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Can Fluoride Exposure be Dangerous to the Health of Wildlife? If so, How can they be Protected from it?

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Abstract

Fluoride is commonly found in varying amounts in various environments, such as soil, water, and air, naturally and/or anthropogenically. Prolonged exposure to fluoride in animals through any medium becomes toxic and gradually their health deteriorates and they even develop a serious disease called fluorosis. From this disease, mainly the teeth and bones of animals get affected and deformed. In its severe condition, animals become lame and their teeth fall out at an early age. Chronic exposure to fluoride can be hazardous to the health of not only domestic animals and humans, but also critically important wildlife. In the world, most studies on fluoride toxicity have been conducted mostly in domestic animals and humans. However, some investigations have also been conducted on endemic fluorosis in some species of herbivorous wild mammals, such as cervids [red deer (*Cervus elaphus* L.), white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), moose (*Alces alces*), etc.], bovids [bison (*Bison bison* and *B. bonasus*)], wild boar (*Sus scrofa*), fruit bats (*Pteropus giganteus, P. poliocephalus,* and *Rousettus aegyptiacus*), rodents [voles (*Microtus agrestis* and *Clethrionomys glareolus*), wood mice (*Apodemus sylvaticus*), and cotton rats (*Sigmodon hispidus*)], small mammals [moles (*Talpa europaea*)], and terrestrial and arboreal marsupials [red-necked wallaby (*Notamacropus rufogriseus*), swamp wallaby (*Wallabia bicolor*), eastern grey kangaroos (*Macropus giganteus*), koala (*Phascolarctos cinereus*), common brush tail possum (*Trichosurus vulpecular*), and common ringtail possum (*Pseudocheirus peregrinus*)]. These studies indicate that wildlife or wild animals are not safe from long-term fluoride exposure. The purpose of the present editorial is to draw the attention of wildlife conservationists to the fact that chronic exposure to fluoride by any means can be threatening or dangerous to the health of wildlife, and on the other hand, to how wildlife can be protected from fluorosis.

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Introduction

Fluorine (F^-) is a very reactive element, so it never exists in the free state in nature and is mainly found in the bound form called fluoride. Fluoride is also a type of slow poison that is commonly found in varying amounts in various environments, such as soil, water, and, air, both naturally and anthropogenically [1]. If animals are exposed to fluoride by consuming fluoride-contaminated vegetation and water or by breathing fluoridated air over a long period of time, it becomes poisonous and eventually deteriorates the animals' health. Even small amounts of fluoride can have beneficial effects, but when consumed in large amounts over a long period of time, adverse effects occur. In fact, prolonged exposure to fluoride by any means will eventually cause or develop a serious disease called fluorosis, not only in humans [1-21] but also in wild and [22-28] domestic animals [29-57]. In general, mammals are more susceptible to fluorosis than birds, amphibians, reptiles, and fish. The primary manifestations of excess fluoride exposure in mammals are known as dental and osteo or skeletal fluorosis.

Chronic fluorosis has been recorded mainly in several species of domestic animals, such as cattle (*Bos taurus*), water buffaloes (*Bubals bubalis*), sheep (*Ovis aries*), goats (*Capra hircus*), camels (*Camelus dromedarius*), horses (*Equus caballus*), donkeys (*Equus asinus*), etc. [29-57]. Acute poisoning in wildlife due to high doses of fluoride is uncommon. However, chronic fluoride toxicity in the form of osteo-dental fluorosis has also been recorded in some species of terrestrial herbivorous mammalian wildlife (Figure 1), such as cervids [red deer (*Cervus elaphus* L.), white-tailed deer (*Odocoileus virginianus*), roe deer (*Capreolus capreolus*), mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), moose (*Alces alces*), etc.], bovids [bison (*Bison bison* and *B. bonasus*)], wild boar (*Sus scrofa*), fruit bats (*Pteropus giganteus, P. poliocephalus* and *Rousettus aegyptiacus*), rodents [voles (*Microtus agrestis* and *Clethrionomys glareolus*), wood mice (*Apodemus sylvaticus*), and cotton rats (*Sigmodon hispidus*)], small mammals [moles (*Talpa europaea*)], and terrestrial and arboreal marsupials [red-necked wallaby (*Notamacropus rufogriseus*), swamp wallaby (*Wallabia bicolor*), eastern grey kangaroos (*Macropus giganteus*), koala (*Phascolarctos cinereus*), common brush tail possum (*Trichosurus vulpecular*), and common ringtail possum (*Pseudocheirus peregrinus*)] [22-28, 58-64]. Osteofluorosis associated with Metabolic Bone Disease (MBD) has also been reported in captive native frogs (*Leiopelma* sp.) in New Zealand [65]. These studies indicate that wildlife or wild animals are not safe from fluoride exposure of any kind and can even cause lifelong lameness in wild animals. The present editorial draws the attention of wildlife conservationists to the fact that long-term exposure to fluoride can threaten the health of wildlife, and on the other hand, to how wildlife can be protected from it.

