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Research Article

DETERMINATION OF FLUORIDE STATUS IN GROUND WATER OF RAJASTHAN

Kumar N., Bansal N* and Sharma SK.

Department of Chemistry, JECRC University, Jaipur-303905, Rajasthan, India.

ABSTRACT

In recent years, great concern has been universally voiced regarding environmental pollution arising as a side effect of industrial and other human activities. In our own country, with the advent of industries, more and more toxic substances are either used as raw material or emitted during manufacturing processes in the form of dusts, fumes, vapours and gases. These pollutants ultimately dissipate in the working environment and pose occupational health hazards. In order to strike a balance between such an environment and general health of human population and live stock of any region, the level of fluoride concentration in potable water, food, soil and atmosphere needs to be an appropriate level. Fluorosis, though a common endemic problem of our country is more widespread and acute in Rajasthan. Over exploitation of groundwater in the last 20 years, is the chief reason for the spread of a dreadful disease. The conventional belief that fluoride affects only bone and tooth has been negated as the evidences on the involvement of soft tissues of the body are convincing. By employing SPANDS (Zr – alizarin red-s visual dye lake) method, fluoride ion concentration in water samples of various places in Rajasthan, were determined spectrophotometrically at 570nm. Since much of our food is ultimately derived from plants often grown in contaminated areas, fluoride in soil is an important source of intake. Anti-oxidants possessing antagonistic effect play prophylactic role in preventing fluorosis. A malady-remedy analysis of the problem of fluorosis has to be holistic in character as the disease not only affects human beings but also plants and animals. Based on such study, an integrated approach has to be evolved to draw up a strategy for the control of this disease. In this manuscript clinical manifestations of various degrees of fluorosis and strategies concerning to mitigation of fluoride content in water, have been delineated.

Keywords: Fluoride, Manifestations, Effect of human beings, Defluoridation.

INTRODUCTION

Millions of men, women and children in many states of India are effected by water borne fluorosis and several lac 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.

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 lac 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 ground water 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 wide spread 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.

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 baoriskunds, water conservation, rainwater harvesting (Injection well technique) and judicious use of under groundwater for drinking and other purposes.

Fluoride exists fairly abundantly in the earth's crust and enter groundwater through natural process. Low levels of fluoride are required for humans as it has beneficial effects on tooth and bone structures. However, ingestion of excessive fluorides, mainly through drinking water causes dental, skeletal and non skeletal fluorosis. Long term ingestion of excessive fluoride has a chronic effect on the kidneys as well, the optimum level suggested by WHO is 0.7 ppm from infancy to 16 years of age. According to the WHO, the maximum acceptable concentration of fluoride ions in drinking water is 1.5ppm, to prevent dental and skeletal fluorosis (Figure-1).

Dental fluorosis**,** also called mottling of tooth enamel**,** is a developmental disturbance of dental enamel caused by excessive exposure to high concentrations of fluoride during tooth development. The risk of fluoride over exposure occurs at any age but it is higher at younger ages.

Fluorine status

Fluorine is 13th most abundant element of halogen group having Atomic Number - 9 and Molecular Weight – 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 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[1].

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 {Ca3(PO4)2} in the bones. Other forms of fluorides are relatively less harmful.

Cattle grazing around fluoride sources, as ceramic rocks, phosphatic fertilizer plants and aluminium 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.

Chemobiokinetics

Fluoride present in water is in a simple form and ingested fluoride is rapidly absorbed through gastrointestinal tract and lungs. The peaks are reached after 30 minute in blood. The rapid excretion takes place through renal system over a period of 4 to 6 hours. 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[2].

Pathophysiology of Fluorosis

Ingestion of fluoride causes decrease in the ionized calcium. This hypocalcaemia leads to changes in internal milieu of the body to maintain the calcium levels and leads to secondary hyperparathyroidism. This causes breakdown of hydroxyl 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 librated, which helps in maintaining the serum calcium level. As a result the solubility of hydroxyappetite crystals also increases, causing its breakdown along with reduced lying 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[3].

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 drinks 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 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 UPSH, 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 official[4].

Geographical Details of Rajasthan[5]

Rajasthan is located in the north western part of the subcontinent. It is bounded on the west and northwest by Pakistan, on the north and northeast by the states of Punjab, Haryana, and Uttar Pradesh, on the east and southeast by the states of Uttar Pradesh and Madhya Pradesh, and on the southwest by the state of Gujarat. The Tropic of Cancer passes through its southern tip in the Banswara district. The state has an area of 132,140 square miles (3, 42, 239 km^2) and subdivided in 33 districts. The capital city is Jaipur.

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).

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, Gujarat to Gurgaon (Harayana) and passing through southeast Rajasthan that is rich in fluorosis, cryolite and fluoroapatite[6]

