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Mini Review

Is Wildlife Safe From Coal-Burning Thermal Power Plants In India In The Context Of Fluorosis?

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Abstract

India has more than 300 coal-fired thermal power plants (TPPs) that generate electricity. They require fossil coal as fuel and sufficient water to run. During the burning of these coals in TPPs, fluoride-containing gases such as hydrogen fluoride (HF), silicon tetrafluoride (SiF_4) and carbon tetrafluoride (CF_4) are emitted which contaminate the surrounding air, soil, surface water, vegetation, agricultural crops, grasslands, etc. Fly ash, a byproduct of coal combustion, and the fly ash ponds of TPPs have also been found to contain fluoride up to 12.6 mg/kg and 9.94 ppm, respectively. These fluoride-rich sources can cause fluoride contamination in freshwater and groundwater, respectively. Most TPPs in the country are located in areas where agricultural crops, forests, grasslands, and freshwater bodies are also found. Various herbivorous wild animals such as antelopes and deer are commonly found in such environments. If these wild animals are exposed to fluoride emissions and fluoride-contaminated food and water for a long time, they are not safe from fluoride poisoning and may develop fluorosis. Due to which the teeth of these animals become mottled, weak, and start falling at an early age (dental fluorosis). Later, these animals also develop bone disease called skeletal fluorosis. In the absence of research, it is difficult to tell how many wild animals of which species in the country are suffering from fluorosis due to TTPs. This communication highlights how herbivorous wildlife, antelopes and deer, can be affected by chronic fluoride poisoning due to prolonged exposed to fluoride emissions and fluoride contaminated food (crop forage, fruits, seeds, grains, grasses, forest vegetation, etc.) and fresh and groundwater due to coal-based thermal power stations in the country.

Keywords: Animals; Coal; Contamination; Exposure; Fluoride emission; Fluoride poisoning; Fluorosis; Fly ash; Freshwater; Groundwater; Pollution; Thermal power plants; Wildlife.

INTRODUCTION

Fluorosis is endemic in areas where people and animals are exposed to fluoride for a long time and is prevalent in many countries [1-4]. In India, the disease is predominantly endemic in rural areas where villagers and their pets drink fluoridated groundwater which is the main source of fluoride exposure for them. The recommended value of fluoride in drinking water in the country is 1.0 ppm or 1.5 ppm [1,5,6]. But in villages, most drinking groundwater sources, such as hand-pumps, bore-wells, and deep dug-wells are found to be contaminated with varying amounts of fluoride [7,8]. Groundwater in most tribal areas of the country has fluoride content of more than 10.0 ppm [9-11]. This is the main reason why fluorosis (hydrofluorosis) is endemic in the rural areas of the country. Millions of people and thousands of domestic animals of various species in the country suffer from this hydrofluorosis disease. Water borne fluorosis in the country has been extensively studied in both humans [12-25] and various herbivorous domestic animals such as cattle (*Bos taurus*), water buffalo (*Bubalus bubalis*), sheep (*Ovis aries*), goat (*Capra hircus*), horse (*Equus caballus*), and donkey (*E. asinus*) [26-42].

In the country, "industrial fluoride emissions" are another source of fluoride exposure that is responsible for the development of fluorosis (industrial fluorosis) in humans [43-45] and domestic animals [46-53] if they are exposed to it for a long time. Fluoride emissions or pollution is generally confined to the vicinity of its production source. The most common sources of fluoride emissions in the country are coal-burning thermal power plants (TPPs) and brick kilns [54,55]. However, industrial fluoride emissions also occur from steel, iron, aluminium, zinc, phosphorus, chemical fertilizers, glass, plastics, cement and hydrofluoric acid producing industries

