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Global Journal of
Biology, Agriculture and Health Sciences

Review Article

Chronic Fluoride Exposure and its Diverse Adverse Health Effects in Bovine Calves in India: An Epitomised Review

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ABSTRACT

Over exposure of fluoride (F) triggers the genesis of several adverse health effects in vertebrates including man and domestic and wild animals in the form of fluorosis. In the rural India, the maximum populations of domestic animals are bovines (cattle and buffaloes). These animals are basic economic sources for villagers and strengthen the rural economy. Though, multiple sources of F exposures are available. However, F containing water and industrial F emissions are the major sources of F exposure for bovine animals. In rural areas, almost all the drinking groundwater sources are fluoridated and contained F beyond the threshold value of 1.0 or 1.5 mg/L. Drinking of such water for long-term is injurious to animal health. Many industrial processes in rural areas are releasing F in their surrounding environment and contaminate the agriculture soil and freshwater reservoirs. These sources of F exposure are potential to develop diverse toxic effects in bovines and their foetus and calves. Most of the epidemiological studies in India on chronic F intoxication have been conducted in adult bovines, cattle (*Bos taurus*) and buffaloes (*Bubalus bubalis*). However, few investigations have also been performed on chronic F intoxication in bovine calves. Nevertheless, toxicological point of view, findings of these studies are significant and unique. Bovine calves are relatively more susceptible to F toxicosis as compared to their counter parts. Various F induced toxic health effects including lameness have been observed in calves aged of 2 months at < 1.0 ppm F in drinking water. In the review, findings on F toxicity in calves are critically reviewed and also identified gaps of future research. The review acknowledges the diverse potential sources of F exposures, susceptibility to F in calves, various F induced toxic health effects, determinates affecting the magnitude of F toxicosis, calves as bio-indicators for chronic F intoxication and prevention and control of fluorosis in calves. Significance of these findings may contribute in preparation of comprehensive healthiness plan for mitigation of F intoxication in bovine animals.

KEYWORDS: Adverse health effects; Bovine calves; Fluoride exposure; Fluorosis; Toxicosis.

INTRODUCTION

In rural India, animal husbandry is one of the important and highly beneficial businesses. However, bovines (cattle and buffalo) husbandry is more prevalent and most common in the rural areas of the country. For the daily income for villagers and livestock owners, rearing of cattle and buffaloes are the most ideal income sources. According to the recent livestock census, 302.79 million bovines (cattle, buffalo, mithun and yak) are in the country. Of these, population of cattle (*Bos taurus*) and buffaloes (*Bubalus bubalis*) is 192.49 and 109.85 million, respectively. In the villages, the deep bore-wells attached with hand pumps are the most common drinking water sources for domesticated bovines. Though, seasonal and perennial water sources such as ponds or reservoirs and rivers are also available for bovine animals. However, deep bore- wells are the principal sources for potable water for both villagers and their domesticated animals. Groundwater of these deep bore-wells contaminated with F and its concentration found beyond the threshold value, 1.0 or 1.5 mg/L [1,2]. Drinking of such fluoridated water for long duration becomes toxic and injurious for animal health.

In India, the most of the epidemiological studies on F induced adverse health effects from exposure of drinking of F containing water have been conducted in humans [3-5] as compared to domestic animals [6-9]. However, few research studies on chronic F intoxication have also been conducted in bovine calves exposed to

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Received: Mar 15, 2021; **Accepted:** May 08, 2021; **Published:** May 15, 2021

Citation: Choubisa SL (2021) Chronic Fluoride Exposure and its Diverse Adverse Health Effects in Bovine Calves in India: An Epitomised Review. Glob J Biol Agric Health Sci 10:107.

fluoridated drinking water and industrial F emissions in the state of Chhattisgarh [10], Madhya Pradesh [11], Orissa [12,13] and Rajasthan [14-20]. Though, studies in calves are limited. However, toxicological and economic points of views, findings of these studies in calves are unique and important which are concisely reviewed. Simultaneously, research gaps on chronic F toxicosis or fluorosis in bovine calves are also identified and highlighted. Ways for prevention and control F intoxication in economically important bovine calves have also been focused.