Dental Fluorosis

Skeletal Fluorosis

Fig.1: Dental and Skeletel Fluorosis

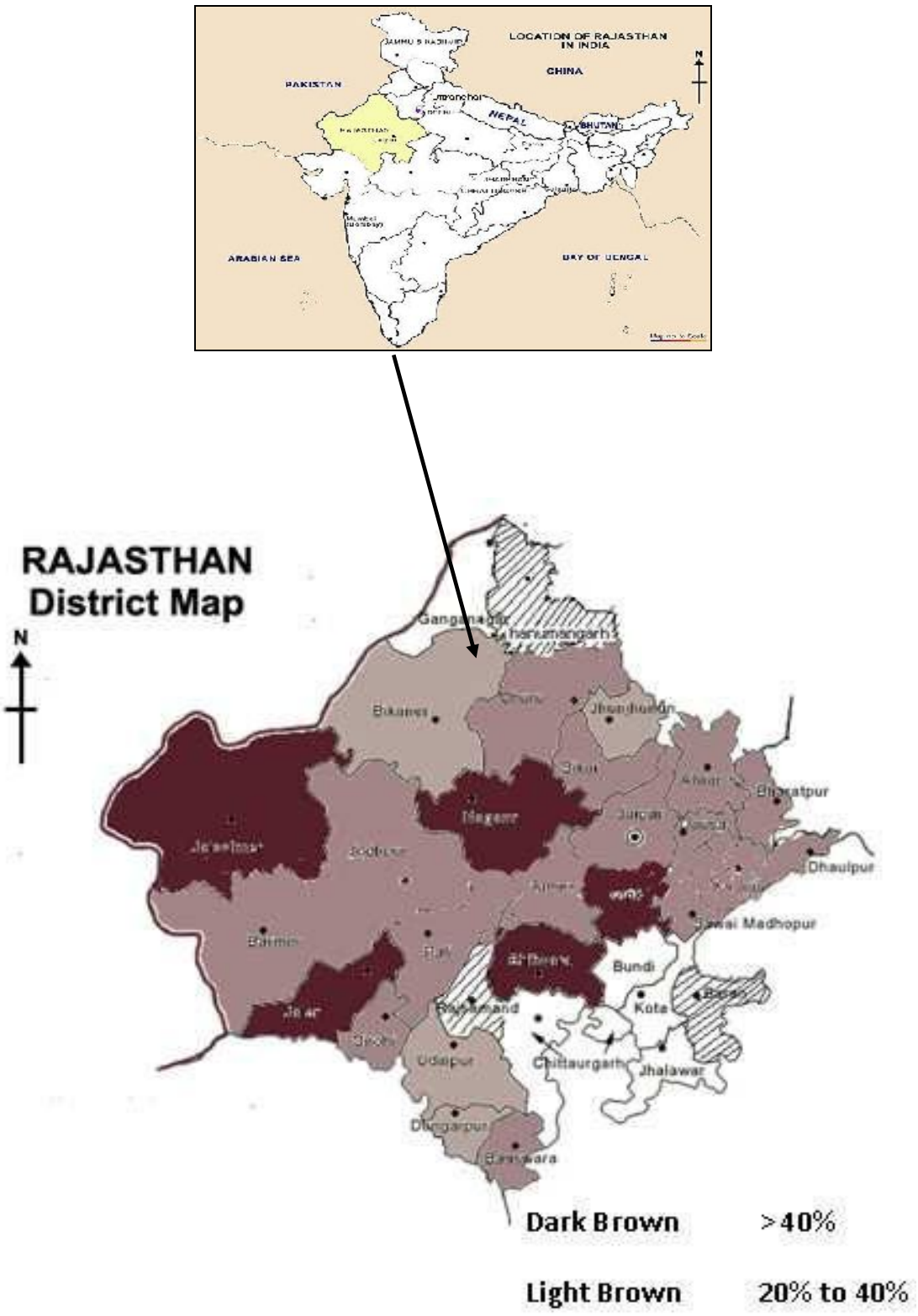

Fig. 2: Map of Rajasthan State

In the west, Rajasthan is relatively dry and infertile; this area includes some of the Thar Desert, also known as the Great Indian Desert. In the south western part of the state, the land is water, hilly, and more fertile. The climate varies throughout Rajasthan. On average winter temperatures range from 8° to 28° C (46° to 82° F) and summer temperatures range from 25° to 46° C (77° to 115° F). Average rainfall also varies; the western deserts accumulate about 100 mm (about 4 inches) annually, while the south eastern part of the state receives 650 mm (26 inches) annually, most of which falls from July through September during the monsoon season[7].

Rajasthan is the largest state, which covers 10% of the country area but receives only 1/100 of the total rain. It shares only 1/10 of the average share of water than rest of the country. The geographical and geological setup leads to deterioration of water quality. Therefore, state faces acute water crisis. The great Indian Thar Desert covers most of the area affected by fluoride. Thus extremely arid and dry climate conditions prevail, receiving 5 mm to 20 mm annual rainfall. Groundwater is deeper and contains high mineral concentrated chemicals which makes the water unfit to drink. The eastern part of the state is semi desert and hilly, therefore the water availability in this region is also limited (Table 1).

The high concentration of fluoride in drinking water leads to destruction of enamel of teeth and causes a number of conditions referred to collectively as fluorosis. This disease is slow and progressively crippling malady. At low concentration (<1.0ppm), fluoride prevents tooth decay, but it has been medically proved that, high fluoride intake by individuals from water, food, air and medicines results in fluorosis[8].

In the villages of Nagaur district, the effects of high Fluoride concentration are severe. Presence of excess Fluoride in groundwater has drawn attention of the society due to its pathophysical impact on human body. Fluoride content in the villages of Nagaur district has been found in the range of 1-62ppm. Over exploitation of water resources in the Didwana block has resulted in the depletion of groundwater table, salination of aquifers and deterioration in chemical quality of groundwater at an alarming rate. Therefore, study area is recommended to adopt adequate measures for conservation and judicious management of groundwater resources[9].

In Jharna Khurd village, 20 kms away from the city of Jaipur, there are no youth. All 1,200 people irrespective of age look old and have cracked teeth. Their shoulders, hips and ankles are swollen and ache all the time. It is painful to stand up, if they squat on the floor. In Jalore, the Fluoride content in water has increased to 6.8 mg/l as against the permissible limit of 1.5 mg/l causing premature ageing in the people. Nearby 120 out of 728 villages in the district are in the grip of fluorosis with some of the villages being the worst hit. Osteoporosis, bone deformation and yellowing of teeth are rampant. Even the unborn children are not safe. People are threateningly dependent on aquifers for their drinking needs[10].

Most of peoples of Tedhasar village of Churu district seem to be totally handicapped due to Fluoride poisoning. In Mulsisar block of Jhunjhunu district, large numbers of patient suffering from skeletal fluorosis have been seen. It was also observed that 1 mg of Fluoride in potable water dissolve 180 mg of Al, when boiled in a utensil made of aluminium. Generally in rural areas, and amongst poorer people, use of Al utensil in quite common feature. Staining, mottling and abrasion of teeth, high Fluoride levels in bone and urine, decreased milk production, lameness and sluggishness are some toxic effects observed in cattles grazing around Fluoride sources as ceramic rocks, phosphatic fertilizer plants and Al factories[11].

Fluoride is easily absorbed by the body from contaminated water. After absorption, fluoride ion is quickly distributed through the body, easily crossing the membranes and going to tissues. It accumulates in body due to the high reactivity of fluoride ion with calcium of teeth and bones. It forms calcium fluorophosphates (fluoroapatite) crystal and leaves unbound calcium in the same tissue, which gets calcified and in turn results in stiffness of tissues and joints. This finally leads to skeletal fluorosis in the later stage. That is why fluoride is called as bones seeking mineral and bone sink for fluoride. About 90% of fluoride retrieved in body is associated with calcified tissues[12] (Table 2).

Gandhi National Drinking Water Mission- The permissible limit is 1.5 mg/l according to the CPHED, Government of India and the World Health

Organization. The district wise number of villages and other habitations having excessive concentration of fluoride (> 1.5 & 3.0 mg/l) is shown in table 3. Total 9741 villages and 6819 other habitations are having fluoride level over 1.5 mg/l in groundwater. Similarly 3280 villages and 2181 habitations are having fluoride concentration more than 3.0 mg/l.