Sources of fluoride exposure for wildlife

Fluorine (F^-) is the seventeenth most abundant substance in the Earth's crust [1] and is widely distributed in sea water, fresh and ground waters, soil, dust, and mineral deposits. Major sources of fluoride exposure to animals are: fluoridated drinking water, vegetation and agricultural crops growing on fluoride contaminated soil and water, fluoridated phosphate feed supplements, mineral admixtures, dust in the air, and some industrial processes such as coal burning power generation stations, and manufacture of steel iron, aluminium, zinc, phosphorus, chemical fertilizers, bricks, glass, plastics, cement, hydrofluoric acid, etc. These industrial processes typically release fluoride into the surrounding environment in both gaseous and particulate/dust forms [13,14]. Ultimately, the emitted industrial fluoride accumulates in the soil and herbs/vegetation and also contaminates fresh water sources or reservoirs. The main risk of long-term consumption of herbicides and agricultural feed contaminated with fluoride is the development of industrial fluorosis in animals. The accumulation of volcanic ash is also polluting water and vegetation. However, the main sources of fluoride exposure for wildlife are fluoride contaminated water and vegetation which can be contaminated with fluoride in varying amounts through natural and anthropogenic means [66-70].

Fluoride induced adverse health effects in wildlife

When wild animals are exposed to fluoride over a long period of time, regardless of its potential source, once fluoride enters the body it is absorbed by the digestive and/or respiratory tract and ultimately it reaches to all parts of the body through the blood. More than 50% of the absorbed fluoride is excreted through feces, urine, and sweat, while the rest is retained in the body where it is deposited in various organs. However, its maximum accumulation is found in growth or remodeling of calcified organs, such as bones and teeth compared to non-calcified organs. Bone fluoride concentrations will increase as animal's age, even in areas with low environmental fluoride [71]. Fluoride absorption by the skeleton in growing animals is close to 100%, and the rate slows as the bones mature [72].

Bioaccumulation of fluoride causes diverse toxic effects or pathological changes and interference with various physiological and metabolic processes and ultimately triggers the occurrence of adverse reversible and non-reversible health effects in wildlife. Diverse fluoride- induced toxic effects or health changes are collectively called fluorosis [1,73,74]. Various fluoride induced anomalies or lesions developing in teeth and bones are commonly known as dental and skeletal fluorosis, respectively. These lesions are permanent, irreversible and not curable and can be easily seen virtually. The appearance and development of dental and osteofluorosis (skeletal fluorosis) in wildlife is almost identical to those in domestic animals (bovines, horses, camels and flocks) [31,39].

Dental fluorosis typically manifests as light to dark brown or yellowish black stains on tooth enamel, abnormal appearance or quality of tooth enamel, or complete absence of enamel and irregular abrasion of teeth [75]. Increase in the rate of tooth wear which may lead to reduced ability to chew food and premature loss of teeth [28,76]. Excessive tooth wear affects the extent of reduction in food particle size, increasing intake requirements with associated costs of time and energy [77], ultimately reducing the longevity of wildlife. These dental changes also affect food consumption, fitness, and well-being due to pain, loss of function, and systemic effects of infection [78,79].

Skeletal lesions include mild to marked periosteal hyperostosis that may be localized or generalized and Degenerative Joint Disease (DJD or arthritis), which can cause severe pain and lameness. Ultimately, these changes impaired general health, fitness, body condition, and reproduction success or performance may be reduced. Interestingly, in ungulates, lesions are first seen in the metatarsus or metacarpus bones of limbs [80]. In macropods (marsupials), lesions were observed mainly in the hind limbs. Only in those macropods in which bone fluoride concentrations were highest lesions were observed in the forelimbs, spine, and ribs. In the koala, most of the periosteal hyperostosis was seen in the mandibles. DJD was observed primarily

in the elbow joints of the koala and possum wild animals [64] and periosteal hyperostosis was seen equally in both the fore and hind limbs of the possum and koala [63]. Other fluoride-induced bone changes including periosteal exostosis, osteoporosis, osteoporosis, and osteophytosis can also be seen on the ribs, mandible and long bones of wild animals as found in human beings [81-83]. Excess accumulation of fluoride in muscles also reduces or restricts bone movement causing lameness in animals. In addition to intermittent lameness, swelling of the joints, wasting of body muscles, and mortality are also prevalent in animals with fluorosis.

