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Review Article

Are Sheep and Goat Animals Relatively More Tolerant to Fluorosis?

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Abstract

Fluorosis disease in domestic animals is a worldwide health problem and is endemic in areas where fluoride is found in the environment, such as in water, soil, food, and air. Fluoride-related disease in animals is usually caused by consumption of vegetation and water contaminated with fluoride. Fluorosis, caused by prolonged exposure to fluoride, is found not only in various species of wild and domestic animals but also in humans. Clinically, the disease is characterized by tooth and bone lesions that are permanent and irreversible and easily visible. In its severe form, bone lesions eventually cause severe pain and develop lameness that may persist throughout the animal's life. Endemic fluorosis in different species of domestic animals, such as water buffaloes (*Bubalus bubalis*), cattle (*Bos taurus*), horses (*Equus caballus*), donkeys (*E. asinus*), dromedary camels (*Camelus dromedarius*), sheep (*Ovis aries*), and goats (*Capra hircus*) living different geographical provinces has been well documented. To determine which species have more and less tolerance to fluorosis, comparative studies will be needed in these animals living in areas with approximately similar fluoride exposure or in areas with approximately similar fluoride levels in drinking water sources. Recent studies conducted on these animals living in areas where fluoride levels in drinking water sources are almost uniform have reported variations in the prevalence and severity of fluorosis among these animal species. Among these domestic animals, the lowest prevalence and severity of fluorosis was observed in sheep and goats living in areas with low and high fluoride levels in drinking water sources. This may be because these ruminants have greater tolerance or less susceptibility to fluorosis than their counterparts. However, more solid research is needed in different species of animals to unanimously accept or prove it. Current communications focus on the diverse factors or determinants responsible for high tolerance to fluorosis in small ruminants, sheep and goats. Along with this, the research gaps are also highlighted for the researchers to do some advance research work on fluorosis in different species of domestic animals.

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INTRODUCTION

Fluorine (F^-) is the most electronegative and highly reactive element, hence, not found free in the nature in element form. It has strong affinity to combine chemically with other elements to form compounds or is commonly found in nature primarily in the bound forms, called fluorides (F). The main natural reservoirs of fluoride in the biosphere are surface rocks and deposits, soils, and oceans [1, 2]. Rock deposits containing high levels of fluoride and its concentrations in groundwater are due to their chemical properties such as decomposition, dissociation and dissolution and interaction with water [3]. Primary sources of industrial fluoride emissions include the coal burning thermal power stations and production of aluminum, chemicals and plastics, agricultural pesticides, glass and ceramics (including brick), manufacturing of dyes and metal parts, and oil drilling and refining [4]. Ultimately, industrial fluoride contaminates the surface water and vegetation.

Fluoride-related diseases in animals Fluorosis is usually caused by chronic consumption of fluoride-contaminated vegetation (food) and water. In animals, fluoride is readily absorbed and has a high affinity for mineralized or calcified tissues such as teeth and bone. In general, mammals are more susceptible to fluorosis than birds, amphibians, reptiles, and fish. Small mammals like rabbits, guinea pigs, rats, mice, and some wild rodents are highly susceptible to fluoride toxicity. Among domestic animals, ruminants have less fluoride tolerance than

simple-stomach animals. Carnivores are even more tolerant than herbivorous simple-stomach animals. Poultry are highly tolerant to fluoride. On the other hand, insects, some other invertebrates, and soft water dwelling fish have low fluoride tolerance [5,6]. The primary manifestations of long-term exposure to fluoride in domestic animals are known as dental and skeletal fluorosis. Chronic fluorosis has been recorded and reported primarily in several species of domestic animals, such as water buffaloes (*Bubals bubalis*), cattle (*Bos taurus*), horses (*Equus caballus*), donkeys (*E. asinus*), dromedary camels (*Camelus dromedarius*), sheep (*Ovis aries*), and goats (*Capra hircus*) [7-31]. However, acute poisoning in domestic animals due to high doses of fluoride is uncommon. Fluorosis or chronic fluoride intoxication occurs not only in domestic animals but also in wild animals or wildlife [32-37] and humans [38-52] when exposed to fluoride. However, varying prevalence and severity of fluorosis in different species of domestic animals has been reported by several workers. But which of these species has comparatively greater tolerance or lesser sensitivity to fluoride or fluorosis and why this is so has been critically discussed and justified in the present communication. Additionally, research gaps for further advance work on susceptibility to fluorosis in different species of domestic animals are also highlighted.