Sources 0f Fluoride (F) Exposures in Bovine Calves

There are multiple sources of F exposure which are potential to causes chronic F intoxication or fluorosis in bovine calves. Most of them are F containing drinking groundwater, milk of fluorosed bovines and vegetations, green grasses, fodder and other agriculture yields of F rich soils or soil irrigated by F contaminated water, F containing phosphate feed supplements and various industrial processes. The first three sources are natural and more prevalent in the country, while the remaining are the resultant of human activities or anthropogenic but these are restricted to a specific area. In the rural areas, number of coal- burning and industrial activities like electric generating processes and aluminium, iron, steel, zinc, chemical fertilizers, bricks and hydrofluoric acid production factories are emitting F into their surroundings. This industrial emitted F is highly potential to contaminate various ecological food chains and webs existing in the surrounding area or environment and also answerable to contaminate the agriculture soil, freshwater sources, air, vegetation, agriculture crops and biotic communities around these F emitting industries, on which animals are generally dependant for drinking water and foods. Long- time industrial F exposure also causes diverse serious ill effects or health hazards (industrial fluorosis) not only in humans but also in domestic and wild animals [21-23]. However, industrial fluorosis is restricted in the surrounding area of F emitting industry. Nevertheless, some time, fumes or gaseous form of F may spread in large area which is depending on the speed and direction of wind [22].

Milk of cows and female buffaloes rearing in the F endemic areas or getting regular F exposure, is also found to be contaminated with F with varying amounts [24-27]. Agriculture yields like grains, vegetables, forage and fodder of F rich soil are also sources of F exposure for bovine calves [28,29]. However, F contaminated milk is relatively more effective and potential for genesis of toxic effects or fluorosis in bovine calves.

F Induced Adverse Health Effects in Calves

Though, multiple potential sources of F exposure are available for the genesis of F toxicosis in calves. However, fluoridated potable water and industrial F emissions are the main sources of F toxicosis in mature and immature bovines [1,22]. What may be of F exposure sources for these animals, once F enters the body, it is absorbed by the digestive and/or respiratory systems. From these F reaches to various organs or tissues of the body through blood circulation. More than 50% absorbed F excreted from the body through excretory products (faeces and urine) and perspiration, while rest is retained in the body where it accumulates gradually in various organ systems. However, due to its greater affinity with calcium, it deposited maximum in the calcified tissues or bones and teeth as compared to non-calcified tissues or soft organs. The accumulation of F triggers the genesis of various adverse reversible and non-reversible health effects. These toxic changes or effects are collectively known as fluorosis [30]. The F induced deformities in teeth and bones are permanent, non-reversible and easily visible. However, F induced changes in different soft tissues or organs are reversible and disappeared when removing of F exposure.

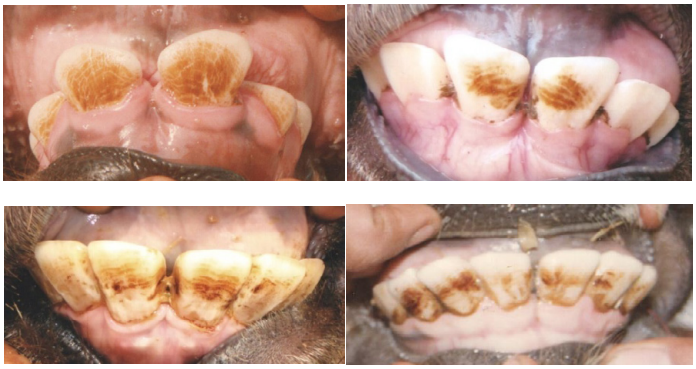
In bovine calves of less than two months, rearing in the F endemic areas, signs of dental fluorosis, skeletal fluorosis and non-skeletal fluorosis have also been observed and reported [31-34]. The F induced toxic changes in the teeth, bones and soft organs in calves become more severe as the advancement of their age and increasing of F concentration in drinking water. If these F induced changes are the resultant of drinking of fluoridated water and industrial F exposure then these are generally referred as hydrofluorosis and industrial fluorosis, respectively. However, in rural India, hydrofluorosis is rampant as compared to industrial fluorosis in animals. These F induced toxic effects can be appeared not only in different species of domestic animals [35] but also in human populations [36,37]. Besides the F induced dental mottling (dental fluorosis) and osteal deformities (skeletal fluorosis), various health disorders in various biological systems including digestive, nervous, excretory, reproductive, thyroid glands, genetic, etc. resultant to chronic F intoxication in humans and domestic and experimental or laboratory animals [38,39] are collectively known as non-skeletal fluorosis.