A district wise categorization is shown in the following Map -1. The survey indicates that the degree of fluoride problem is very serious in 7 districts (Ajmer, Bhilwara, Nagaur, Dausa, Jaipur, Tonk, Jalore) and a serious in 10 districts (Alwar, Barmer, Bharatpur, Dungarpur, Jaisalmer, Sikar, Pali, Sawai madhopur, Karauli, Sirohi), less serious in 9 districts (Banswara, Jhunjhuinu, Udaipur, Churu, Dholpur, Ganganagar, Raj Samand, Jodhpur, Hanumangarh) and insignificant in 6 districts (Baran, Bundi, Bikaner, Chittorgarh, Jhalawar and Kota,). Fluoride level in ground water is spread in all the 32 districts and become a health hazard in 25 districts (Table 3).

Epidemiological Studies

Epidemiology is the study of distribution and determinants of diseases prevalent in human beings and animals. Three aspects are important in an epidemiological study the agent supposed to be causing the disease the person affected by the disease (host) and the environment in which the agent and the host interplay. The agent, host and environment in context of a given disease are called 'epidemiological triad'. Relevant factors pertaining to the agent, host and environment as far as fluorosis is concerned are described below:

Agent

Although primarily fluoride is the agent responsible for determining the occurrence of fluorosis in the community but several factors like alkalinity of drinking water, calcium intake, molybdenum (Mb), aluminium (Al) and phosphates that determine the impact of fluoride on human body also influence as indirect agents in causing fluorosis.

Fluoride

Fluoride is mainly found in groundwater in which the solvent action of water on the rocks and soil of earth's crust derive it from the adjacent soil. The porosity of the rocks or soil through which water passes and the speed with which water flows, the temperature of the interaction of the rock and water, the hydrogen and calcium ion concentration, determine the fluoride content of the drinking water. Concentration of fluoride has been related to the following well established biological effects.

Calcium

Fluoride absorption is reduced to 50 per cent, if calcium in the form of calcium carbonate (CaCO3) or calcium phosphate {Ca3 (PO4)2} or aluminium compound is added. In such cases fluoride is bound in less soluble form and gets excreted through faeces. In areas where water is hard due to calcium and magnesium, the prevalence of skeletal fluorosis is much less. In Rajasthan, low community fluorosis index was reported form fluorotic belt where calcium intake of people was found to be high.

Alkalinity

A direct relationship exists between alkalinity and fluorosis. Most of the water having fluoride more than 2 ppm has lower hardness and higher alkalinity. Most of the alkalinity is found to be due to excess bicarbonates. In natural water, carbonates and bicarbonates appeared to be the main substances in leaching out fluoride from the rock forming minerals fluorospar.

Phosphate

Phosphates enhance fluoride absorption in the intestine presumable by counteracting the inhibitory action of intestinal calcium on fluoride absorption.

Aluminium

While aluminium and fluoride have synergistic effects, the aluminium as such has toxic effects on human body. Since aluminium salts have been commonly used as coagulants in water treatment, persons involved in defluoridation work must be aware of aluminium toxicity. A small amount of aluminium may remain in treated water and transported through distribution system, without any significant loss. While permissible limit for aluminium in water is 0.2 mg/l. Extra precaution should be taken in the use of defluoridation units. Thus, there needs a precautionary approach in using

aluminium salts and making water free from these salts before consumption.

Vitamin C

A more severe type of mottling has been observed in children who had a low intake of vitamin C. Citrus fruits are reported to reduce the toxic effects of fluoride. Thus consumption of fresh fruit is recommended in the fluorotic belts.

Host

Age

With increase in age, prevalence of dental mottling and subsequently skeletal fluorosis increases in the fluorotic belts. By the end of the decade the prevalence reaches to a maximum and plateaus thereafter. Although dental fluorosis is observed in the teeth but it's prevalence starts rising form the time when permanent teeth appear. In highly endemic zones, people become edentulous in the 4th and 5th decade of life and large number of them develops kyphosis (curvature in spine).

Sex and migration

In fluorotic zones males suffer more than females. In India, this is mainly attributed more to migration of females after marriage. Irrespective to migration, there is always a likelihood of women getting less victimized. There is also a hypothesis of higher consumption of drinking water by man doing strenuous physical work but women are more affected during pregnancy and breast feeding, due to lack of sufficient calcium in the body.

Occupational status

People involved in mining fluoride rich source and working in aluminium industries are more likely to suffer from fluorosis. Although it is not an obvious problem in Rajasthan, but it is speculated that in Udaipur, Dungarpur, Jalore and Bhilwara, wherever the fluoroapatite is mined, fluorosis in miners is possible.

Environment

Temperature

The principal source of fluoride for human being is water. Water intake depends chiefly on air, temperature, which is further dependent on latitude of the place, altitude, direction of the wind and proximity to sea. In fact, the annual mean temperature would influence optimal fluoride intake to great extent. Individuals living in areas with a large number of sunny days are exposed to an additional environmental heat stress, not reflected in usual temperature measurements.

Relative humidity

A relative low humidity tends to increase water loss, temperature being equal. It is questionable whether the differences in the relative humidity in the two areas having similar temperature may influence water intake amongst individuals living there.

Fluoride Analysis Types of Fluorosis

Selective ion meter (Mettler Toledo MA 235 pH/ ion Analyzer) was used to determine fluoride ion concentration. Colorimeter method has been used for determination of fluoride content in water samples. Fluoride ions form a Stronger Complex $[ZrF_6]^{2-}$ with zirconium ions therefore can displace its metal complex. The falling absorbance of the complex $[ZrF6]^{2-}$ was measured by spectrophotometer using green LED adopting procedure.

In the determination of fluoride content of water, the reverse Beer's Law is found valid. A decreasing optical density of the solution implied a corresponding higher fluoride contents in the groundwater. The optical density of test water samples was measured under photometer and then, concentration of the fluoride in the test sample was determined by matching the data against calibration graph obtained earlier for the standard solution. By using zirconium alizarin reds visual method, fluoride content in different water samples of various places of Rajasthan was determined, spectrophotometrically. Beside this method spand's method [spand's =sodium 2 – (para – sulphophenylazo)-1,8- dihydroxy-3,6 naphthalene disulphonate] and Ion selective electrode method are also employed for fluoride determination (Table 4).

The above discussion is further supported by slides, film showing dental and skeletal fluorosis evident in the inhabitants of Churu city especially in the underdeveloped areas. It is already known that the nutritional status of people is ultimately linked with the excretion of fluoride, thus the people in such areas are more prone to harmful effects of fluorosis.

