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REVIEW ARTICLE

A Brief and Critical Review of Chronic Fluoride Poisoning (Fluorosis) in Domesticated Water Buffaloes (*Bubalus bubalis*) in India: Focus on its Impact on Rural Economy

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ABSTRACT

In the rural areas of India, fluoridated drinking water, industrial fluoride pollution and fluoride-rich feed phosphate supplements are the major sources of fluoride exposure for domesticated water buffaloes (*Bubalus bubalis*). However, the fluoridated drinking groundwater is the commonest and principal source of fluoride exposure for these ruminants. Chronic fluoride exposure for long-time deteriorate the animal health and causes the fluorosis disease. In the country, the drinking groundwater sources of villages are contaminated with fluoride beyond the threshold value, 1.0 or 1.5 mg/L. At 1.5-1.7 ppm fluoride concentration in drinking water, 62.2% and 21.6% calves and 55.9% and 48.3% adult buffaloes are found to be afflicted with dental and skeletal fluorosis, respectively. The maximum prevalence of dental and skeletal fluorosis, 96.8% and 34.4% in calves and 66.9% and 60.2% in adult buffaloes has also been reported at or > 3.0 ppm fluoride in drinking water, respectively. However, calves are found to be more sensitive and susceptible to chronic fluoride toxicity or fluorosis. Besides the deterioration of the animal health, chronic fluoride intoxication in buffaloes also weakens the rural economy which has been focussed in the present review. In this communication, besides the status of chronic fluoride intoxication in the form of osteo-dental and non-skeletal fluorosis in buffaloes, determinations, bio-indicators and bio-markers of fluorosis and prevention and control of chronic fluoride poisoning in these animals are also considered and briefly and critically reviewed. Simultaneously, research gaps are also identified and highlighted them for further research study on chronic fluoride intoxication in buffaloes. Findings of this review may help in preparation of health policy for improving the health and mitigation of fluorosis in economically important buffalo animals in the country.

INTRODUCTION

The rural economy in India is mainly based on agriculture and animal husbandry. For sustainable income, most people follow cows, buffaloes, goats and sheep along with farming. Still, for more milk production, they prefer to rear buffaloes in villages. According to the livestock census 2019 (Department of Animal Husbandry, Dairy & Fisheries, Ministry of Agriculture & Farmers' Welfare, Government of India), the total population of livestock is 535.8 million in the country. Of this, 302.79 million populations are of bovine animals (cattle, buffalo, mithun and yak). Of these, population of buffaloes (*Bubalus bubalis*) is 109.85 million. The share of major species of domestic animals in the total population of livestock has been shown in figure 1.

In the country, deep- bore wells attached with hand pump and dug- wells are the

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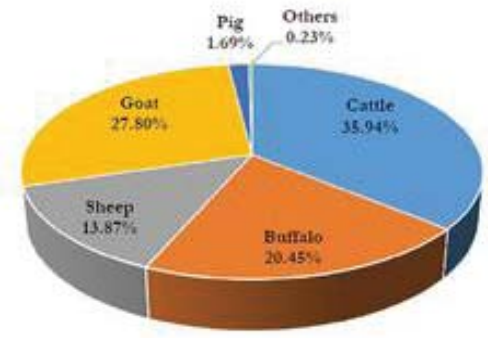

Figure 1 Graph showing share of major species in total livestock population in India, 2019.