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[1,3]. This emission not only contaminates freshwater sources, soil, and air, but also agricultural crops, forest vegetation, grasslands, etc. on which wild and domestic animals generally depend on their food. This industrial fluoride emission can also damage agricultural and horticultural crops. This results in decreasing of crop yields which causes economic losses to farmers [56,57]. Whatever the cause, no comprehensive research has yet been done on industrial fluorosis in Indian wildlife due to exposure to fluoride emissions from coal-burning TPPs in the country. However, in other countries, industrial fluorosis has been extensively studied in various species of antelopes and deer exposed to industrial fluoride pollution due to causes other than TPP [58-70]. In India, industrial fluorosis in wildlife and domestic animals due to TPP has not been reported yet [69,70]. However, industrial fluorosis in domestic animals due to TPP has been reported in other countries [71,72]. The present communication highlights how wildlife may be affected by fluoride poisoning due to continuous exposure to fluoride emissions from TPPs in the country. The author draws the attention of concerned departments, policy makers and environmentalists to the possibility of industrial fluorosis in Indian wildlife due to continuous exposure to fluoride emissions from coal-fired TPPs in the country. The author also provides important suggestions on how to identify chronic fluoride poisoning in wildlife.

COAL-BASED THERMAL POWER PLANTS IN INDIA

According to the latest data, there are about 300 coal-based thermal power plants (TPPs) operating in various states of the country for power generation [73]. They require regular supply of fossil coal fuel and water for their regular operation. That is why they are usually installed where perennial water sources are available, such as rivers, lakes, dams, large ponds, etc. (**Figure 1**) so that they can be supplied with continuous water from there. The Singrauli region of central India in the country has three thermal power plants, namely Singrauli, Vindhyachal, and Rihand running where both coal mine and large reservoir are available, so it is an ideal region for setting up thermal power plants in the country [74]. These thermal power plants use coal obtained from the local mine and water from the Rihand reservoir. Agricultural and horticultural crops, grasslands, and forest vegetation are also found around most of the coal-based thermal power stations in the country on which wildlife usually depends for their food (**Figure 1**).