WHO states that people affected by fluorosis are often exposed to multiple sources of fluoride, such as food, water, air, excessive use of tooth paste etc. Recent studies indicate that the serum fluoride level increases many fold among the school children using fluoridated tooth paste containing 900 mg/l of

fluoride one a day. High intake of fluoride causes both short term and long term effects[13].

Acute high level exposure to fluoride causes immediate abdominal pain, excessive salivation, nausea and vomiting. Seizures muscle spasms, muscle fibrillation and numbness of mouth may also occur. In some individuals allergic reactions have been reported. A continuous high intake of fluoride results in the mottling of teeth enamel. This is sign of chronic poisoning in children less than seven years. High fluoride intake (20-80 mg per day) causes skeletal fluorosis and sometimes an abnormality in bone density which may lead to spondylosis and osteoporosis. Excess fluoride binds with calcium in body and form calcium fluoride which accumulates in kidneys and form stones causing eventual renal failure (Table 5).

Dental Fluorosis

It is the most common feature among the people of fluoride endemic areas. Due to high calcium content teeth easily take up fluoride. Mottling of teeth is one of the earliest sign in most recognizable feature. Teeth become rough, opaque and chalky white. Formation of yellow to dark brown lines takes places, which is followed by putting and chipping of tooth enamel. Some examples of dental fluorosis are shown in Mottling of teeth in children is one of the earliest and most easily recognizable features of fluorosis. Beside a health problem, it is an aesthetic and social problem also. A yellow white discoloration appears which turns brown and presents itself in horizontal streaks, since new layers of matrix are added on horizontally during tooth development.

Severity of dental fluorosis in a group of children in fluorotic belt helps in determining the CFI which depends on identifying the extent of dental fluorosis in individual child. Dean's classification is used in identifying the mild, moderate and severe fluorosis in the teeth and a numerical grading is given by very experienced eyes.

Habit of consistent betel (pan) and tobacco chewing also results in discoloration which should be differentiated from fluorosis by ascertaining the site of colour change on the tooth surface and history of the patient. In dental fluorosis the discoloration which occurs on the enamel surfaces, away from gums, can never be removed, as it becomes an integral part of tooth matrix[14].

Skeletal Fluorosis

Prolonged intake of water having fluoride > 8 mg/l leads to skeletal fluorosis. Bow legs and knock knees are the characteristic feature of skeletal fluorosis. Restriction of the spine movement is the earliest clinical sign and stiffness increases steadily until the entire spine becomes one continuous column of bone manifesting a condition referred to “Pocker back”. Excessive fluoride is deposited more in spongy bones as compared to compact bones. Changes in bones are revealed by X-ray plates. An extremely severe form of fluorosis is characterized by deformities of limb bones most notably in weight bearing lower limbs causing crippling “Knock Knee Syndrome” with hard ening of soft joints of spine (Osteosclerosis) and concomitant osteoporosis of limb bones. Crippling deformity is associated with rigidity of joints, increased convexity in curvature of the spine, lateral curvature of vertebral column, deformity of knee joints and paralysis of lower parts of body including legs. Paralysis begins with vague pain in the back and extremities. This stage usually occurs between 30-50 years of age in endemic regions.

Non Skeletal Fluorosis

Apart from bones and teeth an excess intake of fluoride can damage or impart ill effects on other soft tissues, organs and systems also. A review by earlier workers reveals that almost all systems of body including muscle, liver, kidney, blood, cardiovascular and even reproductive, are affected[15].

Clinical manifestations

Nutritional deficiencies, combined with excess fluoride intake through water, appear to create fluorosis which manifests itself as dental, skeletal and non-skeletal fluorosis.

Gastrointestinal Manifestations

Fluoride affects cellular protein synthesis in gastrointestinal tract. The complaints with GI system in endemic areas are now established as early warning sign of fluoride toxicity. Acute abdominal pain, diarrhoea, constipation, blood in stool, bolted feeling, tenderness in a stomach, feeling of nausea, mouth sores, lose of appetite are common complaints.

Neurological Manifestations

This includes nervousness, depression and tingling sensation in fingers and toes. Neurological complications arise at a late stage of the disease in about one-tenth of the total number of skeletal fluorosis.

Allergic Manifestations

Very painful skin rashes, pinkish red or bluish red, rough or oval shaped spots on the skin which fade away and clear up in 7-10 days are reported from fluoride endemic areas.

Urinary Tract Manifestations

Urine may be less in volume, urinary tract itching may occur. Due to adverse effect of fluoride of brain areas, which control this system, this occurs.

Other System / Functions

Fluoride disturbs hormonal system, irritates respiratory tract, and affects reproductive system and metabolic activities as it interferes with enzymatic. It has been considered as metabolic inhibitor.

Effect on human health

Fluoride contamination is a major health hazard in many parts of the world. Fluoride is considered beneficial to human health if taken in limited quantity (0.5 to 1.5 mg/l). Fluoride prevents tooth decay by enhancing the remineralisation of enamel that is under attack, as well as inhibiting the production of acid by decay causing bacteria in dental plaque (Table 6).

Effect on dental enamel

Dental fluorosis is a condition that results from the intake of excess levels of fluoride during the period of tooth development, usually from birth to approximately 6–8 years of age. It has been termed a hypoplasia or hypomineralization of dental enamel and dentine and is associated with the excessive incorporation of fluoride into these structures. The severity of this condition, generally characterized as ranging from very mild to severe, is related to the extent of fluoride exposure during the period of tooth development. Mild dental fluorosis is usually typified by the appearance of small white areas in the enamel; individuals with severe dental fluorosis have teeth that are stained and pitted ("mottled") in appearance. In human fluorotic teeth, the most prominent feature is a hypomineralization of the enamel. In contrast to many animal species, fluoride induced enamel hypoplasia (indicating a severe fluoride disturbance of enamel matrix production) seems to be rare in affected human enamel[17]. The staining and pitting of fluorosed dental enamel are both post eruptive phenomena (i.e., acquired after tooth eruption and occur as a consequence of the enamel hypomineralization). The incorporation of excessive amounts of fluoride into enamel is believed to interfere with its normal maturation, as a result of alterations in the rheologic structure of the enamel matrix and effects on cellular metabolic processes associated with normal enamel development.[18]

In India, first reported a disease similar to mottled enamel, which is prevalent in human beings in Madras presidency. Mahajan (1934) reported a similar disease in cattle in certain parts of old Hyderabad state. However, was the first to identify the disease as fluorosis? Sub-sequent to these findings, cases of fluorosis were reported from several other parts of the country. Dental fluorosis is caused in human being consuming water containing 1.5 mg/l or more of fluorides, particularly from birth to the age of eight. Mottled enamel usually takes the shape of modification to produce yellow brown stains or an unnatural opaque chalky white appearance with occasional striations patting. The incidence and severity of mottling was found to increase with increasing concentration of fluoride in drinking water. In extensive studies, Dean and co-workers[19] have correlated the appearance and severity of dental fluorosis to different fluoride levels in the drinking water with the aid of a special classification and weighing of severity of the lesion.

