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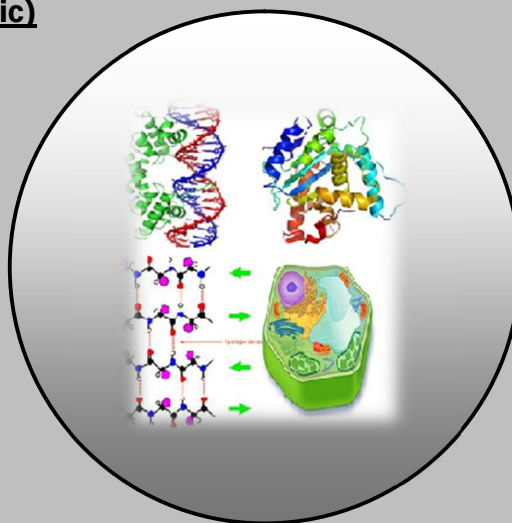
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REVIEW ARTICLE

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Fluoride Contamination in Groundwater of Rajasthan: Its Deleterious Impacts and Preventive Measures

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ABSTRACT

With rising population and dwindling groundwater resources, the groundwater quality of Rajasthan is deteriorating day by day. As per WHO report, 20 per cent of the fluoride-affected villages in the whole world are in India. Out of 33,211 fluoride-affected villages in the country. Drinking water with excessive concentration of fluoride causes fluorosis which progresses gradually and becomes a crippling malady in the long run. It affects young, old, poor, rich, rural, and urban population. It has attained a very alarming dimension. Rajasthan suffers both the problems of quantity and quality of water. In most part of the state groundwater is either saline or having high nitrates and fluoride content. Obviously, groundwater is the major source of drinking water and over 94% of the drinking water demand is met by groundwater. Excess fluoride concentration in drinking water has deleterious effects on human health. All the districts in Rajasthan are engulfed by the clutches of fluorosis, to a varying degree. There being no perennial surface source for drinking water, the state is dependent chiefly on groundwater and its level is deeper year-by-year due to over exploitation. As the water table is receding more and more water sources are becoming prone to higher fluoride concentration. The pattern and prevalence of fluorosis in human population are determined by a number of epidemiological factors like water chemistry, demographic and nutritional profile of the community and high mean annual temperature of the area. UNICEF has taken definite steps in collaboration with Government and NGOs, to deal with the problem of fluorosis in Rajasthan. Beside, changing dietary habits, harvesting rainwater and promoting defluoridation of drinking water at household level can yield spectacular results in this regard. Different defluoridation techniques are being tried to make drinking water free from fluoride contamination. In this manuscript fluoride toxicity in groundwater, its clinical manifestations, preventive measures and various mitigation strategies are delineated precisely.

Keywords: Clinical manifestations, RWH, Reverse osmosis, Capacitative deionization, Fluorosis and Nutritional prophylaxis.

INTRODUCTION

Millions of men, women and children in many states of India are afflicted by water borne fluorosis and several lacs of them are crippled and are leading vegetative life. The poor and economically weaker sections having low nutritional status are affected more. The incurable disease continues to be a major public health problem and urgent preventive measure, are needed. With rising population and dwindling groundwater resources, the groundwater quality is deteriorating day by day. As per WHO report, 20 per cent of the fluoride-affected villages in the whole world are in India. *Out of 33,211 fluoride-affected villages in the country Rajasthan has 16,560 villages, which is more than 51 per cent. From these figures we can draw an inference that nearly 10% of fluoride-affected habitation in the world is in the Rajasthan alone.* Drinking water with excessive concentration of fluoride causes fluorosis which progresses gradually and becomes a crippling malady in the long run. It affects young, old, poor, rich, rural, and urban population. It has attained a very alarming dimension. Rajasthan is the largest state in the country in terms of geographic spread. It has an area of 3.42 lakh Sq kms being largest state of the country having 10.41 % of the country's area and 5.5% of nation's population but has low water resources i.e. 1% of the country's resources. The state has extreme climatic and geographical condition. Rajasthan suffers both the problems of quantity and quality of water. *In most part of the state groundwater is either saline or having high nitrates and fluoride content.*

Obviously, groundwater is the major source of drinking water and over 94% of the drinking water demand is met by groundwater. Excess fluoride concentration in drinking water has deleterious effects on human health. It causes a dreadful disease known as *fluorosis*, though a common endemic problem of our country is more widespread and acute in the state of Rajasthan where all the districts are engulfed by the clutches of fluorosis, to a varying degree, mainly due to presence of high fluoride content in drinking water.