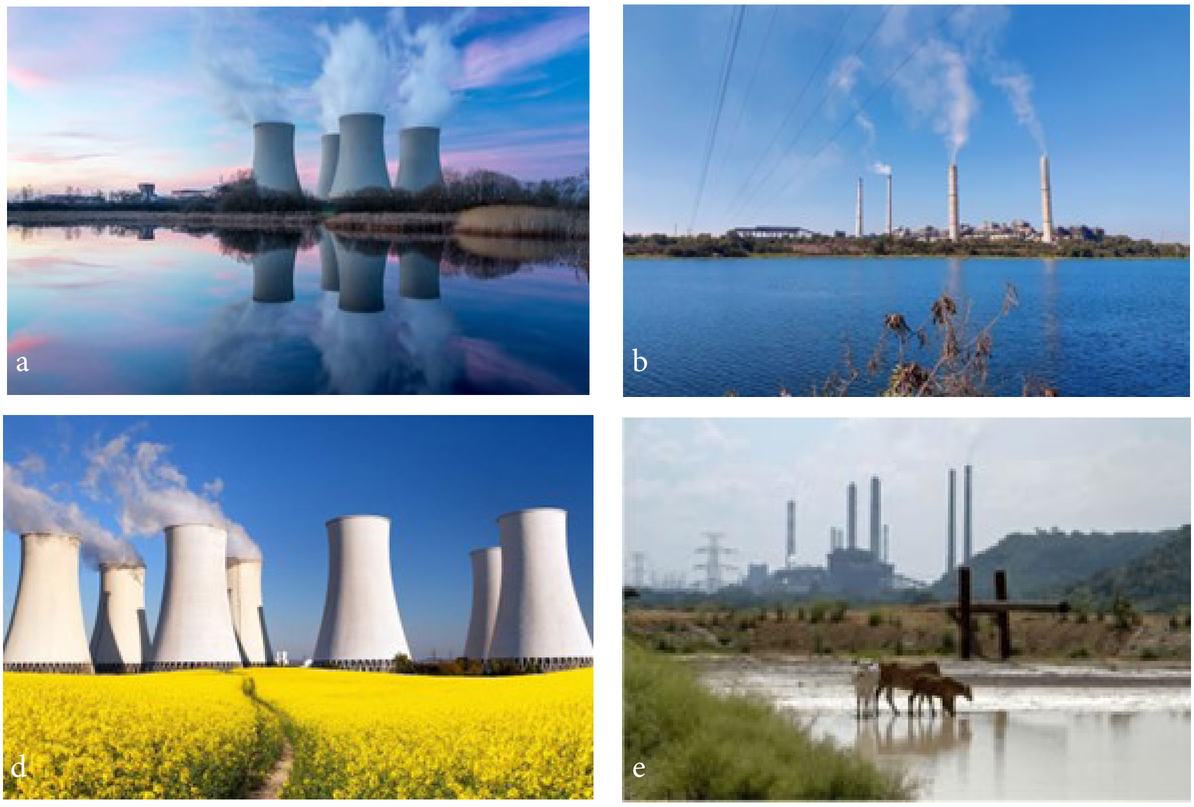

Figure 1. Most of the thermal power plants in the country have been set up in places where there are water reservoirs (a,b,and e), agricultural farms (d), grasslands and forests (a,b,and e) where wild animals are found. These natural sources get contaminated due to fluoride emissions from thermal power plants, on which wild animals depend for air, food and water. Due to which they start developing fluorosis (Industrial fluorosis).

MODE OF FLUORIDE CONTAMINATION FROM TPPS

More than 859.25 million tonnes of natural coals are required annually to run coal-based thermal power stations in the country, which is used as fuel [75]. Most people are unaware that the fossil coal used in TPPs also contains substantial amounts of fluoride in various forms. Generally, most natural coals have fluoride content levels ranging between 20–500 μg g−1, with an average value of about 150 μg g−1 [76-78]. Fluoride in most Indian coals is generally found in the range of 10−20 g/tonne [79, 80]. During the combustion of these coals in TPPs, fluoride is also released as toxic gases such as hydrogen fluoride (HF), silicon tetrafluoride (SiF_4), and carbon tetrafluoride (CF_4) into the surrounding environment [76, 78] and contaminates not only soil, air and freshwater reservoirs but also grasslands, agricultural crops and forest vegetation near TPPs. This emission is also known as industrial fluoride emission which has the potential to contaminate food grains and crop plants on which humans and wildlife generally depend for their food. All these fluorides contaminated natural sources are potential ideal sources of chronic fluoride exposure to humans and wild and domestic animals.

Interestingly, in the country, coal-burning thermal power stations not only emit fluoride into the environment but also generate about 233 million metric tons of coal fly ash annually. This figure is constantly rising, with forecasts suggesting it may exceed 300 million tons by 2025 [81] posing a threat to the environment. It represents a significant environmental challenge due to the need for land-based disposal and the potential for heavy metal and fluoride leaching into groundwater. Fly ash is a fine powder generated as the primary byproduct of coal combustion, accounting for about 80% of the total coal ash generated while the remaining 20% is bottom ash. This fly ash also contains varying amounts of fluoride depending on the quality of coal. Its content in fly ash generally ranges from 0.73 to 1.27 ppm. However, some studies have shown that fluoride levels in fly ash from some Indian power plants can be as high as 12.6 mg/kg [74]. This fluoride-rich fly ash is usually transported in dry form or as a wet slurry to silos or ash ponds located near TPPs, respectively.