Distribution of dental fluorosis at different levels of fluoride in drinking water may be assessed by a mottled enamel index of the community, which is defined in terms of the degree of severity of mottled enamel observed clinically. Since no such data available in India to evaluate community index of fluorosis and in the absence of this permissive or excessive limits of fluoride in drinking water are only arbitrary.

Osteoporosis

Fluoride above 4 mg/l in drinking water may cause a condition of dense and brittle bones known as osteoporosis. It affects tens of million of people worldwide and is responsible for as many as 75% of all fractures in people over the age of 45. Costly and disabling fractures of spine, hip, wrist and other bones can be preceded by years of undetected bone loss. It is found that as many as 20% of those who suffer from osteoporosis related hip fractures die within 6 months. Women are at four time's greater risk of developing osteoporosis than males.[20]

Skeleton fluorosis

The chronic toxic effects of fluoride on the skeletal system have been described from certain geographical regions of the world where drinking water contains excessive quantities of natural fluoride. This form of chronic intoxication was first de-scribed in India from the state of Madras as early as 1937.

At higher levels of ingestion from 2 to 8 mg daily when signs of fluorosis appear in teeth mineralized during the ingestion period, certain other factors (climatic conditions, malnutrition, age, storage, other constituents of water and possibly individual variations in absorption) may be involved. Under

such conditions and over a number of years, skeletal fluorosis may arise characterized by an increased density of bone and demonstrated in adults radiographically.[21]The data put forward by, although no longer regarded as accurate indicate that the limit of total fluoride which may be ingested daily without hazardous body storage is of the order of 4-5mg daily.

Such early cases are usually in young adults whose only complaints are vague pains noted most frequently in the small joints of the hands and feet, in the knee joints and in the joint of spine. These cases are frequent in the endemic areas and may be misdiagnosed as rheumatoid or osteoarthritis. In later stages, there is an obvious stiffness of the spine with limitation of movements and still later, the development of kyphosis. There is difficulty in walking due partly to stiffness and limitation of the movements of various joints and partly to the neurological lesions of advanced cases. Similarly, some of the patients complain of dyspnoea on exertion because of the rigidity of the thoracic cage. In Roholm's series of industrial fluorosis cases, the gastrointestinal symptoms of lack of appetite, nausea and constipation were as frequent as the symptoms of stiffness of joints, but the former have not been described in the different studies of endemic fluorosis.

According to an early estimate, the number of persons at risk of developing skeletal fluorosis was 5 million in Punjab and more in Andhra Pradesh and Madras, India. The frequency of skeletal fluorosis (as identified by the clinical picture) among children 3–10 years of age was 39% (18/46) in a village in India, where the fluoride concentrations in the three wells were 0.6, 4.0 and 1.34 mg/l.[22] It was not possible to discern, from the information available, the contribution of each well to the drinking water of the residents.

A correlation between average water fluoride concentration and prevalence of skeletal fluorosis (assessed by X-ray) was found among adults in 15 villages in Dungapur district in Rajasthan, India.[23] The prevalence ranged from 4.4% at a water fluoride level of 1.4 mg/l to 63.0% at the level of 6.0 mg/l. Crippling fluorosis was consistently observed in villages with fluoride concentrations of >3 mg/l. In a survey carried out in Bhilwara district of Rajasthan, 825 individual were examined for fluorosis due to intake of fluoride above 5.0 mg/l in drinking water. In the skeletal fluorosis positive individuals maximum individual have Grade I skeletal fluorosis, which is characterized by bone and joint pain. Only 4 individual have Grade III type of skeletal fluorosis in which bone and joint pain, stiffness and rigidity of dorsolumber spine and restricted movements at spine and joints are general symptom inclusive deformities of spine and limbs, knock knees, crippled or bed ridden state, kyphosis, invalidism, genuvarum and genuvalgum. Prevalence and severity of skeletal fluorosis were found also increasing with increasing fluoride concentration.

Deformities and crippling fluorosis

The advanced stage of fluoride intoxication results from the continuous exposure of an individual to 20-80 mg of fluoride ion daily over a period of 10 - 20 years. Such heavy exposure is associated with a level of at least 10 mg/l in the drinking water supply. The crippling fluorosis is seen in such numbers in endemic areas of Rajasthan, Punjab and Southern India. The Crippling deformities are due partly to mechanical factors and partly to the immobilization necessitated by pain and paraplegia. The commonest deformities are kyphosis, flexion deformity of the hips, flexion deformity of the knees and fixation of the chest in the position of inspiration due to calcification of cartilages. The quadriplegic patient bent with kyphosis and with restricted movements of his spine, with contractures of hips and knees.[24]

Cardiovascular effects

The cardiovascular effects of fluoride have been attributed to hypocalcaemia and hyperaemia caused by high fluoride levels. Fluoride can bind with serum calcium if the dose is sufficient and cause hypocalcaemia. Calcium is necessary for the functional integrity of the voluntary and autonomic nervous systems. Hypocalcaemia can cause tetany, decreased myocardial contractility, and possibly cardiovascular collapse. Hypercalcaemia has been suggested as the cause of the repeated episodes of ventricular fibrillation and eventual death that are often encountered in cases of fluoride poisoning.[25]

Gastrointestinal effects

The primary gastrointestinal effects following both acute and chronic oral exposure to fluoride consist of nausea, vomiting, and gastric pain. The irritation of the gastric mucosa is attributed to fluoride (as sodium fluoride) forming hydrofluoric acid in the acidic environment of the stomach.[26] The uncharged hydrogen fluoride molecule can then penetrate cell membranes and enter the neutral environment of the cytoplasm.

A study by assessed the prevalence and severity of gastrointestinal disturbance in an area of endemic skeletal and dental fluorosis in India. The highest prevalence (52.4%) of non-ulcer dyspeptic symptoms was found among 288 individuals (69

families) living in a village where the mean fluoride concentration in the 36 separate water sources was 3.2 ppm (range 0.25 to 8.0 ppm). Eleven of these water sources were defined by the authors as safe (i.e., with fluoride levels of 1.0 ppm or less). The authors noted that in patients who reverted to safe water, dyspeptic symptoms and complaints disappeared within 2-3 weeks.