Dental Fluorosis

The earliest and recognizable sign of chronic F poisoning is dental mottling (dental fluorosis) which could be seen by necked eyes in calves. This entity has been reported in calves aged of less than 2 months exposed to F through drinking water containing F below the 1.0 ppm [18]. In general, dental fluorosis appeared in the form of bilateral, striated and horizontal light to deep brownish pigmented streaks on enamel of teeth [31-34,40]. These pigmented streaks are more contrast, condensed and sharply visualized on the surface of front teeth or incisors in caves aged of 2-3 months. This deformity is more prevalent and most common in bovines exposed to either fluoridated water and/or industrial F pollution in the rural areas of the country. In calves, the pattern and appearance of dental fluorosis in lower age groups is almost similar. But as the advancement of their age, the variation in the pattern (polymorphism) of dental fluorosis has been observed. which is more or less dependent on the concentration, duration and regular F exposure. In mature bovines, an unusual pattern of appearance of dental fluorosis such as brownish small spots, patches and dots has also been detected but such forms have not been reported in bovine calves. At or more than 3.0 ppm F concentration in drinking water, dental fluorosis in calves becomes more severe which is characterised with inflammation and recession in gum and excessive wearing of teeth [3,33,40] (Figures 1-8).

In general, dental fluorosis in calves appeared brownish-yellow staining. But in some cases, it may appear deep blackish in colour (Figure 4) instead of brownish-yellow. Such blackish pigmentation on incisors has recently been traced out and reported in cattle and buffalo calves rearing in the desert and humid areas of Rajasthan where ground drinking water having F more than 1.5 ppm [3,19]. Though, such appearance of staining in bovine calves is rare and unusual and reported only from the Rajasthan state in India. Cause of such staining is yet not clear. However, to know the exact reason for such dental pigmentation more studies are suggestive especially in the desert region of Rajasthan, Punjab and Haryana states.

Figure 1-4: Moderate to severe form of dental fluorosis in cattle calves characterised with striated and horizontal deep brownish or blackish staining (Figure 4) on anterior teeth and swelling and recession of gum.



Figures 5-8: Forms of dental mottling or fluorosis in buffalo calves characterised with regular and irregular striated and horizontal deep brownish pigmentation on incisor teeth and swelling and recession of gum.

The highest prevalence (100%) of dental mottling has been observed in bovine calves at 4.7 ppm of F concentration in drinking water [15]. At below the maximum permissible limit of F (1.0 ppm), 42.66% prevalence of dental fluorosis in cattle and buffalo calves has also been reported [18]. This finding indicates that F toxicosis in bovine calves may appear at or below the 1.0 ppm F concentration. It means calves are relatively at high risk of F toxicosis and are relatively more susceptible to F as compared to mature bovine animals. Interestingly, almost at similar F concentration (1.5 ppm) in potable water in different provinces a variable prevalence (20.6%, 27.0% and 36.6%) of dental fluorosis in calves has also been reported [3]. This indicates that the incidence of dental fluorosis is variable from place to place and species to species. In general, the prevalence of dental fluorosis in calves is relatively higher than the prevalence in adult bovines [3,7] rearing in the same F endemic areas. It is possible, since immature animals or calves have relatively low tolerance of F toxicosis. In bovine calves, dental caries have not been reported so far from any of F endemic areas. This indicates that F is an antagonistic or preventing factor against to genesis of dental caries [31].

Whatsoever, dental disfigurement in bovine calves has much significance. Indeed, this entity is one of the factors causes decrease the longevity in calves. When it becomes more severe then it creates problem in grazing and mastication of food which may leads mortality in calves from starvation and frailness [31,41]. Death in calves before the age due to having of dental fluorosis causes much economic losses for villagers/ livestock owners. Despite of economic losses due to dental fluorosis in calves most of the herdsmen/villagers as well as veterinarians in rural areas of the country are unfamiliar and negligent about F poisoning and its health consequences.