main sources of drinking water for the domesticated buffalo animals in the villages. Though, seasonal and perennial freshwater sources, such as ponds, reservoirs, lacks and rivers are also available but their numbers are limited and rarely contaminated with fluoride. In India, except in few eastern states, almost all the ground- drinking water sources of 23, out of 37 states and union territories are contaminated with fluoride and most of them have fluoride beyond the maximum permissible limit 1.0 or 1.5 mg/L [1,2]. Drinking of such fluoridated water for long-time is injurious to animal health and causing dreaded fluorosis disease. Despite the occurrence of high content of fluoride (> 1.0 or 1.5 mg/L or ppm) in ground- drinking waters of rural areas of these states, epidemiological studies on fluoride intoxication (fluorosis) in domesticated buffaloes (*Bubalus bubalis*) are too limited [3-6] as compared to studies conducted in human population [7-10]. In other countries, reports on chronic fluoride intoxication in buffalo animals are also too scanty [3,11]. In India, out of 23 fluoride endemic states and union territories only in five states namely Gujarat [13], Madhya Pradesh [14], Punjab [15,16], Rajasthan [17-22] and Uttar Pradesh [23] studies on endemic fluorosis in buffaloes have been performed. However, in the state of Rajasthan where almost all the drinking groundwater sources in rural areas are contaminated with fluoride [2], endemic fluorosis in various species of domestic animals (cattle, sheep, goats, horses and donkeys) including buffaloes has been well studied [24]. From toxicological point of view, findings of these studies are highly significant and helpful in understanding of fluoride toxicosis in buffaloes. In present communication, chronic fluoride toxicity in the form of dental, skeletal and non-skeletal fluorosis in the buffalo animals, determinations, bio-indicators and bio-markers of endemic of fluorosis, impact of endemic fluorosis on rural economy and the preventive measures of fluorosis in domesticated buffaloes are briefly and critically reviewed. Simultaneously, research gaps have also been identified and highlighted for further research studies on chronic fluorotoxicosis in buffalo animals. Findings of this review may contribute in preparation of comprehensive healthiness plan for better health and mitigation of fluoride intoxication in buffalo ruminant animals which are important economic sources for villagers or animal keepers and strengthens the country's rural economy.

Sources of fluoride exposures

In the villages of India where maximum buffaloes are reared, three major sources of fluoride exposures, fluoridated drinking groundwater, industrial fluoride emission and fluoride-rich feed phosphate supplements are found. However, the commonest source of fluoride exposure is the fluoridated drinking water which is natural or geogenic in origin. This is the principal source, which causing fluorosis (hydrofluorosis) disease in domesticated buffaloes of all over the country. Remaining two sources, industrial fluoride pollution and fluoride-rich feed phosphate supplements, are anthropogenic and restricted to a specific area or region. These sources are also potential for developing of fluorosis in these animals. In the rural areas of the country, 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 gaseous and particulate form of fluoride into surrounding environments. This emitted fluoride contaminate diverse food chains and webs existing in their surrounding area and also answerable to contaminate the agriculture soil, freshwater sources, air, vegetation, agriculture crops and biotic communities around fluoride emitting industries, on which buffalo animals are generally dependant for foods and drinking water. Long-time industrial fluoride exposure also causes diverse serious health hazards (industrial fluorosis) not only in humans [25,26] but also in various species of domestic animals [27-33]. Though industrial fluorosis is restricted in the surrounding area of fluoride emitting industry but it is also possible that fumes or gaseous form of fluoride may spread in large area which is depending on speed and direction of wind [6]. Besides the fluoride containing phosphate feed supplements, agriculture yields like grains, vegetables, forage and fodder of fluoride-rich soil are also potential sources of fluoride exposure and causing fluorosis (food-born fluorosis) in buffaloes [3,34,35]. However, such form of fluorosis is rare in buffalo animals.

Chronic fluoride poisoning (fluorosis) in buffaloes

Fluoride is not an essential element for human growth and development and for most organisms in the environment [36] and is also an undesirable substance in animal feed [37]. However, it has vital role or contribution in strengthening and mineralization of teeth and dental enamel. However, in some animals, fluoride is considered to be an essential element, as diets low in fluoride impaired fertility and development [37].

What may be of fluoride exposure sources, once fluoride enters the body, it is absorbed by the digestive and/or respiratory systems. From these it reaches to various organs or tissues of the body through blood. More than

50% absorbed fluoride is excreted from the body through excretory products, faeces and urine, and perspiration as well, while rest is retained in the body where it accumulates gradually in diverse organs. But due to it has greater affinity with calcium, its maximum bio-accumulation is occur in the calcified tissues, such as bones and teeth compared to non-calcified tissues or soft organs. Nevertheless, the bio-accumulation of fluoride in growing calves and juvenile animals is relatively higher than in adult animals [37]. Hence, calves and juveniles generally revealed an earlier signs of chronic fluoride poisoning in the form of dental fluorosis. This accumulation of fluoride causes toxic changes and interference in physiological and biochemical or metabolic processes which ultimately trigger the genesis of adverse reversible and non-reversible toxic health effects in both man and animals. These fluoride induced toxic or health changes are collectively known as fluorosis [25]. Various fluoride induced anomalies or deformities in teeth and bones are permanent, irreversible, untreatable and identified visually. But the fluoride induced changes in soft tissues or organs are reversible and disappeared when check or remove the fluoride exposure.