There being no perennial surface source for drinking water, the state is dependent chiefly on groundwater and its level is deeper year-by-year due to over exploitation. As the water table is receding more and more water sources are becoming prone to higher fluoride concentration. *It is really shocking that India has only 4 per cent of global water recourses, whereas constitutes 16 per cent of total world population.* The pattern and prevalence of fluorosis in human population are determined by a number of epidemiological factors like water chemistry, demographic and nutritional profile of the community and high mean annual temperature of the area.

United Nations Children's Fund (UNICEF) has taken definite steps in collaboration with Government and Non-government organizations (NGOs), to deal with the problem of fluorosis in Rajasthan. Raising public awareness regarding fluorosis has become more critical. Beside, changing dietary habits, harvesting rainwater and promoting defluoridation of drinking water at household level can yield spectacular results in this regard. Different defluoridation techniques are being tried to make drinking water free from fluoride contamination. Awareness camps are being organized all over the state to make the masses aware of ill effects of fluoride problems.

The state government has also taken up various programmed action plans such as artificial recharge of groundwater, rejuvenation of traditional *baoris-kunds*, water conservation, rainwater harvesting (Injection well technique) and judicious use of underground water for drinking and other purposes.

Fluorosis is an environmental disaster being experienced by millions of people. It has also been experienced for a long time also patients, often get misdiagnosed with *arthritis*, *spondylitis* or *non-specific backache*. According to nationwide study of New Delhi based Fluorosis Research and Rural Development Foundation (FRRDF), “the occurrence of fluorosis can vary among different locations having almost the same fluoride concentrations in drinking water and can be affected by factors such as climate, individual susceptibility and biological response”. The study concluded that “Poor nutrition also plays an important role in aggravating endemic fluorosis”, thus explaining why poor people are often the worst affected. **Fluorosis is an irreversible disease and there is no cure.**

In 21st century depleted groundwater levels and deteriorated quality will be major health and environmental problem. The social, economic and environmental values associated with groundwater are often unrecognized. A large proportion of the world's population relies on groundwater as a primary source for drinking and domestic use. In recent times on account of the increase in population, urbanization, industrialization, use of fertilizers and pesticides in agriculture, there is over increasing threat to surface and groundwater quality. The tremendous use of groundwater for irrigation and other purposes has resulted sharp decline in groundwater table and changes in the natural geochemistry of groundwater.

The presence of fluoride in groundwater is human made. Over exploitation of groundwater in the last 20 years, is the chief reason for the spread of fluorosis in Rajasthan. With the coming of diesel pump sets things have changed. *Farmers have started to dig deeper into the earth's crust and are literally extracting poison. Rajasthan is a classic case of falling water tables and increasing incidence of fluoride in water.*

Thus it appears that the situation vis-a-vis fluoride is on the rise despite substantial efforts by the Government and NGO's action plans in the field. The situation is grim and warrants a holistic approach to ameliorate the situation and a concerted action accordingly.

SOURCES OF FLUORIDE IN ENVIRONMENT

FLUORINE

Fluorine is 13th most abundant element of halogen group having At No - 9 and Mo Wt – 19, available in the earth's crust. It is the most electronegative of all the elements known to the world and exists as a diatomic molecule with a remarkably low dissociation-energy (38 k cal/mole). As a result it is highly reactive and has strong affinity to combine with other elements to produce compounds known as fluorides (Clerklewski, 1997).

It is, in fact, one of the most bones seeking acute toxin of notable chemical qualities and physiological properties as well. The effect of chronic fluoride intoxication is universally known as *fluorosis*. It continues to be a problem of public health magnitude throughout the world. The main occurrence of fluorine in rocks is in the form of fluoride bearing minerals. Usually the surface water does not contain high fluoride whereas groundwater may be contaminated with high fluoride content because the usual source of fluoride is fluoride rich rocks. When water percolates through rocks it leaches out the fluoride from these rocks.