Fly ash ponds of TPPs are also potential sources of fluoride contamination. Fluoride can be released into soil and water through leaching from fly ash, which eventually reaches groundwater aquifers. Generally, slurry water from most ash ponds is usually discharged into freshwater sources such as rivers, lakes, large ponds or reservoirs, dams, etc., located near TPPs, leading to fluoride contamination of freshwater. Fluoride content in slurry water from ash ponds of some TPPs has been reported to be >10.0 ppm [74]. Similarly, the fluoride content in reservoir water near TPP in Singauli area was found to be around 5.0 ppm [74]. These fluoride contaminated groundwater and freshwater are potential sources of fluoride exposure. If wild animals drink or are repeatedly exposed to such fluoride contaminated water over a long period of time, they can certainly develop fluorosis.

Agricultural and horticultural crops, grasslands and forest vegetation near TPPs are generally exposed to fluoride emissions from TPPs and are contaminated with fluoride [71]. In many areas, these crops are also irrigated from reservoirs and groundwater sources (bore-wells). Both fluoride emissions and fluoride-contaminated irrigation water contaminate agricultural crops with fluoride. Consumption of these can also lead to fluoride poisoning in wildlife.

IS WILDLIFE SAFE FROM TPPS IN THE CONTEXT OF FLUOROSIS?

Yes, if wild animals are continuously exposed to fluoride emissions from TPPs and consume fluoride contaminated water (surface and groundwater) and food (crops, fodder, grass, forest vegetation, etc.), they are not safe from fluoride toxicity and may develop fluorosis. In the country, the most common mammalian herbivores are antelope species such asnilgai (*Boselaphus tragocamelus*), chinkara (*Gazella bennettii*), blackbuck (*Antilope cervicapra*), and chowsingha (*Tetracerus quadricornis*) and deer such as spotted deer or chital (*Axis axis*), sambar (*Rusa unicolor*), barasingha or swamp deer (*Rucervus duvauceli*), hog deer (*Axis porcinus*), Indian muntjac or barking deer (*Muntiacus muntjak*), and Indian chevrotain or mouse deer (*Moschiola indica*) species (**Figure 2**) which are found in the vicinity of most TPPs. Therefore, it is possible for them to develop fluorosis. However, there is not a single report available on chronic fluoride poisoning in wildlife due to TPP in India and other countries. However, there are many factories that do not run on coal but emit fluoride into the environment. Various species of herbivorous wild animals have developed fluorosis due to exposure to this fluoride emission, which has been well studied in other countries [58-70].

