INDUSTRIAL FLUOROSIS IN DOMESTIC GOATS (*CAPRA HIRCUS*), RAJASTHAN, INDIA

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SUMMARY: Chronic industrial fluoride (F) toxicosis in the forms of dental, skeletal, and nonskeletal fluorosis was observed in domestic goats (*Capra hircus*) inhabiting the industrial area near Umarda village located 8–12 km south of Udaipur city in southern Rajasthan (India) where superphosphate fertilizer plants are functioning and releasing F fumes or gases into the surrounding environment. Out of 108 goats (≥3-year-old), 9 (8.33%) exhibited mild to moderate pathognomonic signs of osteo-dental fluorosis in the form of light- to deep-brownish staining and excessive abrasion of incisor teeth, intermittent lameness, swollen joints, debility, mortality, wasting of body muscles, and bony lesions in the mandibles, ribs, metacarpus, and metatarsus regions. In these animals, colic, intermittent diarrhea, irregular reproductive cycles, repeated abortions, and still birth were also found as signs of nonskeletal fluorosis. In the study, an unusual pattern of dental staining was observed. Each incisor tooth had a single large deep-brownish spot surrounded by alternate light and deep stained thin layers and located towards the upper (incisal 3rd) region. A homogenous staining was also found at the bottom (gingival 3rd) part of incisors. The cause for this appearance of dental fluorosis in goats living in an industrial F polluted area is discussed.

Keywords: Goats (*Capra hircus*); Industrial fluorosis; Osteo-dental fluorosis; Superphosphate fertilizer plants; Rajasthan (India).

INTRODUCTION

Prolonged fluoride (F) exposure causes adverse health or toxic effects (fluorosis) in both man and domestic animals. If these effects are generated by drinking of fluoridated water, then they are collectively referred to as hydrofluorosis which is natural, more prevalent and wide spread in nature. In contrast, industrial fluorosis is anthropogenic, relatively less prevalent, restricted to a particular location or herd, and caused by the long term exposure to F emitted from various industrial operations. Different types of coal-burning and industrial activities, such as power generation and the manufacture or production of steel, iron, aluminum, zinc, phosphorus, chemical fertilizers, bricks, glass, plastic, cement, and hydrofluoric acid, generally release F in both gaseous and particulate/dust forms into the surrounding environments.[1,2] Ultimately, the emitted industrial F deposits on the ground and the herbage/vegetation. The principal hazard of ingesting of F-contaminated herbage for a prolonged period is the development of animal fluorosis. [1-2]

Industrial fluorosis was recognized for the first time in 1932 by Møller and Gudjonsson[3] in Danish cryolite workers. Following the identification and thorough investigation of several cases of fluorosis due to the inhalation of F dusts by Roholm, [4] industrial fluorosis has been reported in both human beings[5-9] and diverse species of domestic animals [1,2,10-19] from several countries including

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Germany, USA, Great Britain, Soviet Union, Norway, France, Switzerland, and China. In India, most of the studies have been conducted on hydrofluorosis.[20-28] Despite having a number of different types of industrial activities in the country, only few reports on industrial fluorosis in man [29-32] and animals [32-35] are available. Therefore, the present investigation was undertaken to ascertain the effect of industrial F pollution caused by superphosphate fertilizer plants in domesticated goats (*Capra hircus*) as these animals are the basic income sources of poor villagers.

MATERIAL AND METHODS

Study area: For the present study, the industrial area near Umarda village, located 8–12 km south of Udaipur city in southern Rajasthan (India), where superphosphate fertilizer plants are functioning and emitting F fumes or gases into the surrounding environment, was selected. Industrial fluorosis in bovines has already been reported from this area.[34] Similarly, the F concentrations in the environmental samples, collected from within 1 km of the fertilizer plants, have also been estimated: fodder (534.4±74.9 mg/kg), pond water (1.19±0.29 mg/L), and tube-well water (0.479±0.351 mg/L).[34] These sources are sufficient to generate chronic F toxicosis in animals living in the vicinity of the phosphate fertilizer plants. The goats in this industrial area depend for their food on perennial bushes of the local Ber (*Zizyphus mauritiana, Z. jujube,* and *Z. nummularia*) and trees of Vilayati babool (*Prosopis juliflora*). These plants and other vegetation are regularly contaminated with industrial F pollution.[34]