Fluorspar- CaF_2 (Sedimentary rocks like lime stones, sandstones), Cryolite – Na_3AlF_6 (Igneous rocks like Granite) and Fluoro-apatite – $\text{Ca}_3(\text{PO}_4)_2$ are the main rocks which are rich in fluoride.

Fluorides come next to sulphur dioxide (SO_2) in the hierarchy of atmospheric gaseous pollutants. Fluorides are released in the air as gaseous hydrogen fluoride (HF) and volatile fluorides like cryolites and silicon fluoride (SiF_4). These pollutants result from aluminum factories, brick kiln, pottery industries, ferro-enamel works, stacks of factories processing-ore and oil (Dean and Elvove, 1935).

Fluoride contamination occurs through a natural process in which fluoride bearing rocks crumble and breakdown but the process can be speeded up if the chemistry of the aquifer is disturbed. Fluoride is known to contaminate groundwater reserves globally. In India its occurrence in top aquifer system is endemic in many places of Andhra Pradesh, Tamil Nadu, Karnataka, Gujarat, Rajasthan, Punjab, Harayana, Bihar and Kerala. Abnormal level of fluoride in water is common in fractured hard rock zones with pegmatite veins. The veins are composed of minerals such as topaz, fluorite, fluoroapatite, villuamite, cryolite and fluoride-replaceable hydroxyl ions in ferromagnesium silicates. Fluoride ions from these minerals leach into the groundwater and contribute to high fluoride concentrations.

High profile of fluoride in shallow zone groundwater is due to the geo-chemical deposition in the vicinity of the groundwater extraction structures.

The toxicity of fluoride is also influenced by high ambient temperatures, alkalinity, calcium (Ca) and magnesium (Mg) contents in water.

Climatic conditions play a major role in deciding the extent of fluoride in groundwater. For instance a 2002 research article *Fluoride in shallow aquifers in Raj Garh Tehsil of Churu district, Rajasthan- an arid environment* – published in esteemed journal **Current Science** points out that “the arid climate with high evaporations and insignificant natural recharge might have accelerated the strengthening of fluoride concentration in the groundwater of this (Churu district) area. In the vast geographical expanse and varied geographical set-up in Rajasthan the cause of fluoridation of groundwater are many. Some natural, some human-made. Fluoride bearing rocks are leached out due to various natural processes such as soil formation.”

SOURCES OF FLUORIDE FOR HUMAN, ANIMAL AND PLANT EXPOSURE

Major sources of fluoride for human exposure are: Water, Food, Air, Medicament, and Cosmetics. It is roughly estimated that 60% of the total intake of fluoride is through drinking water. 96-99% of it combine with bones, as fluoride has affinity for calcium phosphate $\{\text{Ca}_3(\text{PO}_4)_2\}$ in the bones. Other forms of fluorides are relatively less harmful. Fluoride rich food items are also a source of fluoride for human consumption, some of these are tea, fluoridated toothpaste, plants and vegetables grown in soil, rich in fluoride, pan, supari, tobacco, green garlic, onion, cabbage, soybeans, carrot, corn, potato, baking powder, egg, cow liver and kidney. Prolonged use of certain drugs has been associated with the chronic adverse effects of fluoride e.g. sodium fluoride (NaF) for treatment of Osteoporosis, Ni-fluoric acid for the treatment of rheumatoid arthritis and the use of mouth rinses.

The use of fluorides in industries can often lead to occupational exposure e.g. inorganic fluoride compounds are used in the production of aluminum and phosphate fertilizers.

Cattle grazing around fluoride sources, as ceramic rocks, phosphatic fertilizer plants and aluminum factories often develop fluorosis. The toxic effects are staining, mottling and abrasion of teeth, high fluoride levels in bone and urine, decreased milk production and lameness. Animals become lethargic.

Fluoride content of water depends on the soil. Soft water contains little fluoride while significant amounts may be present in hard water. The crop plant grown in high-fluoride soils in agricultural and non-industrial area had fluoride content as high as 300 ppm.

Fish-food, tea, cottonseed and some vegetables have relatively large amounts of fluoride. *Fluoride present in food is organically bound and is not toxic.* Some of the drugs like anti-carcinogenic drugs, drugs used for treatment of osteoporosis and related metabolic disorders, certain anaesthetic drugs, fluoridated cortico-steroids and dentine obludents contain fluoride that can be metabolized in the body.