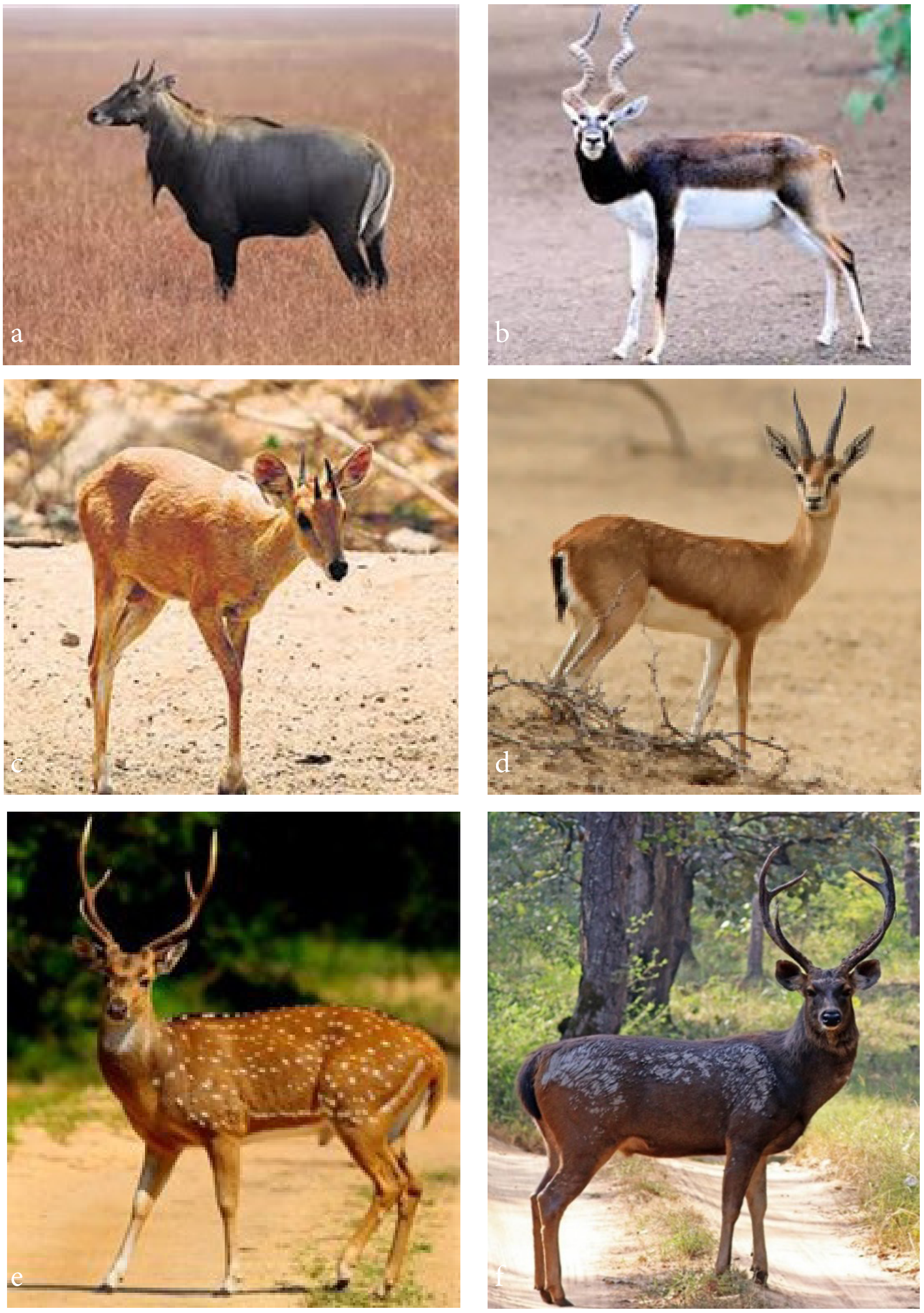

Figure 2. The most common species of antelopes, (a) nilgai or blue bull (*B. tragocamelus*), (b) blackbuck (*A. cervicapra*), (c) chousingha (*T. quadricornis*) and (d) chinkara (*G. bennettii*) and deer, (e) spotted deer or chital (*A. axis*) and (f) sambar (*R. unicolor*) are found in the areas adjacent to TPPs in India.

In chronic fluoride poisoning in animals, generally, teeth and bones are affected. During tooth development, fluoride is usually beneficial in their mineralization and strengthening. But excessive deposition of fluoride in teeth is harmful and leads to hypocalcification or discoloration and weakening of teeth. Dental mottling is the earliest visible pathognomonic or clinical sign of chronic fluoride poisoning in wild and domesticated animals and even in humans, which is usually identified by the presence of bilateral striated, condensed or diffused and horizontal light to dark brown stripes of varying degrees on the surface of the anterior teeth (Figure 1) [82]. The various pathological changes in teeth caused by fluoride are collectively known as dental fluorosis. The worst aspect of dental fluorosis is that it reduces the life span or longevity of animals. Its severe form causes serious problems in grazing and mastication of food which may lead to loss of appetite and weakness in animals and may even lead to death [1].

Excessive bioaccumulation of fluoride in the bones of animals exposed to any source of fluoride causes various pathological changes in the bones such as periosteal exostosis, osteoporosis, osteosclerosis, and osteophytosis [83-85], collectively known as skeletal fluorosis. This fluoride-induced bone disease is extremely painful and reduces or limits the movement of bones leading to lameness in animals. This is the worst condition of fluoride intoxication in animals. Inflammation of bone joints, loss of body muscle mass and mortality are common in these animals. These bone changes persist in the animals for their entire life and cannot be treated.