FLUOROSIS IN ANIMALS

Almost all types of domestic animals develop fluorosis due to prolonged exposure to fluoride or ingestion of excessive amounts of fluoride. As fluoride levels increase or fluoride accumulates in mineralized tissues, a series of characteristic lesions develop and are observed in the teeth (dental fluorosis) and bones (osteo or skeletal fluorosis). Dental fluorosis typically manifests as an abnormal appearance or quality of dental enamel, or the complete absence of enamel [53]. In young animals, increased levels of fluoride affect the production of tooth enamel. Light to dark brown stains on the enamel and irregular wear of teeth are the initial or first pathognomonic symptoms of chronic fluoride intoxication (Figures 1).

Skeletal fluorosis is very painful and even more dangerous than dental fluorosis and is of utmost importance as it reduces mobility by causing gradual changes in the bones such as periosteal exostosis, osteoporosis, osteoporosis, and osteophytosis [54-57]. These changes manifest clinically as vague aches and pains in the body and joints associated with stiffness, lameness, reduced body growth, and detectable bone lesions. These changes in bone are progressive and irreversible and become severe as animals age and as the duration and frequency of fluoride exposure increases. Intermittent lameness, enlarged joints, emaciation, invalidity, body muscle wasting and bone lesions in the ribs, metacarpus and metatarsus regions were well recognized in animals suffering from severe skeletal fluorosis (Figure 1). Excess accumulation of fluoride in muscles also reduces mobility and this condition leads to lameness in animals.

Apart from dental and bone lesions fluoride causes various histological, biochemical, and physiological changes in the soft

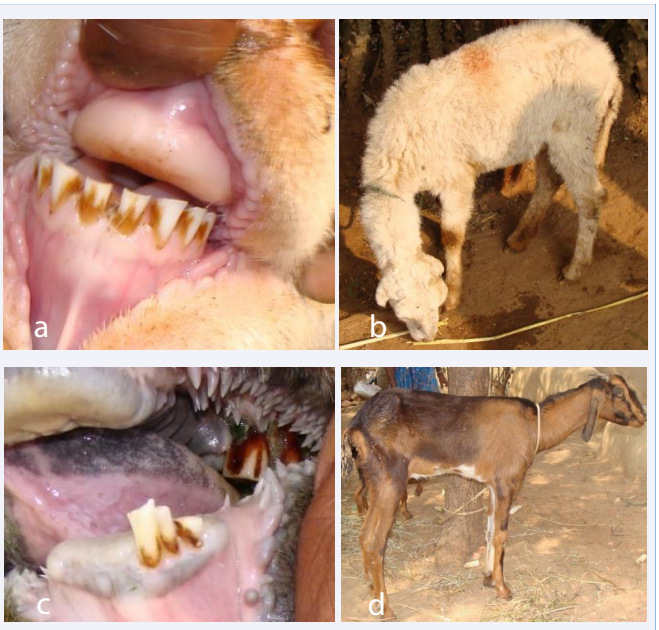

Figure 1 Dental fluorosis and skeletal fluorosis in sheep (Figures a,b) and goats (Figures c, d).Dental fluorosis characterized with brownish staining with wearing of teeth whereas skeletal fluorosis is characterized with intermittent lameness, enlarged joints, emaciation, invalidity, and body muscle wasting.

organs of animals (non-skeletal fluorosis) and due to these changes various health complaints develop in sheep and goat animals. The most common of these complaints are gastrointestinal discomforts (intermittent diarrhea or constipation, abdominal pain, flatulence, etc.), tendency to urinate frequently (polyuria), excessive thirst (polydipsia), lethargy, muscle weakness, irregular reproductive cycles, miscarriage, stillbirth, etc. [58]. However, these 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 these fluoride- induced health outcomes occur at the same time in the animal.