CHEMOBIOKINETICS

Fluoride present in water is in a simple form and ingested fluoride is rapidly absorbed through gastro-intestinal tract and lungs. The peaks are reached after 30 min in blood. The rapid excretion takes place through renal system over a period of 4 to 6 h. in children (3 yrs of age only) about 50% of total absorbed amount is excreted, but in adults and children over 3 years – about 90% is excreted.

Approximately 90% of the fluoride retained in the body is deposited in skeleton and teeth. The biological half-life of bound fluoride is several years. Fluoride also passes through the placenta and also appears in low concentration in saliva, sweat and lacteal secretion (milk). Fluorides present other than in water are relatively less harmful. Fluoride ions from soluble inorganic fluoride compounds are rapidly absorbed. Fluoride sufficient in amount to cause mottling of primary dentition may reach through placenta. Fluoride is mainly excreted in the faeces (Beena, 2006).

PATHOPHYSIOLOGY OF FLUOROSIS

Ingestion of fluoride causes decrease in the ionized calcium. This hypocalcemia leads to changes in internal milieu of the body to maintain the calcium levels and leads to secondary hyperparathyroidism. The increased activity of osteoblasts in bones by activating membrane bound 3'5' cycle AMP.

This increased osteoblastic activity cause's increase in citric and lactic acids released from ruffled border of osteoblasts. This causes increase in H^+ ion concentration, and hence lysis of lysosomes takes place. Release of lysosomal enzymes viz acid protease, collagenase, hyaluronic acid in bones and other tissues of the body catalyses the reactions favouring the depolymerisation of the glycoprotein of bones and of the cartilage. This causes breakdown of hydroxy proline, which is responsible for stabilisation of collagen triple helix. As the protein polymer desegregates, and dissolves the mineral binding capacity (mbc), also get reduced and calcium is liberated, which helps in maintaining the serum calcium level. As a result the solubility of hydroxyapatite crystals also increases, causing its breakdown along with reduced laying down of collagen by reducing hydroxylation of proline and lysine.

This event simultaneously led to the elevation of the serum mucoprotein or polysaccharide levels. The net result of degradation of ground substance in bones and other calcified tissues like teeth leads to symptoms of fluorosis like delayed eruption of teeth, dental fluorosis and premature ageing.

FLUORIDE STANDARDS

In 1984, the World Health Organization gave a guideline value of 1.5 mg/l (1.5ppm) as the maximum permissible level for fluoride in drinking water. This reflected the state of research on fluoride. A certain amount was considered good for human health but more research changed this attitude.

According to UNICEF studies "fluoride has no beneficial health effects. Rather, fluoride destroys teeth. Fluoride has no role in prevention of dental caries, which is basically a bacterial disorder" WHO guideline value is unsafe for some countries.

In tropical countries such as India, people drink more water hence consume more fluoride. Also many food items have high concentration of fluoride.

In accordance with a report of a national sanitary engineer, WHO-New Delhi "WHO only gives guide lines. *The Indian Government is free to notify its own acceptable limits, the reason being that Indian population is already exposed to fluoride through many sources.*"

During an International workshop on fluoride and de fluoridation held in Cheang-Mai (Thailand) 20-24 November 2000, it was recommended that WHO should reduce its guideline value from 1.5 mg/l to 0.5 mg/l.

The permissible limit as laid down by the United States Public Health (USPH) drinking water standards and Indian Standard Institute (ISI) are 1.5 mg/l and 3.0 mg/l respectively. The ISI value available for fluoride level in domestic water supplies is just double as prescribed by USPH, obviously for no good reasons. "Setting up guidelines for fluoride in water requires carrying out large-scale epidemiological studies. No, such studies have been carried out in India", in accordance with a report of RGNDWM (1993) official.

The Indian government through the Bureau of Indian Standards (BIS) prescribed the acceptable limit of 1 mg/l fluoride in drinking water in 1992. But this does not mean that it is safe. Malnourished children can be affected even at fluoride levels below 1 mg/l says UNICEF. Moreover fluoride standards are canonically vague. There exists an "acceptable level" 1 mg/l. But there also exist a cause of rejection level (1.5 mg/l) the water may not be acceptable in the absence of an alternative and better source. Thus it is shocking and yet legal that the Government continues to follow the 1.5 mg/l limits in its water programmes.