In buffalo calves aged of < 2 months (Figure 2), rearing in the fluoride endemic areas, clinical signs of dental, skeletal and non-skeletal fluorosis have also been reported [24]. In buffaloes, generally, fluoride induced changes in teeth, bones and soft organs become severe as increasing of duration of fluoride exposure, age and fluoride concentration in potable water. Various fluoride induced changes resultant of fluoride exposure through fluoridated drinking water, industrial fluoride pollution and fluoride-rich feed supplements are referred as hydrofluorosis, industrial fluorosis and food-born fluorosis, respectively. However, in India, hydrofluorosis is rampant in animals. These fluoride induced toxic effects are not restricted in buffaloes but are also found in various species of domesticated animals [38-41] and human population [42,43] as well. Besides, dental mottling (dental fluorosis) and bone deformities (skeletal fluorosis), various fluoride induced health disorders in man and animals are generally referred as non-skeletal fluorosis [1,4,9].

Dental mottling (dental fluorosis): The earliest and most recognizable sign of chronic fluoride poisoning is dental defragmentation or mottling (dental fluorosis) which could be seen by necked eyes. This entity has been identified and reported in buffalo calves aged of < 2 months (Figure 2) exposed to fluoride through drinking water containing fluoride < 1.0 ppm [24]. Dental fluorosis in buffaloes, generally, characterised with bilateral, striated and horizontal streaks stained with light to deep brownish in colour on enamel of teeth [1,9]. These pigmented or stained streaks are more contrast, regular, condensed and sharply visualized on anterior teeth (incisors) in calves and juveniles of buffalo animals (Figures 2A-C). This deformity is more prevalent and common in buffaloes exposed to either fluoridated water or industrial F pollution [6,44]. In most of the calves, the pattern and appearance of dental fluorosis is almost similar. But as the advancement of their age, the variation in the pattern of dental fluorosis has also been observed (Figures 3A-E). This is due to variation in the duration and continuity of fluoride exposure. In buffaloes, an unusual pattern of dental fluorosis, brownish small spots, patches and dots has also been found but such pattern of dental fluorosis is however, rare in occurrence. At or > 3.0 ppm fluoride concentration in drinking water, dental fluorosis in buffaloes become severe characterised with inflammation and recession in gum and excessive wearing of teeth (Figure 3E). Based on pattern of dental staining, it can be inferred that the animal is suffering from the hydrofluorosis or from the industrial fluorosis. Usually,

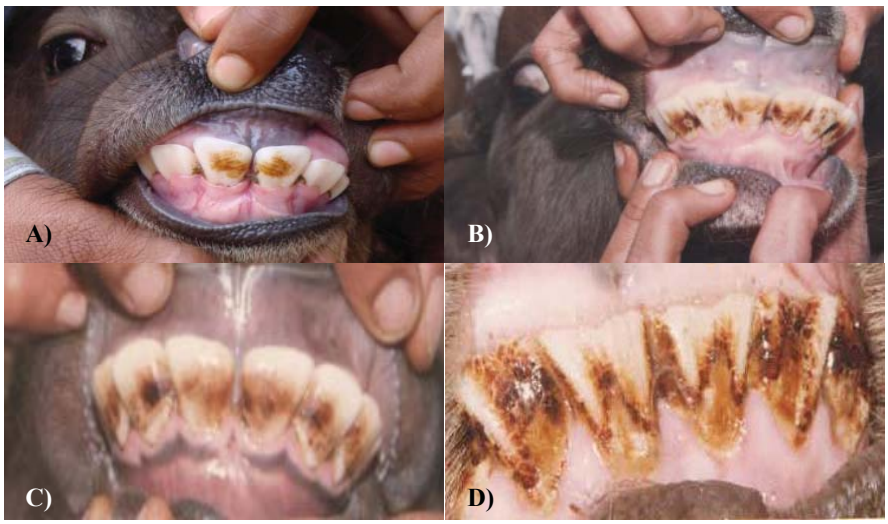

Figure 2 Buffaloes afflicted with moderate to severe dental fluorosis characterised with bilateral, striated, deep brownish staining in calf below two month age (Figure A), juveniles (Figures B and C) and adult buffalo (Figure D). In adult buffalo, excess wearing of teeth and recession of gum indicate severe dental fluorosis.