FLUOROSIS TOLERANCE IN SHEEP AND GOAT RUMINANTS

Among livestock and domestic animals, cattle are considered the most vulnerable species [59]. Dental and skeletal fluoroses have been documented in several species, but most commonly in humans and hoofed animals, including domestic animals [60]. However, without comparative studies on the prevalence and severity of fluorosis in different species living in areas where fluoride levels in drinking water are almost the same, it is very difficult to justify or say which species of domestic animals is relatively more or less tolerant to fluorosis or fluoride poisoning. Nevertheless, few such studies are available and have been conducted in areas where drinking water sources have low and high fluoride concentrations. Prevalence and severity of dental and skeletal fluorosis in different species of buffaloes, cattle, donkeys, horses, dromedary camels, sheep and goats, at low (<1.5 ppm) and high (>3.0 ppm) levels of fluoride in drinking water sources shown in tables 1 and 2. The findings revealed

Table 1: Prevalence (%) of Dental Fluorosis (DF) and Skeletal Fluorosis (SF) in immature animals of different species living in areas with low F (< 1.5ppm) in drinking water [18].

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)	- (0.00)	5 (16.66)
Horses (*E. caballus*)	21 (< 3 years)	3 (14.28)	- (0.00)	3 (14.28)
Camels (*C.dromrdarius*)	23 (< 6 years)	- (0.00)	- (0.00)	- (0.00)
Sheep (*O. aries*)	92 (< 1 year)	- (0.00)	- (0.00)	- (0.00)
Goats (*C. hircus*)	96 (< 1 year)	- (0.00)	- (0.00)	- (0.00)

Table 2: Prevalence (%) of Dental Fluorosis (DF) and Skeletal Fluorosis (SF) in domestic animals living in areas with high F content (> 3.0 ppm) in drinking water. Lameness indicates severity of skeletal fluorosis [19].

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

that the prevalence and severity of dental and skeletal fluorosis in sheep and goats is the lowest compared to their counterparts. This suggests that both ruminant species have high tolerance or low susceptibility to fluorosis. There is no doubt that the prevalence and severity of fluoride toxicity depends on the level of fluoride in drinking water and the duration and frequency of fluoride exposure. But other determinants like age, sex, food, nutrients and chemical components of water, environmental factors, etc. also control fluoride toxicity [61-67]. On the other hand, the natural food of both species is completely different from the food of other herbivore species and contains ample amounts of Calcium (Ca) and ascorbic acid (vitamin C) which are antidotes to fluorosis [68, 69]. Apart from these determinants, "genetics" of both the species is also one of the important factors that highly influence tolerance, susceptibility and sensitivity in animals as well as humans [70]. However, more extensive and deep research or epidemiological studies are still needed on this topic to unanimously accept that food nutrients and genetics play a more important role in fluoride toxicity in different species of animals.

CONCLUSION

Fluorosis is the result of chronic fluoride exposure for prolonged period. Studies on fluorosis in different species of domestic animals show that the prevalence and severity of fluorosis varies from species to species. Among various species of domestic animals, the prevalence and severity of fluorosis has been found to be lowest in sheep and goat animals. This shows that these ruminant species have greater tolerance to fluorosis than other species of domestic animals. However, the prevalence and severity of fluorosis depends greatly on the fluoride concentration and its duration and frequency of exposure, age, sex, diet, nutrients, and environmental factors, etc. But food nutrients and the "genetics" of animals are also most important factors causing variation in fluoride toxicity in animals.

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