Mode of survey and identification of fluorosis: House to house surveys were made, in the early morning and late evening when the goats were generally available and in the herds in the fields in the day-time, to derive estimates of the prevalence and severity of chronic industrial F toxicity in the forms of dental, skeletal, and nonskeletal fluorosis in mature goats above three years age. Only native goats that had been in the study area from birth were considered. For the evidence of dental fluorosis, the anterior teeth of the animals were observed for dental mottling or staining. For skeletal fluorosis, poor body condition, lameness, reluctance to move or stiffness, skeletal deformities, bony exostosis, muscle wasting, and a snapping sound from the feet during walking were looked for. For evidence of nonskeletal fluorosis, the goat owners were also asked about common complaints in their animals including colic, diarrhoea, constipation, bloating, emaciation, estrous cycle, abortion, and still birth. The fluoride concentrations in blood plasma and urine were not estimated in the fluorosed goats. The data on industrial F toxicity in the goats were based only on the clinical findings and history.

OBSERVATIONS AND DISCUSSION

Dental fluorosis: Out of 108 goats, 9 (8.33%) exhibited mild to moderate grades of fluorotic dental mottling. Their anterior teeth revealed an unusual pattern of staining. Each incisor tooth had a single large deep-brownish spot surrounded by alternate light and deep stained thin layers and located towards the upper (incisal 3^{rd}) region (Figure1). Homogenous staining was also present at the bottom (gingival 3rd) part of the incisors (Figure1). Irregular wearing or excessive abrasion of incisor teeth and recession and swelling of gingiva were also observed in the fluorosed goats (Figure1).

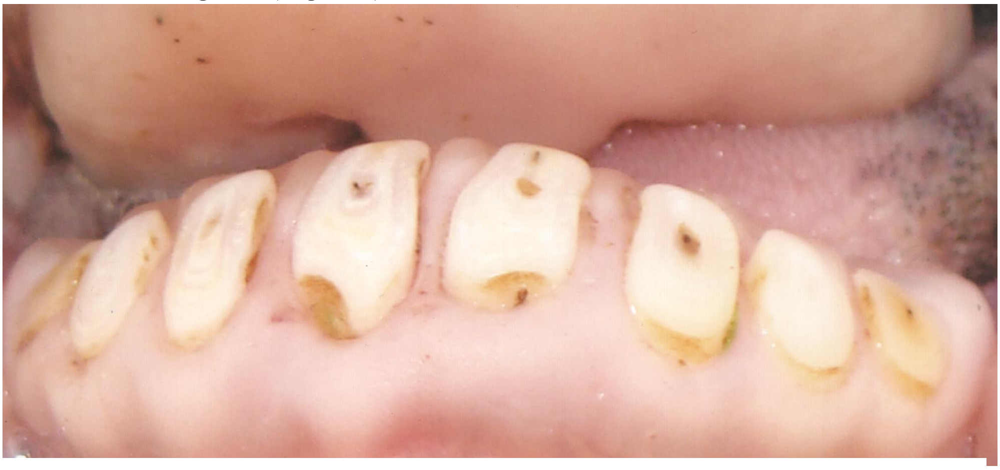

Figure 1. Industrial dental fluorosis in a mature goat characterized by excessive abrasion of the teeth which have a large deep-brownish spot surrounded by alternate light and deep stained thin layers located towards upper (incisal 3rd) region and the appearance of homogenous staining towards the lower (gingival 3rd) region of each incisor.

Skeletal fluorosis: The nine goats who had dental mottling, from the total examined of 108, also had evidence of skeletal abnormalities but not in a severe form. On careful examination and gentle palpation of the mandibular, scapular, tarsal, metatarsal, carpal, and cage regions of these fluorosed animals, diffuse to well-marked bony lesions (periosteal exostoses) were found (Figure 2).

Figure 2. An emaciated 3-year-old female goat afflicted with moderate skeletal fluorosis. Note wasting of body muscles and bulging lesions on the legs and in the mandibular region. The tail region indicates that the goat had diarrhoea.

These goats were physically weak, indolent, and reluctant to move. In these animals, mild to severe intermittent lameness, especially in the hind legs, stiffness of the leg tendons, and wasting of the main mass of the hind quarters were also observed. During walking, these animals also showed a lowering of the neck.