EXTENT OF FLUOROSIS IN RAJASTHAN

In 1947, Ajmer-Mewar, was first reported as endemic region by Shourie. Voluminous work on the subject was done by workers like Kesliwal and Solomon (1950); Bhargava (1974) and Mathur (1977) on various aspects of fluorosis. Later on, zonal labs of National Environmental Engineering Research Institute, NEERI in Jaipur, reported high fluoride content in groundwater from different parts of Rajasthan. Geologically, there is a belt underneath Aravali range, beginning from Panch Mahal, Gujrat to Gurgaon (Harayana) and passing through southeast Rajasthan that is rich in fluorospar, cryolite and fluoroapatite Gupta, et al., 1993).

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REFERENCES

- Clerklewski, F.L. 1997. "Fluoride Bioavailability - Nutritional and Clinical Aspects", *Nutrition Research*, No.17, pp. 907-929.
- Dean, H. T. and Elvove, F. 1935. "Studies on the Minimal Threshold of the Dental Sign of Chronic Endemic Fluorosis (Mottled Enamel)", *Public Health Report*, No.50, pp.1179.
- Fluorine and fluorides (*Environmental Health Criteria-36*). WHO, Geneva 1984. pp 93.
- Beena Rani, 2006. Fluoride & Fluorosis in Rajasthan: An Overview, A Project Report (IGNOU), ND, DNHE
- Gupta, S. K., Seth, A.K., Gupta, A. and Gavane, A.G. 1993. "Transplacental Passage of Fluorides in Cord Blood". *The Journal of Pediatrics*, No.6. pp.-141.
- Gupta, S.K. Gupta, R.C. Seth, A.K. and Gupta, A. 1996." A Reversal of Fluorosis in Children", *Acta Paediatrica Japonica*, No.38, pp. 513-19.
- Maheshwari, R. and Bansal, N. 2007. "Excess Fluoride in Groundwater: Its Clinical Manifestations, Preventive Measures and Preventive Processes", *Proceedings of National Conference on Environmental Conservation*, B ITS, Pilani, pp. 113-120.
- Maheshwari, R., Rani, B. and Gupta, N. 2007. "Fluoride Toxicity", *Everything About Water*, No.7, pp.31-37.
- Maheshwari, R. 2007. "Fluoride Toxicity: An Alarming Threat", *Proceedings of International Conference on Toxicology, Toxicogenomics and Occupational Health*, Jiwaji University, Gwalior, MP.
- Maheshwari, R. 2007. "Fluoride Distribution: Recent advances in Mitigation Strategies for Sustainability of Modern Styled Era", *Proceedings of International Conference on Recent Advances in Environmental Protection*, St John's College, Agra.
- Mittal, A. Trivedi, N., Gupta, S.K., Kumar, S. and Gupta, R.K. 1993. "Radiological Spectrum of Endemic Fluorosis: Relationship with calcium intake". *Skeletal – Radiology*, **22** (4): 2pp.57-6.
- Ozha, D. D. and Gilani, F.M. 2006. "Water for life" 38th Annual convention, IWWA-Jaipur
- Rajiv Gandhi National Drinking Water Mission- Prevention and control of fluorosis in India. Water quality and Defluoridation Technique Vol II published by RGNDWM Ministry of Rural Development, ND 1993.
- Rock, W.P. and Sabien, A.M. 1997. "The Relationship between Reported Toothpaste Usage in Infancy and Fluorosis of Permanent Incisors". *British Dental Journal*, **183** (5), pp.165-70.

- Villena, R.S., Borges, D.G. and Cury, J.A. 1996. "Evolution of Fluoride Content of Bottled Drinking Water in Brazil", *Rev-Saude-Publica*, No.6, pp.512-18.
- Yang, Y. Wang, X. and Guo, X. 1994. "Effects of High Iodine and High Fluoride on Children's Intelligence and the Metabolism of Iodine and Fluorine", *Chung-Hua-Liu-Hsing-Tsa-Chih*, No.5, pp. 296-8.

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