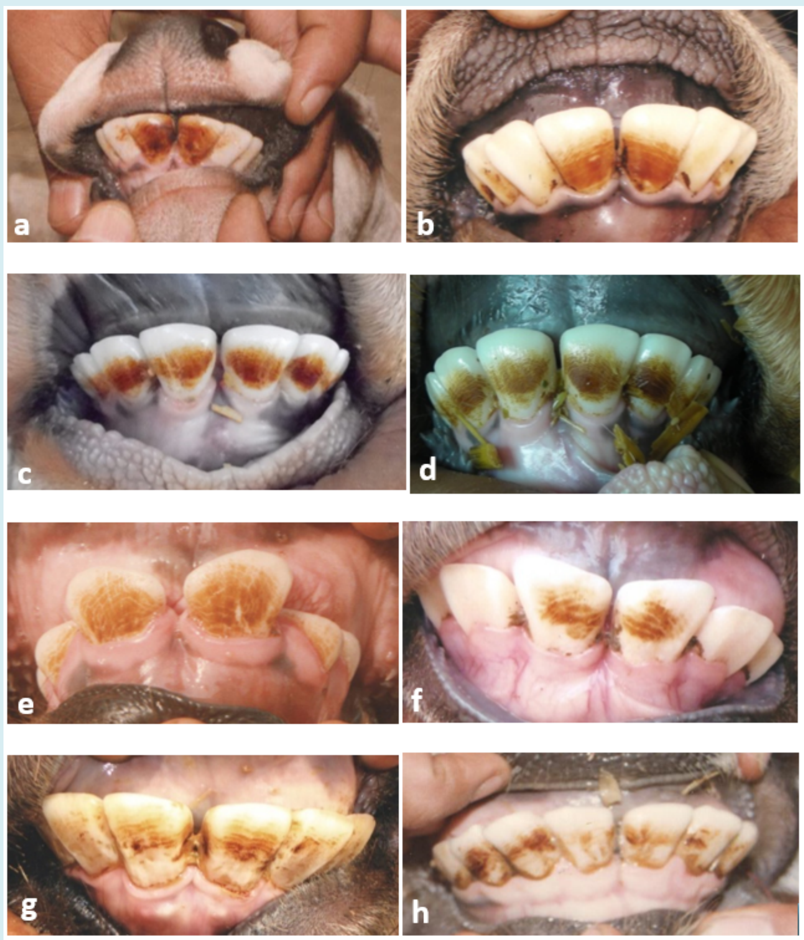

Figure 1: Moderate to severe dental fluorosis in calves of cattle (a-d) and buffalo (e-h) of different ages characterised with regular /irregular striated and horizontal deep brownish or blackish (d) pigmentation on the front teeth and swelling and recession of the gums.

In general, herbivorous mammals are more susceptible to fluorosis than birds, amphibians, reptiles, and fish. Among various species of domestic animals, bovine species (cattle and buffalo) are found to be relatively more susceptible to fluorosis. However, buffaloes are comparatively more sensitive to fluoride toxicity [69,71]. Nevertheless, in general, growing animals (calves/juveniles) are relatively more sensitive and susceptible to fluoride toxicity than adult or mature animals [32,53,54,73]. This statement is supported by recent studies conducted on mature and immature bovines, equines, camels, goats, and sheep animals living in two different provinces whose drinking water sources had fluoride concentrations <1.5 ppm and >1.5 ppm [74,75]. Below 1.5 ppm fluoride concentration, the prevalence of fluorosis in cattle and buffalo calves was found to be 58.42% and 6282%, respectively [74]. But the prevalence of fluorosis in immature donkeys and horses was found to be low, 16.66% and 14.28%, respectively. Interestingly, immature camels, goats, and sheep did not show evidence of chronic fluoride toxicity at < 1.5 ppm fluoride concentration (Table 1). Among mature animals of these animal species, the highest prevalence of fluorosis was also observed in the bovine species [75]. It is clearly evident that bovine animals are less tolerant or highly sensitive and susceptible to fluoride toxicity (Table 2).

Table 1: Prevalence (%) of dental fluorosis (DF) and skeletal fluorosis (SF) in immature animals of different species living in areas with low fluoride (< 1.5ppm) in drinking water [74].