Figure 3 Buffaloes (calves, juvenile and old buffaloes) afflicted with mild to moderate skeletal fluorosis. A calf < 2 months (Figure 3A) had dental fluorosis (Figure 2A). Remaining buffaloes had also dental flurosis. They usually seem physically normal when viewed from a distance, but they are quite lethargic. They take time to get up and sit and have a lot of difficulty. They often move slowly and intermittently and have mild lameness in their back legs.

in hydrofluorosis, the staining of teeth is more deep and regular, whereas in industrial fluorosis it is light or diffuse and mostly irregular in appearance.

In general, dental fluorosis in buffaloes found brownish-yellow staining. But in some calves and juvenile buffaloes rearing in fluoride endemic areas, it may appear deep blackish in colour [19,24]. Recently, such blackish pigmentation on incisors has also been reported in cattle calves rearing in the desert areas of Rajasthan where ground drinking water contains fluoride > 1.5 ppm [40]. Though, such dental staining in animals is rare. Reason of such form dental staining in animals is not yet clear. However, to know the exact reason of such form fluoride toxicity more studies are suggestive in different fluoride endemic geographical areas.

In India, the highest prevalence (100%) of dental mottling has been observed in calves at 4.7 ppm of fluoride concentration in drinking water [45,46]. At 1.5-1.7 ppm fluoride concentration in drinking water, the prevalence of dental fluorosis, 62.2% in calves and 55.9% in adult buffaloes was observed [46]. However, the maximum prevalence of dental fluorosis at > 3.0 ppm fluoride in drinking water, 96.8% in calves and 66.9% adult buffaloes has also been reported [47]. This indicates that fluoride toxicosis in buffalo calves may appear at or below the maximum permissible limit of fluoride (1.0 or 1.5 ppm) in drinking water. It is not surprising; it is possible, calves and juveniles are found to be more sensitive and susceptible to fluoride toxicosis compared to adult buffaloes [44]. Secondly, calf and juvenile animals have regular F exposure because they spend most of their time in one place. In some studies, it has also been reported that the prevalence of dental fluorosis in calves is found to be higher than adult buffaloes [24] rearing in the same fluoride endemic areas. Interestingly, almost at similar fluoride concentration (1.5 ppm) in portable water in different provinces, a variable prevalence 20.6%, 27.0% and 36.6% of dental fluorosis in calves has also been reported [24]. This indicates that the incidence of dental fluorosis is variable from place to place, individual to individual and species to species. Interesting, dental caries have not yet been reported in buffaloes from any of fluoride endemic

areas in the country. This indicates that fluoride may prevent the dental caries in animals [24].

The worst aspect of dental fluorosis is that it decreases the life span or longevity of buffaloes. Its severe form causes a serious problem in grazing and mastication of food which may leads mortality in animals from starvation and frailness [25,48]. Death of animals before the age due to having of severe dental fluorosis causes much economic losses for livestock owners. But most of the livestock farmers are unaware about this economic loss. Even they do not know the cause of dental fluorosis in their animals.

Bone deformities (skeletal fluorosis): Excess accumulation of fluoride in various bones of skeletal and attached muscles and ligaments causes mild to severe deformities which are dangerous and painful. These deformities ultimately restrict the mobility due to various morphological changes in the bones, such as periosteal exostosis, osteosclerosis, osteoporosis and osteophytosis [49-51]. Clinically, these changes appear in the form of vague aches and pains in the body and joints which are associated with rigidity, lameness, diminutive body growth and detectable bony lesions in buffaloes. These bony changes are progressive and irreversible and become severe with advancing of age of animals and increasing of duration of fluoride exposure as well. Intermittent lameness, enlarged joints, debility, invalidism, hoof deformities, wasting of body muscles and bony lesions in the mandibles, ribs, metacarpus and metatarsus regions are well recognized in fluorosed buffaloes (Figures 3A-E). In few fluorosed cases ankylosis deformity in buffaloes has also been reported in India [24,52]. However, such deformity is uncommon.

In many villages of Rajasthan state (India) where F concentration in drinking water sources has fluoride in the range of 1.5-1.7 ppm, the prevalence of skeletal fluorosis in calves and adult buffaloes was reported to be 21.6% and 48.3%, respectively [46]. The maximum prevalence of skeletal fluorosis at fluoride concentration of > 3.0 ppm in drinking water 34.3% in calves and 60.2% in adult buffaloes has also been reported [47].

