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Is Naturally Fluoride Contaminated Groundwater Irrigation Safe for the Health of Agricultural Crops in India?

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Abstract

In India, before the eighties, traditional water sources, namely deep dug-wells, ponds, and rivers were used for irrigation in agriculture. Later, apart from these sources, people started doing irrigation more from bore-wells. Surveys reveal that groundwater of most of deep dug-wells and bore-wells found to be contaminated naturally with fluoride toxicant. Long-term exposure to fluoride through these water sources is not only harmful to the health of humans and animals but also to diverse agricultural crops. In rural India, where most agriculture takes place, more than 90% of groundwater of these sources contains fluoride beyond the level of 1.0 ppm or 1.5 ppm. Persistent fluoride exposure through naturally fluoridated groundwater irrigation in agriculture adversely affects various physico-biochemical parameters of crops; sometimes without visible signs of injury. The most common visible fluoride- induced morphological changes or signs in crop plants are necrosis, chlorosis, leaf blight or damage, tip burning, and leaf curling. Dwarfism syndrome or stunted growth was also found in these fluorosed crop plants, which is also a common sign of chronic fluoride toxicity. Fluoride also has tremendous potential to cause adverse changes in various physiological and metabolic processes, such as seed germination, photosynthesis, CO_2 assimilation, respiration, protein nucleotide synthesis, carbohydrate metabolism, hormonal imbalance, various enzyme activities, gene expression pattern, inhibition in the developmental and reproductive capabilities, etc. Research findings indicate, fluoridated groundwater irrigation is not healthy for crop plants and ultimately causes economic losses to farmers due to reduction in crop productivity or yield. In the present communication, whether groundwater irrigation in India is safe for the health of agricultural crops with respect to fluoride is briefly highlighted. Along with this, research gaps are also highlighted for the researchers to do further research work on chronic phytotoxicosis in different species of crops at different levels of fluoride in irrigation water.

Keywords: agricultural crops; contamination; dwarfism; fluoride; germination; groundwater; irrigation; metabolism; necrosis; photosynthesis; phytotoxicity

Introduction

There is no doubt that India is still basically an agricultural country where agriculture is mainly done in rural areas. Before eighty decades, traditional water sources like deep dug- wells (Figures 1), rivers, and ponds or reservoirs were used for irrigation in agriculture. Later, the villagers started using water from bore-wells (Figures 5 and 6) for irrigation purposes. At present, this water source is available in abundance in the rural areas of the country. One of the main reasons behind this has also been the commencement of “Dracunculus Eradication Programme” in various states in the country [1]. Because the drcunculiasis disease, caused by infection of human nematode worm, dracunculus (*Dracunculus medinensis*), was endemic especially in the rural areas of several states and union territories, hand-pumps and bore -wells were dug at various places to break the life cycle of this dreaded worm [2,3]. But the farmers are still unaware of the fact that the water of deep dug-wells and bore-wells is contaminated with fluoride in varying amounts [4, 5]. Based on survey reports, >90% of drinking groundwater sources (bore- wells, hand-pumps, and dug- wells) are naturally contaminated with fluoride and most of these source’s groundwater has fluoride beyond the allowable levels >1.0 ppm or 1.5 ppm (Figure 2) [6-8]. Prolonged exposure to such fluoridated groundwater and/or industrial fluoride pollution is not only spoiling the health of humans [9-21] and domestic animals [22-46] but also causes huge damage to agricultural crops [47-49]. In the present communication, attention has been drawn to the concerned people whether the groundwater of rural areas of India is safe for the health of agricultural crops in terms of fluoride or not. Simultaneously, research gaps have also been highlighted for researchers to do some advance research work on fluoride induced phytotoxicity in different species of agricultural crops at different fluoride level in the irrigation groundwater. Through this article, an attempt has also been made to attract the attention of the farmers and concerned departmental people towards this vital and important subject.

Figure 1: In rural areas of India, water from dug wells (Figures A-D) and bore-wells (Figures E and F) is used for irrigation of agriculture by adopting traditional and advanced methods, respectively.