Skeletal Fluorosis

Regular F exposure either through fluoridated water or industrial F emissions for long time adversely affects bones and joints. Its accumulation in osteal tissues induces to develop numerous deformities in bones and attached muscles and ligaments. These deformities are perilous and highly painful and ultimately diminish the mobility and develop lameness in calves. Excessive quantities of F deposition in bones leads increase the bone hardening as well as increasing of mass and density of bones (osteosclerosis) but these are becoming more fragile, weak and porous (osteoporosis). Their surface becomes irregular and rough due to deposition of F leading to develop various degree of bony out growths or spurs (exostosis and osteophytosis) [42-45]. These changes appeared clinically in the form of severe pain, stiffness and rigidity in the neck (cervical vertebrae), back bone (vertebral column) and hip (pelvic girdle) regions as well as in various bony joints [3]. However, these deformities become more severe in cancellous bones as compared to cortical bones as they have maximum F deposition tendency. Whatever, F induced bony changes are, generally, referred as skeletal fluorosis. In calves, at 1.0 ppm F concentration in potable water, 16.2% incidence of skeletal fluorosis has been reported [17,33].

F induced bony changes generally develop stiffness and various degrees of lameness. Calves afflicted with severe skeletal fluorosis, in generally, they have weak bodies, stunted growth, wasting of body muscles, inactive and unable to stand. During walking, lowering of neck and snapping sound from legs in calves are the resultant of chronic F intoxication or skeletal fluorosis [3,5,7,39]. On bones such as ribs, femoral, fibular, metatarsal, etc., excessive bony out growths or exostoses (Figures 9-12) can be easily recognized by simple palpation as these are the resultant of excessive accumulation of F in bones. The F induced bony changes could be identified and recognized by radiological study. But, usually such study has not been performed in animals. Though, F toxicological point of view, radiological studies in calves are highly significant. The magnitude of these F induced osteal deformities increases with the increasing of the age of calves. Moreover, skeletal fluorosis in calves also affects the economy of villagers and livestock owners because lamed fluorosed calves, generally, have low market values.

Non-Skeletal Fluorosis

Fluoride, not only affect the calcified or hard tissues teeth and bones but also affect adversely to various soft tissues or organs of the body. Indeed, F induces the various histological, histochemical and physiology changes in almost all kinds of organs. The term non-skeletal fluorosis has been given for whatever manifestations or ill effects are the resultant to F toxicity in soft organs. The most common manifestations of chronic F toxicosis in calves are gastro-intestinal discomforts such as decreased appetite, abdominal pain, constipation, excess gas production or formation and loose watery faecal matter. In fluorosed calves, frequent urination and drinking of water is also prevalent. Body muscles of such calves are found to be weakened. Such health problems have also been reported in the immature equine animals [46,47]. However, these F induced

health consequences are temporary and reversible after withdrawal of F exposure source or shifting of calves from F endemic to non F endemic areas (Figures 9-12).


Figures 9-10: Cattle calves afflicted with moderate (Figure 9) and severe (Figure 10) skeletal fluorosis charecterised with weak body, indolent, wasting of the body muscles, bulging lesion on the legs and ribs and lameness in hind legs (Figure 10).


Figures 11-12: Buffalo calves afflicted with mild (Figure 11) to severe (Figure 12) skeletal fluorosis charecterised with weak body, indolent, wasting of the body muscles, bulging lesion on the legs and ribs and lameness in hind legs (Figure 12).

Determinants of Chronic F Poisoning in Calves

It is well known that F leaves no one with its toxic effects or fluorosis who are exposing with F for prolonged duration. Studies conducted in various domestic animals including bovines, camels, equines and flocks rearing in the different geographical provinces where drinking water sources have almost similar level of F revealed much variation in the prevalence and severity of F toxicosis [1,3,5,7]. This means that the magnitude of F toxicity is varied from place to place and species to species. This indicates that certain biological and non-biological factors are responsible to influence the F toxicity beside the F concentration. These determinants are age, sex, species of animal, habits, F susceptibility or tolerance capability, biology and genetics of individuals, quality of drinking water (alkalinity, hardness, total dissolved salts, pH, etc.), environmental factors (temperature and humidity) and food nutrients [48-54]. However, besides these factors, duration and frequency of F exposure and concentration F are the major factors for accelerating the magnitude or severity of fluorosis in calves. It has also been well established that the prevalence and severity of F intoxication is proportional to the frequency of F exposure or intake [55]. In general, bovine calves have less tolerance to F toxicosis and have relatively higher F gastrointestinal and respiratory absorption capacity; hence, calves are early and severely afflicted with F intoxication compared to mature bovines [11,16,56,57]. Though, studies of F toxocosis in relation to different determinants are meagre, therefore, more survey studies are highly suggestive in F endemic desert and non-desert areas for the understanding of their contributory role in F intoxication.