Other signs: According to the information given by the goat owners and veterinarians, other signs of nonskeletal fluorosis caused by chronic industrial F intoxication such as intermittent diarrhoea, colic, and bloating were also present in the fluorosed goats. In female goats, repeated abortions, still births, and irregular estrous cycles were also prevalent.

It is noteworthy that the pathognomic signs of skeletal and nonskeletal fluorosis in the goats, due to the chronic industrial F exposure, are similar to those previously reported in flocks and other domestic animal species living in areas with either with ground water containing high F levels[23-28] or industrial F pollution.[10-19] However, the dental mottling found in the present study is different to that observed and reported in sheep (Figure 3), goats (Figure 4), cattle (Figure 5), and buffalo (Figure 6) in hydrofluorosis endemic areas.[36,37] Generally, the dental staining due to prolonged F exposure appears homogeneously and vertically in sheep and goats but in bovines it becomes stratified and horizontal in appearance. Saw teeth, excessive abrasion or wearing of enamel, and loss of teeth are more prevalent in goats living in an industrial F polluted areas.[18] Damage to all of the enamel surface of the fluorosed teeth has also been observed in goats due to industrial F intoxication.[38,39] When these dental lesions become severe enough to cause difficulty in grazing and mastication, the animals die at a young age from hunger and cachexia.[1,38]

Figure 3. Dental fluorosis in a mature sheep reared in a hydrofluorosis endemic area characterized by excessive abrasion and bilateral homogenous and vertical deep-brownish staining on the enamel surface of the incisor teeth.[36,37]

Figure 4. Dental fluorosis in a mature goat reared in a hydrofluorosis endemic area characterized by excessive abrasion and bilateral homogenous and vertical deep-brownish staining on the enamel surface of the incisor teeth.[36,37]

Figure 5. Dental fluorosis in a cattle calf reared in a hydrofluorosis endemic area characterized by bilateral stratified and horizontal deep-brownish staining of the incisor teeth.[36]

Figure 6. Dental fluorosis in a buffalo calf reared in a hydrofluorosis endemic area characterized by bilateral stratified and horizontal deep-brownish staining of the incisor teeth.[36]

The form of dental fluorosis found in the goats in the present study has not been reported previously in the literature on either goats or other animals. The appearance of a single large spot on each incisor tooth surrounded by alternate light and dark thin layers might be due to an irregular exposure to a variable concentration of F. The extent to which deposited F persists on the herbage or food (leaves, pods, flowers, and small fruits) of the animals may vary between the rainy and dry seasons. In the rainy season, most of deposited F may be washed off the contaminated herbage so that a low level of F exposure is possible. In contrast, during the dry season, cleaning of the vegetation by rain will be less frequent, and the concentration of F will increase steadily due to the regular accumulation of F emitted from the fertilizer plants. Another possible reason for the discontinuous F exposure is the seasonal replacement of leaves, fruits, pods, and flowers by new ones, which will initially have a low F content.

The prevalence and severity of F toxicosis in both man and animals varies greatly, even if the exposure of F is similar. From the area of industrial F pollution studied in the present study, a relatively high prevalence and severity of osteo-dental fluorosis has been observed in both cattle and buffaloes [34] as compared to goats. Compared to cattle and buffaloes, goats are relatively more tolerant to ingested F[36,37] as their food contains ample amounts of calcium (Ca) and ascorbic acid (vitamin C), nutrients that counteract F toxicity.[36,37] The seasonal variation in the F intake in the goat may also contribute to the lower prevalence and severity of osteodental fluorosis.[26]

It is well known that skeletal fluorosis is highly painful and restricts the movement of animals. Dental disfigurement or fluorosis is also important because it reduces the life-span of goats. The death of goats at an early age has economic consequences for the herdsmen. To overcome these problems, the following alleviation measures are recommended for consideration by herdsmen: chemical feed supplementation to reduce the absorption of F and to counteract the effects of absorbed F; removal of goats from high to low F areas; relocation of goats from high to low F areas for reproduction; dry season nutrient supplementation; grass cultivation and/or low F grass storage for use for supplementary goat feeding in the dry season; and the mechanical trimming of saw teeth.[40] The findings of the present study are significant and add to the existing knowledge on industrial fluorosis.

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