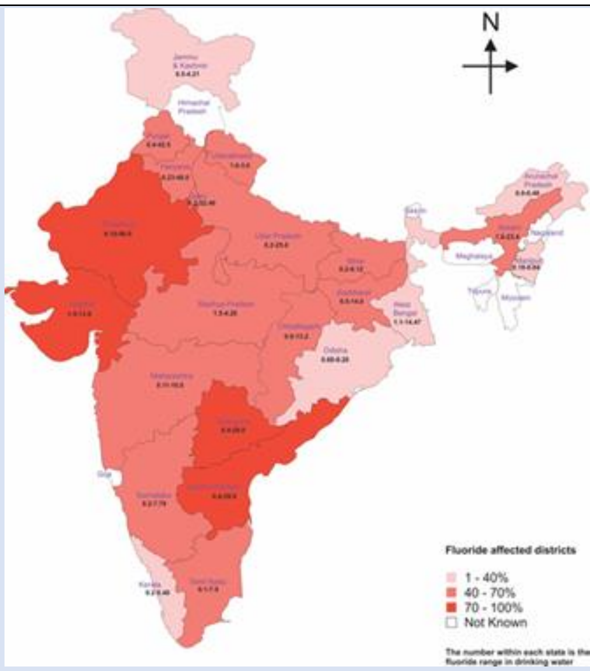

Figure 2: Map of India showing fluoride (in ppm) contamination of groundwater in different states and union territories. Source: [5].

Fluoride transportation in plants

In most rural areas of India, due to low rainfall, frequent droughts, and inadequate and uneven distribution of perennial fresh water, farmers or villagers are forced to depend on groundwater for continuous irrigation [50-52]. But due to the high content of fluoride in the groundwater, its repeated use in irrigation also increases the fluoride level in agricultural soil. Such fluoride contaminated soil is not suitable for growing various agricultural staple food crops or varieties.

In fact, fluoride enters plants through two main routes. First, airborne deposition of gaseous fluoride (due to industrial fluoride pollution) enters through stomatal diffusion. Through leaf stomata, fluoride penetrates the cell wall and migrates to the margins and tips of leaves, which are the sites of greatest volatilization [53]. The second route is through a passive diffusion process in the roots of plants from fluoride contaminated soil and groundwater. Fluoride is subsequently transported via apoplastic and symplastic routes in directional distal movement through the xylem to the shoot [54]. In fact, fluoride moves into the transpiration stream from the roots or through the stomata and then eventually accumulates in the leaf margins. Generally, fluoride accumulation follows the order of soil > root > shoot > grain. The bioavailability of fluoride to plants is, generally, influenced by the presence of metal ions such as calcium (Ca), aluminium (L), and phosphorus (P), the pH of the solution, and the type of soil [55].

Fluoride induced toxic effects in crop plants

Repeated fluoride exposure through irrigation of naturally fluoridated groundwater, fluoride-enriched soils and/or industrial fluoride pollution and its bio-accumulation produces several adverse health effects in both seasonal and off-season agricultural crops, vegetables, and trees [56-59]. In fact, the bio-accumulation of fluoride in various parts of plants triggers the genesis of various toxic effects. Fluoride bio-accumulation affects not only the anatomy and morphology of crop plants but also their various most important and critical physiological and biochemical processes. Ultimately, these changes in the physio-biochemical activities reduce the annual crop productivity or yield or harvest index.

The most common visible morphological changes or pathological signs induced by fluoride in crop plants are necrotic lesions or necrosis, chlorosis, leaf damage, tip burning, and curling of leaves that spread inward (Figures3 and 4) [56, 57]. Symptoms of dwarfism syndrome (stunted growth) have also been found in most of the fluoride affected crop plants. In fact, fluoride strongly inhibits or has the potential to adversely alter photosynthesis and other biological processes such as seed germination, CO_2 assimilation, respiration, protein and nucleotide synthesis, carbohydrate metabolism, hormonal imbalance, various enzyme activities, gene expression pattern, inhibition in the developmental and reproductive capabilities, etc. These parameters are well studied scientifically by several researchers in different agricultural crops [60-69]. Ultimately, these fluoride-induced morphological and physiological changes affect the rate of annual agricultural productivity or yield due to which the farmers suffer huge economic losses. This is neither known to the farmers nor the concerned department people. On such economic losses, scientific evaluation has not yet been done in the country, which is also very important. Because such type of evaluation is more significant and helpful in framing or making of economic policy in the country.

