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Opinion

Are Bovine Calves in India Safe from Industrial Fluoride Pollution? More Epidemiological Studies are Needed

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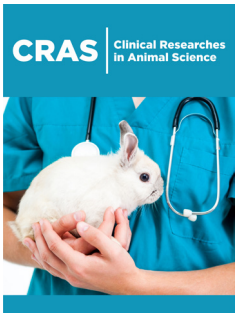

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Opinion

Fluorine ranks seventeenth in the order of abundance in the Earth's crust [1] and is varyingly distributed in air, sea water, freshwater, groundwater, soil, dust, and in mineral deposits of sallaite (MgF_2), villiaumite (NF), fluorspar (CaF_2), cryolite (Na_3 Al F_6), bastnaesite (CeLaY) $(CO_3)F$, fluorapatite $[Ca_5(PO_4)_3$ F] etc., with concentrations (%) of 61, 55, 49, 45, 9, and 3.5, respectively. Fluoride concentration in the atmosphere in unpolluted areas usually varies between 0.02 and 2.0prg/m^3 [2]. Atmospheric fluoride can be in gaseous or particulate forms. Most common gaseous forms include Hydrogen Fluoride (HF), Sulphur Hexafluoride (SF_6), Silicon Tetrafluoride (SiF_4), Hexafluorosilic Acid (H_2SiF_6), and Carbon Tetrafluoride (CF_4). Particulate forms include Sodium Aluminum Fluoride ($NaAlF_3$), Calcium Phosphate Fluoride ($CaFO_4P$), Sodium Hexa Fluorosilicate (F_6Na_2Si), Aluminum Fluoride (AlF_2), Calcium Fluoride (CaF_2), and Lead Fluoride (PbF_2). However, hydrogen fluoride and inorganic fluoride particulates (sodium and calcium fluoride) are major inorganic fluorides present in the atmosphere, accounting for nearly 75 and 25%, respectively [1]. Although small amounts of fluoride are essential for dental health or the proper mineralization of developing and growing teeth, excessive fluoride intake, especially from drinking water or prolonged inhalation, is hazardous to the health of humans and animals and can lead to a serious disease called fluorosis [1,3-10].

The main source of long-term fluoride exposure for humans is drinking fluoridated water. Therefore, the World Health Organization (WHO) recommends an upper limit of fluoride of 1.5mg/L [1]. In India, the Indian Council of Medical Research (ICMR) and the Bureau of Indian Standards (BIS) have set the desirable limit of fluoride in drinking water at 1.0mg/L, with the permissible limit going up to 1.5mg/L [11,12]. However, no universally established maximum acceptable limit for air fluoride has yet been determined. Therefore, it is not possible to state the threshold at which excess fluoride in the air is harmful to human health. Generally, fluoride is naturally present in low concentrations in the air, typically ranging from 0.1 to 0.6µg/L [13]. Environmental fluoride pollution is one of the biggest health problems worldwide today because of its harmful effects on humans [14-18], animals [19-22], agricultural crops or plants [23-26]. In most cases, fluoride is primarily released into the atmosphere by human activities. Natural sources such as volcanic eruptions, rock dust, and marine environments contribute only slightly to the global atmospheric emissions of this compound [27-29]. Major anthropogenic sources for industrial fluoride pollution include coal-fired brick kilns and thermal power plants, zinc and aluminum smelters, phosphate fertilizer factories, and industrial activities such as tile, pottery, and cement works, ceramic industries, and glass manufacturing [30].

Due to government regulations, most fluoride emitters have recently been equipped with effective filters. But in India, no special attention is still paid to controlling such industrial fluoride pollution. That is why the owners of most of the factories spreading fluoride pollution are still careless about it. However, atmospheric fluoride compounds emissions remain a problem all over the world [31]. Anthropogenic fluorine emitted into the atmosphere is highly reactive and readily hydrolyses to form Hydrogen Fluoride (HF) which is highly toxic to humans, animals, and plants. Other fluoride containing gases, SiF_4, and CF_4 are also released from coal-burning brick kilns and thermal power plants which are also highly toxic for bio-communities. These toxic gases react with many materials (both in the vapor phase and in aerosols), typically forming non-volatile, stable fluorides [15]. Alternatively, anthropogenic fluoride emissions include HF, SiF_4, CF_4, and particulate fluoride [32]. However, the distribution and concentration of airborne fluoride depend on various factors, such as emission levels [33], particulate particle size [34], and chemical reactivity of the species [35]. They also depend on meteorological conditions such as temperature, wind direction and speed, turbulence, and rainfall [36-38].