Fluoride induced bony changes develop stiffness and various degrees of lameness. Buffaloes afflicted with severe skeletal fluorosis, generally have weak bodies, stunted growth, wasting of body muscles, inactive and unable to stand. During walking, lowering of neck and snapping sound from legs are resulting of severe skeletal fluorosis. On bones, such as ribs, femoral, fibular, metatarsal, etc., excessive bony out growths (exostoses) (Figures 4A-D) can be easily recognized by simple palpation as these are the resultant of excessive deposition of fluoride over the surface of bones. The fluoride induced various stages of skeletal fluorosis or degree bony changes could be identified and recognized by radiological study. But, such study has not yet been conducted in buffaloes and in other species of domestic animals. Toxicological point of view, radiological studies in animals exposed to fluoride are significant and useful in understanding of chronic fluoride toxicosis. The magnitude of fluoride induced skeletal changes is also increased with the advancement of age of buffaloes [47].

Toxic effects in soft organs (non-skeletal fluorosis): Fluoride affects not only calcified organs, teeth and bones but also affects various kinds of soft organs. Indeed, fluoride is potential to induce the various histological, biochemical and physiology changes in all kinds of soft organs [36,37]. The most common fluoride induced manifestations reported in buffaloes are gastro-intestinal discomforts (decreased appetite, abdominal pain, constipation, excess gas production or formation and loose watery faecal matter), muscles/body weakness, polydipsia, polyuria, allergic reactions, irregular reproductive cycles, repeated abortion, still birth, etc. [36,37]. But these fluoride induced health consequences are temporary and reversible after withdrawal of fluoride exposure or removing buffaloes from the sources of fluoride exposure. Most of these health complaints in buffaloes are generally observed during observational studies. Therefore, for the confirmation of these health complaints in buffaloes, experimental studies are more reliable and need more. Research works on chronic fluorotoxicosis in reproductive system, endocrine glands and nervous system (brain) in these animals are also needed as these are vital and sensitive organs and physiologically these organs are also very important.

Bio-indicators, bio-markers and determinants for chronic fluoride intoxication

In general, bio-indicators indicate the changes in the environment and give measurable and unique biological responses such as chemically, physiologically and behaviourally. These may be animals, humans, plants, microbes, etc. and are generally used in the assessment of environmental health and bio-geographical changes [53,54].

The most ideal bio-indicators for chronic fluoride poisoning are those who have less tolerance and higher sensitivity and susceptibility to fluoride. Based on these criterions, for humans and animals, children and bovine calves are excellent bio-indicators for chronic fluoride intoxication. However, buffalo caves are relatively better bio-indicators for endemic fluorosis. In fact, both children and calves are highly susceptible to chronic fluoride poisoning and reveal the earliest clinical or pathognomonic sign of F toxicosis in the form of dental fluorosis [55,56]. Secondly, both children and calves are easily available in every fluorosis endemic provinces and they do not cause any problem to observe evidence of dental fluorosis [57].

Recently, a large study was performed in mature and immature cattle (*Bos taurus*), buffaloes (*Bubalus bubalis*), sheep (*Ovis aries*), goats (*Capra hircus*), horses (*Equus caballus*) and donkeys (*Equus asinus*) of such provinces where almost all the drinking water sources are contaminated with