Endocrine effects

In the endocrine system where the intermediary metabolism and synthesis of highly sensitive hormones involves enzymatic action, it is expected that interferences with the mechanism by chemical agents would produce early and pronounced clinical effects. Considerable attention has consequently been given of recent years to the behaviour of fluoride in hormone chemistry and to the possible and to the possible clinical disturbances of endocrine function, particularly the thyroid gland. Significant increases in serum thyroxin levels were observed in residents of North Gujarat, India with high levels of fluoride in the drinking water (range of 1.0–6.53 mg/L; mean of 2.70 mg/L). No significant changes in serum triiodothyronine or thyroid stimulating hormone levels were found. Increases in serum epinephrine and norepinephrine levels were also observed. It is unclear if nutritional deficiencies played a contributing role to the observed endocrine effects.

Immunological and lymphoreticular effects

A request to the American Academy of Allergy was made by the U.S. Public Health Service for an evaluation of suspected allergic reactions to fluoride as used in the fluoridation of community water supplies. The response to this request included a review of clinical reports and an opinion as to whether these reports constituted valid evidence of a hypersensitivity reaction to fluoride exposure of types I, II, III, or IV, which are respectively, anaphylactic or reaginic, cytotoxic, toxic complex, and delayed type reactivity. The Academy reviewed the wide variety of symptoms presented (vomiting, abdominal pain, headaches, scotomata, personality change, muscular weakness, painful numb-ness in extremities, joint pain, migraine headaches, dryness in the mouth, oral ulcers, convulsions, mental deterioration, colitis, pelvic haemorrhages, urticaria, nasal congestion, skin rashes, epigastric distress, and hematemesis) and concluded that none of these symptoms were likely to be immunologically mediated re-actions of types I–IV. No studies were located that investigated alterations in immune response following fluoride exposure in humans. No studies were located that investigated alterations in immune response following fluoride exposure in human. In a study with rabbits administered 4.5 mg fluoride/kg/ day as sodium fluoride for 18 months, decreased antibody titters were observed.[27] These results were observed after 6 months of treatment; the authors hypothesized that a threshold level is reached at which time the immune system is impaired. However, as only one dose level (4.5 mg fluoride/kg/day) was tested, no dose effect.

Neurological effects

The neurological manifestations have been exclusively reported from India. Credit for the earliest description of neurological complications in fluorosis must be given to, who reported ten such cases from the Nellore district of Madras. A few sporadic cases have also been described from other parts of India. Fluoride has been shown to interfere with glycolysis. Because the central nervous system relies heavily on this energy source, hypotheses have been advanced as to a mechanism for fluoride effects on the central nervous system. Although effects on glycolytic enzymes could explain the neuromuscular symptoms seen frequently in cases of fluoride poisoning (e.g., tetany, parenthesis, paresis, convulsions), studies tend to indicate that hypocalcaemia caused by fluoride binding of calcium causes these symptoms.[28] The decreases in intelligence were reported in children living in areas of China with high levels of fluoride in the drinking water, as compared to matched groups of children living in areas with low levels of fluoride in the drinking water, but these studies are weak in as much as they do not address important confounding factors.

Reproductive effects

There are limited data on the potential of fluoride to induce reproductive effects in humans following oral exposure. A meta-analysis found a statistically significant association between decreasing total fertility rate and increasing fluoride levels in municipal drinking water. Annual county birth data (obtained from the National Centre for Health Statistics) for over 525,000 women aged 10–49 years living in areas with high fluoride levels in community drinking water were compared to a control population approximately 985,000 women) living in adjacent with low fluoride drinking water levels. The fluoride exposed population lived in counties reporting a fluoride level of 3 ppm or higher in at least one system. The weighted mean fluoride concentration (county mean fluoride level weighted by the 1980 size of the population served by the

water system) was 1.51 ppm (approximately 0.04 mg fluoride/kg/day), and 10.40% of the population was served by water systems with at least 3 ppm fluoride. The mean weighted mean fluoride concentration in the control population was 1.08 ppm (approximately 0.03 mg fluoride/kg/day). However, this meta analysis relied on a comparison of two quite disparate data sets, in as much as the fluoridation population often did not correlate well with the population for whom health statistics was available. Furthermore, other studies have not found a similar correlation. Another study found significantly decreased serum testosterone levels in 30 men diagnosed with skeletal fluorosis and in 16 men related to men with fluorosis and living in the same house as the patient.[29] The mean drinking water fluoride levels were 3.9 ppm (approximately 0.11 mg fluoride/kg/day), 4.5 ppm (0.13 mg fluoride/kg/day), and 0.5 ppm (0.014 mg fluoride/kg/day) in the patients with skeletal fluorosis, related men, and a control group of 26 men living in areas with low endemic fluoride levels. No correlations between serum testosterone and urinary fluoride levels or serum testosterone and serum fluoride levels were found. One limitation of this study the control men were younger (28.7 years) than the men with skeletal fluorosis (39.6 years) and the related men (38.7 years). In addition, the groups are small and potentially confounding factors are not well addressed.

Developmental effects

Fluoride crosses the placenta in limited amounts and is found in fatal and placental tissue. The available human data suggest that fluoride has the potential to be developmentally toxic at doses associated with moderate to severe fluorosis. The human and animal data suggest that the developing fetus is not a sensitive target of fluoride toxicity. Analysis of birth certificates and hospital records for over 200,000 babies born in an area with fluoridated water and over 1,000,000 babies born in a low fluoride area found no difference in the incidence of birth defects attributable to fluoride. Exposure to high levels of fluoride has been described together with an increased incidence of spin bifida. The occurrence of spin bifida was examined in a group of 50 children aged 5–12 years living in an area of India with high levels of fluoride in the drinking water (4.5–8.5 ppm) and manifesting either clinical (bone and joint pain, stiffness, and rigidity), dental, or skeletal fluorosis. An age and weight matched group of children living in areas with lower fluoride levels served as a control group. Spin bifida was found in 22 (44%) of the children in the high fluoride area and in six (12%) children in the control group. This study did not examine the possible role of potentially important nutrients such as folic acid, however, and had other study design flaws.