In India, many coal-fired brick kilns and thermal power plants and units producing steel, iron, aluminium, zinc, phosphorus, chemical fertilizers, cement, glass, hydrofluoric acid, etc. are generally located near urban and rural areas, where most people or villagers also rear their cows (Bos taurus) and female water buffaloes (Bubalus bubalis) and their calves (age <3.0 or 3.5 years). From these industrial activities, fluoride is emitted in the gaseous or particulate forms in surrounding environment which creates industrial fluoride pollution. An industrially emitted fluoride not only contaminates the surrounding diverse ecosystems or environments including soil, air, and freshwater reservoirs, but also contaminates vegetation, agricultural crops and many other biological communities on which these domesticated animals generally survive [1,13,39-45]. In the country, most livestock owners are unaware that continued exposure to industrial fluoride emissions from these industrial operations can adversely affect the health of their livestock. In fact, long-term exposure to industrial fluoride pollution can cause a serious disease called industrial fluorosis not only in livestock owners but also in their domesticated animals. Interestingly, studies show that among various domestic animal species, bovines are the most sensitive to fluoride poisoning [46-48]. However, their calves have been found to be more sensitive and susceptible to fluoride toxicity [49-51]. Therefore, calves are not immune or safe to the toxic effects of industrial fluoride pollution and may be affected by fluoride toxicity earlier than adult and older bovines. Therefore, bovine calves are ideal bio-indicators for chronic fluoride poisoning [50,51]. When these calves are severely affected by fluoride toxicity, they become physically weak and lame, which is the worst-case scenario of fluoride toxicosis [52-55].

Livestock farmers can easily identify whether their cow calves are suffering from fluoride poisoning by looking at their teeth. If their teeth show light to dark brownish-yellow horizontal striated stripes or spots (Figure 1), the calves are suffering from fluoride toxicity, also known as dental fluorosis. This is the first visible clinical sign of industrial fluoride poisoning in both animals [56] and humans [57]. In India, studies conducted in rural areas showed a high prevalence of dental (89.9%) and skeletal (78.5%) fluorosis in cattle under 4 years of age in areas with industrial fluoride pollution due to the presence of numerous phosphate fertilizer processing units, coal-burning brick kilns and rock phosphate mines [58,59]. These results suggest that immature animals or calves are more sensitive to industrial fluoride emissions than their adult and older counterparts. The most serious aspect of dental fluorosis is that it shortens the lifespan of bovine calves. When these dental lesions become so severe that grazing and chewing become difficult, calves can die from starvation and cachexia at an early age [1,60]. Nevertheless, calf deaths result in economic losses for animal owners. If calves are repeatedly exposed to fluoride pollution over a long period of time, their bones and ligaments are severely affected and various pathological changes develop in the bones, commonly known as skeletal fluorosis. Bone changes, such as periosteal exostosis, osteosclerosis, osteoporosis, and osteophytosis also occur [61,62].