Interestingly, all changes in bone appear only when fluoride level in bone exceeds threshold level that is variable across animal species. It appears that the rate of fluoride accumulation in bone affects the type of skeletal lesions seen. Periosteal hyperostosis may develop rapidly if bone fluoride levels are sufficiently high in young individuals and generally develops more slowly in response to chronic exposure and increases in bone fluoride levels with increasing age of animals. However, the severity of bone deformities such as periosteal hyperostosis and osteophytosis increases with increasing bone fluoride levels. In general, fluoride levels in the bones of affected wildlife have been shown to be above "normal" (approximately >1000 µg F/g). A threshold level of approximately 4000 µg F/g dry bone, above which overt lesions become evident, has been described in various mammalian species [63,84-86]. However, according to Underwood (1977) no macro and microscopic changes in bones are found in animals with fluoride bone levels up to 2,500 ppm [87].

In addition to fluoride-induced changes in teeth and bones, fluoride also affects various organ systems and causes many of the same health problems in wildlife as it does in domestic animals. In fluoride-emitting industrial areas inhabited by wildlife, the most common health complaints like gastrointestinal discomforts, weakness, irregular reproductive cycles, etc. are also found. These health problems are collectively known as non-skeletal fluorosis. All these health complaints do not appear simultaneously in the same animal and are also temporary and may disappear after cessation of fluoride exposure [73-74]. However, the importance of these complaints is that they are early symptoms of chronic fluoride toxicity. Due to which it can also be inferred or there can be a possibility that the animal may have fluorosis disease.

Nevertheless, the prevalence and severity of fluorosis varies greatly among wildlife species living in the same fluoride contaminated ecosystem or environment. In fact, many determinants other than the concentration, duration, and frequency of fluoride exposure are also responsible for the severity of fluoride toxicity [88-95]. In wildlife in any given area, the current status of fluoride toxicity can be determined by estimating fluoride levels in biological samples (urine, blood serum, bones, and hair) and environmental samples (water, air, plant leaves, grass, etc.) [96]. Bone may be obtained from dead animals, or through a bone biopsy obtained under sedation or anesthetic.

How to protect wildlife from fluorosis?

Once manifestations of chronic fluoride intoxication or fluorosis develop in wild animals, treatment is ineffective. One of the most negative aspects of chronic fluoride toxicity in wildlife is the reduced reproductive success that can impact wildlife populations. Therefore, there is a strong need for prevention and control of fluoride intoxication in wildlife. This requires a few key things and can be done easily. One of the important ones is to reduce or control fluoride exposure in young and pregnant wild animals. This is only possible if wild animal species are prevented from grazing in areas around factories that release fluoride into the environment or these animals should be relocated to areas where no industrial fluoride pollution is found. Fluoride emission can also be controlled by adopting advanced technology to absorb fluoride. The effects of fluorosis can also be prevented by giving nutritious food to wild animals. Fluoride toxicity in animals can also be reduced by reducing fluoride absorption or increasing excretion through supplements of calcium carbonate or gluconate, aluminum salts, magnesium metasilicate, magnesium hydroxide, boron, etc. [1].

Figure 1: Fluoride sensitive species of wildlife, **(a)** red deer (*C. elaphus* L.), **(b)** moose (*A. alces*), **(c)** white-tailed deer (*O. virginianus*), **(d)** eastern grey kangaroos (*M. giganteus*), **(e)** bison (*B. bison*), and **(f)** wild boar (*S. scrofa*).

Conclusion

Long-term chronic fluoride exposure is never safe for health and can be dangerous to wildlife and can cause the serious disease fluorosis which is well recognized globally. Excessive fluoride exposure or ingestion leads to abnormal tooth development and fluoride is deposited in the bone throughout life and if levels reach certain limits, the skeletal disease, osteofluorosis, results. Both dental and osteofluorosis (skeletal fluorosis) have been observed in many species of wildlife living in high fluoride environments. Once clinical manifestations of fluorosis are established in wildlife there is no treatment other than risk reduction. Due to limited research work on fluoride toxicity in wildlife, there is still a need for more comparative epidemiological studies on fluorosis in different species of herbivorous and

carnivorous wild animals.

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