Effect at molecular level

The acceleration of the aging process by fluoride occurs at the bio-chemical level through enzyme inhabitation, collagen break down, genetic damage or disruption of the immune system. Fluoride damage enzymes, and results in a wide range of chronic disease. Fluoride as low as1 mg/l causes breakdown of collagen, the most abundant of the body protein at 30%. It leads to irregular formation of collagen, which serves as a major structural component of skin, ligaments, tendons, muscles, cartilage, bone and teeth. A number of studies revealed that fluoride causes genetic damage. The mechanism cannot be exactly pinpointed because fluoride interferes with a number of physiological processes. Most evidence indicates that it acts on the DNA Repair Enzyme system. It may also interfere with DNA synthesis. If the unprepared DNA damages occur in a cell, producing a sperm or egg it will be replicated in every cell of the offspring body and leads to birth defects. Irreparable damage of a segment of DNA is responsible for control of cell growth and may cause tumours or cancer.

To summarize three approaches are suggestes

Fluorosis not only affects older persons, but there are ample evidences that even newborn baby and children of younger age have also been its victims. It not only affects the body of a person but also renders them socially and culturally crippled. There is a need to develop a well thought out strategy to attack this problem, which requires an urgent attention from both medical as well as of social workers.

Considerable work has been done all over the world on treatment of fluorosis. Unfortunately the results indicated that the effects of fluorosis are irreversible in children. Numerous people have conducted surveys on the problem of fluoridation and treatment option available for defluoridation processes, but however a safe efficient and cost effective defluoridation technique/process needs to be developed in order to prevent the occurrence of fluorosis [16].

Health education

Creating awareness about the fluoride and fluorosis: the main area of interest will be

(a) Creating disease awareness: Creating awareness about the disease should be in the form of graphic presentation of the final consequences of the

disease to the extent possible. If required, live presentations of the patients who are suffering from the severe form of the disease in areas where the gravity of the problem has not reached to that extent. It may be of use to demonstrate the most severe extent of the disease and to motivate them to use the preventive or therapeutic measures.

Treatment of the Disease

Vitamin C and D, salts of Ca, Mg or Al were prescribed in an attempt to reverse these effects. Published results were, however, inconclusive and largely negative. Recent studies conducted in Rajasthan under Raj DST sponsored studies

Indicated that fluorosis could be reversed, at least in children by a therapeutic regimen (Nutritional prophylaxis), which is cheap and easily available. The choice of the reported therapy was logical. The presence of calcium in directly affects the absorption of fluoride ions and also improves serum levels as observed. Vitamin D3 in low doses enhances Ca absorption and retention without causing hypercalcaemia and thus directly affects the absorption of fluoride ions. It also inhibits the excessive release of parathyroid hormone thereby preventing excessive activation of osteoblasts thus preventing hyperosteoidosis and osteopenia. Ascorbic acid controls collagen formation, maintains the teeth structure and bone formation. The structures are adversely affected by higher fluoride intake [30].

Preventive Measures

(a)Providing Defluoridaled Water for Drinking Purpose

Methods of defluoridation recommended so far are aimed at bringing the fluoride levels to the WHO standards.

Desirable characteristics of defluoridation process, cost effectiveness, easy to handle, (operation by rural population) the major sufferer - independent of input fluoride concentration alkanity, pH, temperature, no effect on taste of water, no addition of other undesirable substances.

(b) Changing the Dietary Habits

Defluoridation of drinking water alone shall not bring the fluoride level to safe limit. It would be necessary to overcome the toxic effects of the remaining fluoride ingested through other sources. This can be done by effecting minor changes in the diet and dietary habits of the population compatible with their social system and available resources.

In people with exposure and those with clinical and sub clinical symptoms, the only available measure as of today is eliminating the intake of fluorides. No chemical till date is capable of extracting fluoride absorbed in the body. In patients with disease symptoms, the following interventions should be given:

1. Reduce as much as possible the fluoride through water and food.
2. Practice consumption of diet rich in calcium, vitamin C (ascorbic acid), vitamin E and antioxidants.
3. A properly designed nutritional regimen can beneficially interfere with the toxic effects of fluoride. Vitamin C, vitamin E and anti-oxidants, which are beneficial and are not very expensive, can be produced in rural areas without much investment.

Calcium: Milk, Curd, Yoghurt, Green leafy vegetables, Jaggery, Drumstick, Sesame seeds

Vitamin C: Lemon, Orange, Tomato, Sprouted cereals/pulses and Coriander leaves

Vitamin E: Vegetable oil, Nuts, White grain cereals, Green vegetables and dried beans

Anti-oxidants: Garlic, Ginger, Carrot, White onion, Papaya, Pumpkin and Green leafy vegetables.

All the above items have antagonistic effect; thereby play the prophylactic role in preventing fluorosis.

(c) Rain Water Harvesting: (Alternative water source)

Fluoride affects the people and the animals as well. Therefore it is desirable that the animals should also be provided with fluoride free water for maintaining their longevity. Defluoridation of drinking water for animals will be too costly and not feasible and therefore the only solution of this problem is water harvesting. The water harvesting technology should be aimed not only to provide fluoride free water to human beings but also to animals. Rainwater storage can be a major source of fluoride free drinking water for the animals.

These three pronged attacks can prove to be a blessing for the population especially for the younger generation living in fluoride rich areas having no choice except to drink the water contaminated with fluoride and suffer the inevitable consequences including permanent deformities.

Defluoridation processes

Advantages and disadvantages of various commonly used processes available for defluoridation:

Nalgonda Process

It looks a cumbersome technique not suitable for use by less educated population - the section that needs it the most. The process can be used only for water

having a fluoride content of <10ppm & turbidity <1500ppm. There is a high residual Al content in output water. It is reported that the residual Al ranges from 2.01ppm to 6.80ppm. It is relevant to note that Al is a neurotoxin and concentration as low as 0.80ppm of Al in drinking water is reported to have caused Alzheimer's disease.

Activated Alumina Process

Reactivation of filter material is cumbersome and it can be done only with the help of trained persons generally not available in most of our villages. This process also results in high residual Al in output water ranging from 0.16ppm to 0.45ppm.

KRASS Process

This process differs from the known processes in its simplicity, cost effectiveness and only traces of residual Al in outlet water. There is no limit on fluoride concentration in input water. Temperature, pH, alkalinity and TDS of input water do not affect this process. It is a practical approach especially for our rural population.

Other process

Processes like electro-dialysis, ion exchange and reverse-osmosis require special equipment, power, especially trained person to operate and require maintenance and are expensive.