Figure 3: Rice plant (*Oryza sativa*) showing leaf necrosis with burnt margin due to fluoride toxicity Source [57].

Figure 4: Fluoride poisoning in leaves of rice plant. Healthy leaf (A), chlorosis leaves (B), tip burning (C), and burning of tip and side margin of fluorosed leaf (D). Source: [57].

Most of these fluoride-induced changes are observed mostly in well-designed experimental studies conducted on different agriculture staple food crops. The magnitude of these changes was more depending on doses of fluoride concentration and its frequency of exposure. These studies are enough to accept that repeated exposure of fluoride through irrigation of fluoridated water is highly phytotoxic but these studies are not indicating the toxic level or optimum value of fluoride in plants as decided the standard value for human beings (1.0 or 1.5 mg/L). Therefore, studies are needed on this direction or aspect for deciding the standard level of fluoride for starting the phytotoxicosis. Though in humans and domestic animals' diverse determinants of magnitude or severity of fluoride toxicity have been well studied [70-78]. Such studied are also needed in crop plants. The findings of such studies are more useful in amelioration of fluoride toxicity in agricultural crops. In addition, "there is a need for a universally accepted guideline for the diagnosis of fluoride-induced chronic phytotoxicosis, similar to the identification of fluoride exposures in humans and animals [79, 80]. So that the ill effects of fluoride in crops can be easily identified or diagnosed.

On the sinister aspect, fluoride poisoning in crops not only has a profound effect on their production, but there is also a possibility of dangerous fluorosis disease in domesticated animals and villagers, respectively, by consumption of fodder and grains of these crops. In fact, several studies revealed that in fodder and various food stuffs (grains, pulses, fruits, and vegetables) contain high amount of fluoride content [81-86]. Intriguing that neither the farmers and nor the agriculture and medical scientists concerned has accurate information about all these fluorides borne threats. However, several scholars and scientists discourage and unfavoured the cultivation of various agricultural crops and vegetables in fluoride containing soil and irrigated by fluoridated groundwater. Actually, drinking such fluoridated groundwater is not even safe for the health of humans and animals [87,88].

Conclusion

In rural areas of India, apart from drinking, groundwater is also used for irrigation in agriculture. Most groundwater of deep dug-wells and bore- wells are contaminated with varying degrees of fluoride. No doubt, based on numerous studies, it is unanimously accepted that fluoridated groundwater irrigation in agriculture is not only unsafe for the health of crops, but also reduces their annual agricultural productivity or grain yield. Due to which the farmers suffer huge economic losses. Long-term ingestion of fluoridated groundwater is also unsafe for the health of farmers and their domesticated animals and can lead to a disease called fluorosis, which can also lead to lameness. Though there are number of signs or symptoms, such as necrotic lesions, chlorosis, leaf damage, tip burning, curling of leaves, stunted growth or dwarfism, inhibition of photosynthesis, etc. of chronic fluoride poisoning in diverse agriculture crops but sometimes these may create confusion in diagnosis of fluoride induced phytotoxicosis. In absence of ideal guidelines for diagnosis of fluoride poisoning in crop plants can also be confirmed by assessing fluoride in feed crops. However, there is still a need for more field and well-designed scientific experimental studies on chronic fluoride poisoning in different species of agricultural crops in relation to different fluoride concentrations of groundwater, different environments or ecosystems, types of soil, and duration and frequency of fluoride exposures. The findings of these studies will be helpful in reducing fluorotoxicosis in plants as well as increasing agricultural productivity or yield.

Conflict of interest

There is no conflict of interest of the author.

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