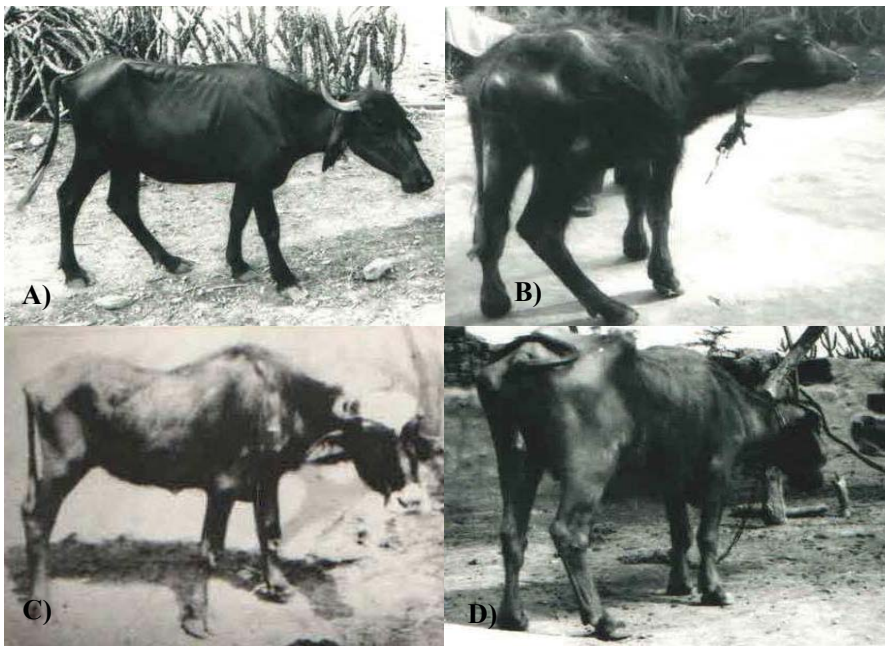

Figure 4 Buffaloes (calves, juvenile and old buffaloes) afflicted with severe skeletal fluorosis characterised with lameness and/or ankylosis in hind legs, enlarged joints, debility, invalidism, hoof deformities, stunted growth, wasting of body muscles and bony lesions in the mandibles, ribs, metacarpus and metatarsus regions.

fluoride [58]. Interesting, among these animals, immature animals were found to be revealed the earliest sign of chronic fluoride poisoning, dental fluorosis. Among these animals, bovine calves are, however, better bio-indicators for fluorosis compared to lames and kids. Findings this study also revealed that buffalo calves are slightly better bio-indicator than cattle calves for the evidence of endemic fluorosis. However, more survey studies are needed to confirm this fine difference.

Bio-markers may be substance, molecule, structure, gene, etc. and exist in natural state. These are often measured and evaluated to examine normal biological and pathogenic processes and used as an indicator of some biological state, physiological process, disease, etc. A fluoride biomarker is of value primarily for identifying and monitoring deficient or excessive intakes of biologically available fluoride [59]. Fluoride content in the environmental samples like forage and fodder indicates the persistence of fluoride contamination in the environment. However, in contrast to morbidity and mortality, fluoride contents in biological samples such as milk, saliva, sweat, urine, blood serum, teeth, bones, hairs, etc. are good bio-markers for chronic fluoride poisoning [60-64]. To know the current status of endemic fluorosis, estimation of fluoride in blood serum and urine is the most authentic way in man and animals [33]. However, among the various bio-markers, urine fluoride concentration is unanimously accepted as the best bio-marker for endemic fluorosis because at the spot, it can be easily recollected noninvasively and systematically [65,66]. The level or concentration of fluoride in urine is variable in subject to subject and area to area and is also depend on age of subjects, diverse physical factors of environment and fluoride content in drinking water [67].

The severity of fluorosis in buffaloes is variable whether these animals living in the different areas having almost similar fluoride concentration in their drinking water sources and this situation is also for different species of domestic animal [24]. This indicates that besides the fluoride level in potable water some other factors or determinants influence the fluoride toxicity. Many workers have been studied on these determinants and reported that besides the fluoride concentration and its frequency and duration of fluoride exposure, age, sex, habits, nutrients of food, chemical components of potable water, environmental factors, individual susceptibility, biological response, tolerance and genetics are also potential determinants of fluoride toxicity [68-73].

A study was conducted in different species of domesticated ruminants of such provinces where drinking waters have low fluoride level (1.5-1.7 ppm) [46]. In this study, grass eaters bovines revealed maximum incidence and severity osteo-dental fluorosis compared to plant eaters flocks [46]. This indicates, bovines are more susceptible to fluoride toxicosis as compared to flocks. These findings suggest that some nutrients of foods are responsible for making the difference and influence the chronic fluoride toxicity in these animals. In fact, flock animals generally feed on fresh leaves, pods and fruits of trees and shrubs which contain ample amount of Calcium (Ca) and ascorbic acid (Vitamin C) nutrients [46]. Both nutrients may interfere with the fluoride metabolism and ultimately reduce the fluoride toxicity. However, for its confirmation experimental studies are still needed. In

addition, the severity of fluorosis is depends on the density and rate of fluoride accumulation or the severity of fluorosis is directly proportional to the rate of fluoride accumulation.