CONCLUSION

The triumph in the fluoride and fluorosis mitigation achieved through persistent and consistent effects spanning over a period of 2 decades by scientists. From a variety of disciplines including the water sector and biomedical sciences across the country have made the proud. It is no small an achievement. It is the desire of very Indian that let the success achieved in the fluoride and fluorosis front be a model for those involved in dealing with other contaminants like nitrate, salinity, arsenic, heavy metals and pesticides, to be pursue a path, resulting in unquestionable victory. Several years of fundamental research on fluoride action on animal and human body tissues at the cellular and molecular levels generated a wealth of information and knowledge. The path breaking discoveries emerged through unconventional approach adopted for multidisciplinary investigations of both soft and hard tissues were a revelation. The true disease characteristics emerged, ted to early diagnostic procedures for the disease. Differential diagnoses of fluorosis from other disease with overlapping clinical manifestations become necessary. Simple tests with focus on assessing that poison levels in body fluids provided meaningful information. No sooner the disease could be correctly diagnosed at very early stages, it become necessary to eliminate / reduce the poison levels in the body fluids, leading to disappearance of health complaints that are non-responding to medication.

Table 1: Occurrence of excess flouride in Rajasthan

Villages having excess fluoride	Districts of Rajasthan (Drinking water sources having fluoride >1.5 ppm)
Up to 10%	Shri Ganganagar, Bundi, Kota, Chittor garh, Jhalawar
10 to 20%	Bikaner, JhunJhunu, Udaipur, Dungarpur
20 to 40%	Churu, Sikar, Karauli, Dausa, Alwar, Jaipur, Bharatpur, Sawai madhopur, Dholpur, Banswara, Sirohi, Barmer, Jodhpur, Pali, Ajmer
> 40%	Jaisalmer, Nagaur, Jalore, Bhilwara, Tonk
To be confirmed	Hanuman Garh , Rajsamand, Baran

Table 2: Fluoride concentration and affected population of villages in Rajasthan

S. No.	Fluoride concentration mg/l	Number of affected Village	Total population under threat
1.	1.2 to 2.9	1467	1643542
2.	3.0 to 4.9	668	719309
3.	5.0 to 9.9	255	238447
4.	Above 10	43	35477
	Total	2433	26, 36,755

Table 3: Detail of Fluoride Affected Villages in Rajasthan

S.No	Name of District	Total Number of		No. Of Villages/Habitation Where F> 1.5				No. of Villages/ Habitation Where F> 3.0		
		Villages	Habitation	Total	Villages	Habitation	Total	Villages	Habitation	Total
1	Ajmer	985	952	1931	654	371	1025	352	232	584
2	Alwar	1946	2449	4395	537	342	879	155	68	223
3	Banswara	1431	3175	4606	293	551	844	35	60	95
4	Bharatpur	1345	549	1894	529	81	610	152	11	163
5	Barmer	1623	2780	4403	597	221	818	181	68	249
6	Bhilwara	1566	963	2534	678	318	996	392	227	619
7	Bikaner	580	366	946	84	2	86	7	0	7
8	Bundi	826	332	1158	42	9	51	3	0	3
9	Chittorgarh	2173	904	3077	115	48	163	14	9	23
10	Churu	926	199	1125	240	8	248	27	1	28
11	Dholpur	551	983	1534	142	157	299	22	18	40
12	Dungarpur	846	681	1527	127	225	362	30	55	85
13	S.Ganganagar/ Hanumangarh	4437	4190	8627	425	418	844	149	129	273
14	Jaipur/ Dausa	3140	7518	10758	117	1795	3172	491	739	1230
15	Jaisalmer	518	1172	1690	300	184	484	96	65	161
16	Jalore	666	823	1489	369	107	476	115	45	160
17	Jhalawar	1448	124	1572	42	5	47	15	3	18
18	Jhunjhuinu	824	208	1032	96	3	99	15	1	16
19	Jodhpur	860	2801	3661	314	99	413	59	8	67
20	Kota / Baran	1881	288	2169	44	0	44	17	0	22
21	Nagaur	1374	1972	3346	778	147	925	322	42	364
22	Pali	904	651	1555	242	83	330	69	34	103
23	Sawai madhopur/Karauli	1464	2191	3655	452	263	725	121	69	190
24	Sikar	931	2401	3332	331	471	792	125	144	269
25	Sirohi	446	92	544	176	5	181	43	1	44
26	Tonk	1019	881	1900	516	209	724	199	71	270
27	Udaipur/Raj Samand	3179	5561	8740	431	497	923	74	81	155
	Total	37889	45311	8200	9741	6619	16560	3280	2181	5461

Table 4: Fluoride content in potable water in Churu city

S.No.	Source	Place/ Well of Collection of Water Sample	Fluoride Content (ppm)
1	TW	Shitlamata	4.8
2	CWR	Goyanka Street	2.8
3	TW	Madersa	8.5
4	TW	Eye's Hospital	7.3
5	TW	Van Vihar	7.8
6	TW	Mayur Hotel	4.2
7	TW	Gautam Ice Factory	1.5
8	TW	Nathji Street	3.8
9	CWR	-----	2.8
10	TW	Tanka	1.8
11	OW	Mishra Street	2.8
12	OW	Chaulawa	1.3
13	OW	Ramjus	1.2
14	OW	Butia Tree	1.8

TW= Tube Well; CWR= Central Water Reservoir; OW= Open Well

Table 5: Fluoride content in various food items

Food Item	Fluoride (mg/kg)
Cereals	
1. Wheat	4.6
2. Rice	5.9
3. Maize	5.6
Pulses	
1. Gram	2.5
2. Soybean	4.0
Vegetables	
1. Cabbage	3.3
2. Tomato	3.4
3.Cucumber	4.1
4. Ladyfinger	4.0
Fruits	
1. Banana	2.9
2. Mango	3.2
3. Apple	5.7
4. Guava	5.1
Beverages	
1.Tea	60 – 112
2. Coconut water	0.32 - 0.6
Spices	
1. Coriander	2.3
2. Garlic	5.0
3. Ginger	2.0
Food from Animal Sources	
1.Mutton	3.0 - 3.5
2.Beef	4.0 – 5.0
3.Pork	3.0 – 5.0

Table 6: Concentration of fluoride and Biological effects

S. No	Fluoride in drinking water mg/l	Effect
1.	0.002 mg/l in air	Injury to vegetation
2.	1 mg/l in water	Dental caries reduction
3.	2 mg/l or more in water	Mottled enamel
4.	3.1 to 6.0 mg/l in water	Osteoporosis
5.	8 mg/l in water	10%osteoporosis
6.	20 – 80 mg/day or more	Crippling skeletal fluorosis
	in water or air	
7.	50 mg/l in food or water	Thyroid change
8.	100 mg/l in food or water	Growth retardation
9	More than 125 mg/l	Kidney change
	in food or water	
10	2.5 – 5.0 gm in actual dose	Death

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