These skeletal changes can be seen on the ribs, jaws, and long bones of wild animals. Excessive accumulation of fluoride in the muscles also reduces or limits the movement of bones leading to lameness in animals which is a very painful and worse condition of skeletal fluorosis in animals. Intermittent or lame walking (lameness), swollen joints, loss of body muscle mass and mortality are common in animals suffering from chronic fluoride poisoning [82]. The bone changes caused by fluoride poisoning remain in the animals for their entire life and currently there is no treatment available for these changes. Changes caused by fluoride in wildlife bones depend on the level of fluoride deposited in the bones. Generally, these changes are seen in animals when fluoride levels in bones are found to be above "normal" (approximately >1000 μg F/g). A threshold level of approximately 4000 μg F/g dry bone, above which obvious lesions become apparent, has been described in various mammalian species [78,86-88]. However, according to Underwood (1977), no macroscopic and microscopic changes were found in the bones of animals with fluoride bone levels up to 2,500 ppm [89].

Interestingly, wild animals suffering from fluorosis may suffer from some health issues like gastrointestinal problems (loss of appetite, bloating, abdominal pain, constipation, intermittent diarrhea, etc.), weakness of body muscle, polydipsia, polyuria, allergies, reproductive health problems (irregular reproductive cycles, frequent abortions, and stillbirths), anaemia, etc. [82]. But it is not necessary that all these health problems occur in the same animal suffering from fluorosis. However, these health problems are useful and indicate the onset of fluoride toxicity in animals. Nevertheless, these health consequences of fluoride are temporary and reversible in animals.

Though, the severity of fluoride poisoning in wildlife depending on the fluoride concentration and its duration and frequency of exposure. But many determinants are also governing the severeness of fluorosis in animals like age, dietary nutrients, environmental factors, individual sensitivity, biological response, and tolerance, genetics, etc. [90-96].

Fluorosis can be easily identified in domestic animals [82, 97] because they can be easily handled by humans. However, fluorosis is more difficult to identify in wild herbivores because they are difficult to handle or capture. However, wild animals suffering from chronic fluoride poisoning can be determined by measuring the fluoride content in their hair, faeces, urine, and the teeth and bones of dead animals [98]. Fluorosis can also be confirmed by the presence of dental fluorosis and bone changes in dead animals. Estimation of fluoride content in environmental samples also gives an indication of endemic fluoride and fluorosis in areas where wildlife is present. However, in the absence of epidemiological studies on fluorosis in wild animals, it is difficult to say which species of wildlife is more sensitive or less tolerant to fluoride toxicity due to chronic exposure to industrial fluoride emissions or pollution (industrial fluorosis) and to fluoridated water (hydrofluorosis) and food (foodborne fluorosis). The findings of these studies will be useful in formulating health plans or policies to protect wildlife health from fluorosis caused by TPPs and other industrial activities in the country.

CONCLUSION

There are more than 300 coal-burning thermal power plants (TPPs) in operation in India. Due to the combustion of fossil coal in TPPs, fluoride containing gases are also being emitted into the environment and contaminating the natural sources, such as water, soil, air, horticultural and agricultural crops, grasslands, and forest vegetation in their vicinity. Fluoride emissions from TPPs and fluoride contaminated water and food are potential sources of fluoride exposure for animals. If wild animals living and grazing around TPPs are exposed to any of these potential sources of fluoride for a long time, they will be affected by the disease fluorosis. Although this disease has been observed in domestic animals due to TPPs, studies of fluorosis in wildlife due to fluoride emissions and continuous exposure to fluoridated water and food have not been conducted in the country yet. Hence, more epidemiological studies in wildlife in the country are highly recommended or suggested. The findings of these studies will be useful in formulating health policy to protect the health of wild animals exposed to fluoride emissions from coal-based thermal power stations in the country.

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