Calves as Bio-Indicator for F Toxicosis

For consideration of ideal bio-indicators for evidence of endemic chronic F intoxication in any area, these should be having relatively higher susceptibility, less tolerance to F and efficient to indicate early sign of F toxicosis. Recently, few epidemiological studies in various species of domestic animals (bovines, camel, equines and flocks) have been conducted in both low and high F endemic areas revealed relatively a higher prevalence of osteo-dental fluorosis in immature animals as compared to their counterparts [51,58,59]. These immature animals were also afflicted with severe form of osteo-dental fluorosis. Among different species of animals, bovine calves are more sensitive and less tolerance to F toxicity. Hence, these were severely afflicted with fluorosis [59]. Nevertheless, bovine calves are ideal bio-indicators for endemic of chronic F intoxication. The easiest way for the identification F toxicosis is the clinical examination of teeth of calves for evidence of dental fluorosis.

For knowing the current status of chronic F poisoning in humans and animals of any geographical provinces, the estimation of F content in biological (urine, blood serum, hair, nails, bones etc.) and environmental (forage and fodder) samples is one of the most reliable ways instead of morbidity and mortality [60-65]. Indeed, these samples are also good bio-markers for F toxicosis.

Mitigation and Control of F Intoxication in Calves

It is evidently cleared that osteo-dental fluorosis is irreversible and not cure by medicine. Therefore, prevention is only way by which animals/calves can be protected or saved from chronic F poisoning or fluorosis. This is possible by providing F- free drinking water. Though, numerous defluoridation techniques are available for defluoridation of fluoridated water. However, Nalgonda de-fluoridation technique is an ideal for defluoridation of fluoridated water [66]. Simultaneously, villagers, farmers, herdsmen and veterinarians should be educated about the preventive measures of F intoxication. However, to get regular F free water for animals, rainwater harvesting is the one of the most ideal and suitable way. Unpolluted water from perennial fresh surface water sources is also an alternative way for animals for drinking as water of these sources contains 0.01–0.3 ppm F [31,67]. As far as possible, water of hand-pumps and bore-wells should be avoided for drinking for domesticated animals. Since, in the country, ground-drinking waters are mostly contaminated with high amount of F (>1.0 to 1.5 ppm). Shifting of animals from F endemic areas to non F endemic areas is also effective way for the prevention from flourosis.

Prevention of chronic F poisoning in bovine calves is important, significant and beneficial for human health also. Since fluorosed calves are also sources of F exposure. Consumption of meat of such calves for long time may causes fluorosis in humans. However, more studies are needed on this aspect for its confirmation.

CONCLUSION

In India, for bovine calves, fluoridated drinking water and industrial F emissions are the major sources of chronic F poisoning. However, former source of F exposure is the common in the rural area of the country. These F exposures are potential for genesis of adverse health hazards in both mature and immature bovines. As increasing of age and F concentration, these toxic effects become more severe. In severe form of skeletal fluorosis, lameness and paralysis can be developed in calves. Bovine calves are also ideal bio-indicators for endemic of F and fluorosis as these are more susceptibility to F [68,69]. In India, an epidemiological survey

studies on fluorosis in calves are very limited. Therefore, to know the current status on chronic F intoxication in bovine claves, more scientific investigations are highly suggestive. Findings of this review are useful in framing of comprehensive healthiness plan for mitigation and control of fluorosis in domestic animals as these animals are economic sources for villagers and strengthen the rural economy.

ACKNOWLEDGEMENT

Author extends his sincere thanks to Dr. Darshana Choubisa, Associate Professor, Department Prosthodontics, Geetanjali Dental Research Institute, Udaipur 313002, Rajasthan, India and Dr. Anurag Choubisa, Geetanjali Medical College & Hospital, Udaipur 313002, Rajasthan, India for cooperation.

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