Animals (spp)	No. of animals (age)	No. of animals showed		Total
	Investigated	DF	SF	
Buffaloes (*B. bubalis*)	78 (< 3 years)	41 (52.56)	8 (10.25)	49 (62.82)
Cattle (*B. taurus*)	89 (< 3 years)	44 (49.43)	8 (8.98)	52 (58.42)
Donkey (*E. asinus*)	30 (< 3 years)	5 (16.66)	0	5 (16.66)
Horses (*E. caballus*)	21 (< 3 years)	3 (14.28)	0	3 (14.28)
Camels (*C. dromrdarius*)	23 (< 6 years)	0	0	0
Sheep (*O. aries*)	92 (< 1 year)	0	0	0
Goats (*C. hircus*)	96 (< 1 year)	0	0	0

Table 2: Prevalence (%) of dental fluorosis (DF) and skeletal fluorosis (SF) in domestic animals living in areas with high fluoride content (> 3.0 ppm) in drinking water. Lameness indicates severity of skeletal fluorosis [75].

Animal (species)	Immature animals		Mature animals		Lameness
	DF	SF	DF	SF	
Buffaloes	62/64 (96.8)	22/64 (34.3)	209/312 (66.9)	188/312 (60.2)	+++
Cattle	63/78 (80.7)	21/78 (26.9)	328/518 (63.3)	267/518 (51.5)	+++
Donkeys	16/33 (48.4)	6/33 (18.1)	39/106 (36.7)	28/106 (26.4)	++
Horses	7/16 (43.7)	3/16 (18.7)	23/70 (32.8)	17/70 (24.2)	++
Camels	4/18 (22.2)	2/18 (11.1)	13/67 (19.4)	12/67 (17.9)	+
Sheep	12/126 (9.5)	–/126 (0.0)	112/544 (20.5)	54/544 (9.9)	+
Goats	8/108 (7.4)	–/108 (0.0)	102/538 (18.9)	47/538 (8.7)	+

+, mild; ++, moderate; +++, severe

Bio-indicators are those who are potential to reveal the presence of pollutants or contaminants by the occurrence of unique or typical symptoms or measurable responses. These are may be an organism (animals, humans, plants, microbes, etc.) or biological responses which deliver information on alteration in the environment by changing in one the ways: physiologically, chemically or behaviourally. Hence, these are generally used in assessing of environmental health and bio-geographical changes [76-78].

It is evidently clear that calves of bovine animals comparatively have the greatest sensitivity and susceptibility to fluoride and fluorosis. In other words, bovine calves have the lowest tolerance for fluoride toxicity. Therefore, bovine calves can be considered bio-indicators [79,80] for fluoride and fluorosis endemicity because they have the ability to reveal the presence of fluoride contaminants in the environment by the occurrence of unique or specific symptoms of dental fluorosis that are the earliest pathognomonic sign of chronic fluoride intoxication [1,56]. Bovine calves are available almost everywhere to be examined for evidence of dental fluorosis and can be easily handled without any fear. If dental fluorosis is present in calves, further studies such as analysis of fluoride in biological (urine, blood serum, hair, etc.) and environmental (urine, blood serum, hair, etc.) samples are not needed to confirm fluorosis endemic areas. No doublet, bovine calves are ideal bio-indicators for chronic fluoride toxicity or endemicity of fluorosis.

Conclusion

Fluorosis in animals is the result of chronic fluoride exposure through fluoridated drinking water and air-borne fluoride (industrial fluoride pollution) and manifests as dental and bone lesions. Thousands of animals in the world are suffering from this serious disease. Whether the disease is endemic in geographical provinces can be predicted by its bio-indicators without the analysis of fluoride in biological and environmental samples. Based on several studies, it can be assumed that bovine calves are ideal bio-indicators for endemic fluorosis because even at low fluoride levels these are the first to be affected by chronic fluoride toxicity or revealed dental fluorosis compared to other animal species. It is also well known that dental fluorosis is the first and most recognizable pathognomonic sign and biomarker of chronic fluoride intoxication or endemic fluorosis. However, genetic-based studies have also been suggested to further confirm this and are useful as well as relatively more reliable.

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