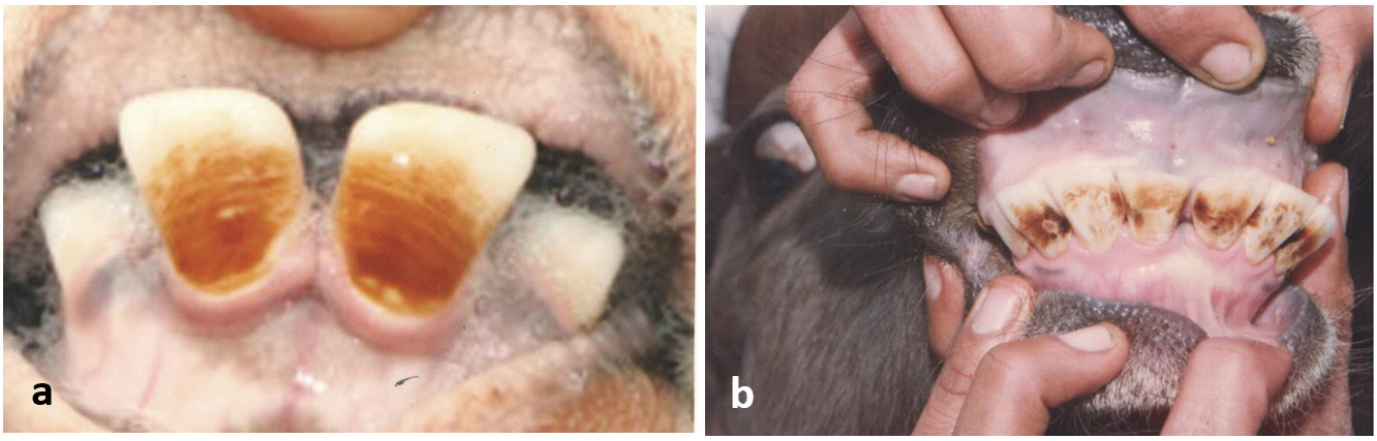

Figure 1: Cattle (a) and buffalo (b) calves with severe dental fluorosis, characterized by deep brownish staining (b) with striated and horizontal stripes on the anterior teeth.

Excessive fluoride accumulation in the muscles also reduces or restricts bone movement, leading to lameness in calves (Figure 2). Although intermittent lameness, swollen joints, debility, mortality, wasting of body muscles, and bony exostosis or lesions in the mandibles, ribs, metacarpus, and metatarsus regions (Figure 2) are well recognized in the calves exposed to industrial fluoride emissions [56]. In fact, skeletal fluorosis in calves is a cause of economic loss to livestock farmers [63]. However, the prevalence and severity in industrial animals is very much dependent on several dominants, such as fluoride concentration in air, duration of industrial fluoride exposure, environmental factors, genetics, fluoride susceptibility or tolerance, etc. [64-68]. Apart from dental and skeletal fluorosis, fluoride poisoning in calves also causes other health problems, such as gastro-intestinal problems (bloating, abdominal pain, constipation, and intermittent diarrhoea), excessive thirst (polydipsia), frequent urination (polyurea), body weakness, etc. [56]. These health problems can make the cattle owner suspect that their cow calves are suffering from fluoride poisoning or fluorosis. However, the status of fluorosis or chronic fluoride poisoning in bovine calves can be determined by estimating the fluoride content in their fresh urine and blood serum which is the ideal and authentic way [56]. Estimation of fluoride content in the environmental samples like forage and fodder indicates the persistence of fluoride contamination in the environment [69,70].

Figure 2: Cattle calves suffer from severe skeletal fluorosis, characterized by weak body, lethargy, loss of body muscles, raised lesions on the legs and ribs, and lameness in the hind legs.

Conclusion

India also has many industries/factories, such as coal-fired brick kilns and thermal power stations, steel, iron, aluminum, zinc, phosphorus, chemical fertilizers, glass, plastics, cement, and hydrofluoric acid manufacturing units, which typically release fluoride into the surrounding environment in the form of both toxic gases and particulate/dust, leading to widespread industrial fluoride pollution. Many people living near these factories also rear livestock. However, they are unaware that repeated exposure to this fluoride-laden air not only harms their own health but also the health of their livestock, such as cows, buffaloes, and their calves, and can lead to a disease called fluorosis. Sometimes, this fluoride poisoning can even cause lameness in calves. Therefore, livestock farmers should avoid raising cows, buffaloes, and their calves in areas where industrial fluoride pollution is found, as it is hazardous and unsafe for their health and increases their risk of developing fluorosis. There is a great need for epidemiological research studies on calves of different ages living in different regions of the country and exposed to various sources of fluoride from industrial emissions. The results of these studies will not only be useful in understanding industrial fluorosis in calves but will also help in formulating a national policy for the prevention of this disease in livestock in the country.

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