Impact of chronic fluoride poisoning on rural economy

Agriculture and animal husbandry have the most contribution in strengthening the rural economy in India. That is why most of the people in rural areas or villages rear animals like cows, buffaloes, sheep and goats for the business of milk, meat and wool for income. Still, people keep female buffaloes more because they have more milk production capacity than any other animals. Due to which selling of milk in the market also makes a lot of money. On the other hand, selling their male calves in the market also gives good income. The dung of these animals is also used to make manure and bio-gas in the villages. Both of these are also a better source of sustainable income for the rural people, which make it more convenient to run the household expenses.

It is well documented that chronic fluoride exposure decreases the milk production in animals, which directly affects the income of animal keepers [3]. On other hand, due to severe dental fluorosis, animals also die at a young age [25,48]. Due to which there is a lot of economic loss to the animal owners, which can be compensated with great difficulty. In general, those domesticated buffalo animals who are suffering with skeletal fluorosis are physically weak and lame; people buy such animals less in the market. Due to this people are forced to sell such fluorosed animals at low prices. This is also an economic loss for villagers. In addition, chronic fluoride exposure impairs reproductive function in animals, which ultimately affects animal productivity. Whatever may be endemic of sources of fluoride exposure and fluorosis both are responsible for weaken the rural economy in some way or the other. Neither the rural people nor the people of the concerned government departments or policy makers have information about such economic losses due to fluorosis in domesticated animals. Interesting, most of them are also unaware.

It is difficult to state that due to fluoride exposure or endemic fluorosis in buffaloes how much economic loss is caused to the animal owners. But it can be evaluated after doing scientific and factual assessment research studies on this aspect. No one in the world has yet evaluated or assessed how much economic loss due to endemic of fluoride and fluorosis in animals. This type of assessment is more important and necessary in making a health and economic policy to check such type economic losses in rural areas of India.

Prevention and control of fluorosis in buffaloes

No doubt, fluoride induced chronic dental and skeletal anomalies are permanent, irreversible and incurable. Therefore, prevention is only way by which buffalo animals can be saved from chronic fluoride intoxication. The prevention is possible by providing fluoride free drinking water to domesticated buffaloes. In fact, in the rural areas of India, fluoridated drinking water is the principal source of fluoride intoxication for these ruminants. Though, numerous defluoridation techniques are available in the country for defluoridation of fluoridated water. However, Nalgonda de-fluoridation technique is an ideal technique for defluoridation of fluoridated water [74]. However, to get regular fluoride free water for animals, rainwater harvesting is the one of the most ideal and suitable way. Unpolluted water from perennial fresh surface water sources (ponds, reservoirs, lakes, rivers, etc.) is also an alternative way for domesticated buffaloes for drinking as water of these sources contains traces of fluoride or 0.01-0.3 ppm fluoride [25]. As far as possible, water of deep bore-wells and any other groundwater sources should be avoided for drinking for these animals. Since, in the rural areas of country, ground-drinking waters are mostly contaminated with fluoride (> 1.0 to 1.5 ppm). Shifting of animals from fluoride endemic areas to non-fluoride endemic areas is also effective way for the prevention from both hydrofluorosis and industrial flourosis. In fluoride endemic areas, feeding nutritious foods to buffalo animals also helps in controlling fluorosis disease. Simultaneously, villagers, herdsmen and veterinarians should be well educated about the general awareness and preventive measures of chronic fluoride intoxication.

CONCLUSION

In the rural areas of India, fluoridated drinking groundwater and industrial fluoride emissions are the major sources of chronic fluoride poisoning in domesticated buffalo animals. However, former is the principal and commonest source of fluoride exposure in the country. Both sources of fluoride exposures are potential to cause various toxic health hazards or osteo-dental fluorosis in both mature and immature buffaloes. Hundreds of these animals are suffering with this dreaded disease in fluoride endemic villages of India. As increasing of age of animals and duration of fluoride exposure and fluoride concentration, this disease becomes more severe. In severe skeletal fluorosis, lameness, ankylosis and paralysis are more prevalent in domesticated buffaloes. Their calves are highly susceptible and have less tolerance to fluoride poisoning. Therefore, these are also good bio-indicators of chronic fluoride poisoning in animals. In the fluoride endemic villages of the country, epidemiological studies on chronic fluoride poisoning in buffalo animals are limited though these animals are economically very important and strengthening the rural economy. Therefore, to know the current status of chronic fluoride poisoning in these animals, more scientific investigations are recommended. Findings of this review are useful in making of comprehensive health policy and its implication for mitigation and control of chronic fluoride poisoning or fluorosis in buffalo animals.

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