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FLUORINE-LADEN WATER'S NEGATIVE SKELETAL EFFECTS

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Abstract: Fluorides are present naturally in water and soil at varying levels. It was subsequently found that fluoride can prevent and even reverse tooth decay by inhibiting bacteria that produce acid in the mouth and by enhancing remineralization. In addition to building up in teeth, ingested fluoride accumulates in bones leading to severe bone disorders. Some of the various consequences associated with consumption of fluoride are Skeletal Fluorosis and Bone fractures. In India, the most common cause of fluorosis is fluoride-laden water derived from deep-bore wells. Over half of ground water sources in India have fluoride above recommended levels. This paper highlights the effect of water contaminated by larger amounts of Fluorides. Here the author investigates the impact of fluoride content on the skeletal organization of people using contaminated water for drinking purpose.

Key words: *Fluoride, Skeletal fluorosis, Genu valgum, Dental flourosis, Trace elements, Remineralization, Bone remodelling, Arthritis, Osteoporosis, Osteomalacia, Osteosclerosis, Hip Fractures, Environmental Protection Agency, National Research Council USA.*

INTRODUCTION

Fluoride compounds are salts that are formed when the element, fluorine, combines with minerals in soil or rocks. Many communities add fluoride to their drinking water to promote dental health. Exposure to excessive consumption of fluoride over a lifetime may lead to increased likelihood of bone fractures in adults, and may result in effects on bone leading to pain and tenderness. Children aged 8 years and younger exposed to excessive amounts of fluoride have an increased chance of developing pits in the tooth enamel, along with a range of cosmetic effects to teeth.

In 1974, Congress passed the Safe Drinking Water Act. This law requires Environment Protection Agency, USA (EPA) to determine the level of contaminants in drinking water at which no adverse health effects are likely to occur. These non-enforceable health goals, based solely on possible health risks and exposure over a lifetime with an adequate margin of safety, are called Maximum Contaminant Level Goals (MCLG). Contaminants are any physical, chemical, biological or radiological substances or matter in water. The MCLG for fluoride is 4.0 mg/L or 4.0 ppm as set by EPA based on the best available science to prevent potential health problems.(US, Environmental Protection Agency, 2014). Maximum Contaminant Levels (MCLs) are set as close to the health goals as possible, considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies. In this case, the MCL equals the MCLG, because analytical methods or treatment technology do not pose any limitation. EPA has also set a Secondary Maximum Contaminant Levels (SMCL) standard

for fluoride at 2.0 mg/L or 2.0 ppm. Secondary standards are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply. However, states may choose to adopt them as enforceable standards. Tooth discoloration and/or pitting is caused by excess fluoride exposures during the formative period prior to eruption of the teeth in children.

Fluoride is voluntarily added to some drinking water systems as a public health measure for reducing the incidence of cavities among the treated population. The decision to fluoridate a water supply is made by the states or local municipality, and is not mandated by EPA or any other entity. The Centers for Disease Control and Prevention (CDC) provides recommendations about the optimal levels of fluoride in drinking water in order to prevent tooth decay.Some fluoride compounds, such as sodium fluoride and fluorosilicates, dissolve easily into ground water as it moves through gaps and pore spaces between rocks. Most water supplies contain some naturally occurring fluoride. Fluoride also enters drinking water in discharge from fertilizer or aluminum factories. Also, many communities add fluoride to their drinking water to promote dental health.The fact that fluoride can damage your bones, often is no longer in dispute because of the misdiagnosis and lack of knowledge associated with it. Millions of people throughout the world are currently suffering from skeletal fluorosis-a crippling bone disease caused by too much fluoride and marked by irregular bone growth and calcification of the joints. It takes a high dose of fluoride to cause crippling fluorosis.But fluoride accumulates over time, so the severity of skeletal fluorosis exists along a continuum, with the earlier stages produced by lower doses and marked by more subtle symptoms, such as joint pain and stiffness.These early symptoms, which may not be accompanied by obvious bone changes, are often very hard to distinguish from common forms of arthritis. (WHO, 1993, 1999 and CDC, 1999).

And, indeed, researchers over the years have repeatedly cautioned that the early stages of skeletal fluorosis may be misdiagnosed as a form of arthritis. In 2006, skeletal fluorosis was identified by the United States, National Research Council (NRC) as an adverse effect that needs to be considered by the EPA when lowering the maximum safe level of fluoride in water. While case studies in recent years have documented advanced skeletal fluorosis in the US among high-tea drinkers, the EPA has done no serious analysis of the extent to which the disease may be occurring throughout the country. While fluoridation proponents and US health authorities claim that clinically obvious skeletal fluorosis will only develop at prolonged exposures to 10 milligrams (mg) of fluoride per day, virtually no attention, and even less research has focused on the earlier, less obvious stages of the disease.

This review aims to highlight the skeletal disorders especially skeletal fluorosis, associated with abnormal levels of fluoride supplied in drinking water in various tropical countries.

BACKGROUND

Fluoride Linked to the Development of Bone Fractures

In addition to skeletal fluorosis, the National Research Council's 2006 landmark review of fluoride toxicity also expressed concern about fluoride's ability to decrease bone strength and increase the risk of fractures. Of particular concern was fluoride's potential to increase hip fracture rates in the elderly, as hip fractures often send elderly patients into a spiral of declining health ending in death. Based on available evidence, the NRC concluded that fluoride increases the rate of fracture at 4 parts per million (ppm) (the level currently considered "safe" by the EPA), and noted that fluoride may increase the fracture risk at levels lower than 4 ppm.To understand fluoride's potential to damage bone structure, some basic information about how fluoride acts in your body may be helpful. (WHO, 1993, 1999).

First, up to half of ingested fluoride accumulates in your bones, with the other half excreted in urine. Second, once fluoride enters your bones it is removed very slowly. The NRC estimates, for instance, that the biological half-life of fluoride in bone (the time for half of it to be removed) is as long as 20 years. Third, most people have constant low level exposures to fluoride, and are taking more fluoride into their bones than is being removed. As a result, the fluoride level in bone increases steadily with time. Thus, whereas young people generally don't have more than a few hundred ppm fluoride in their bones, older people living in fluoridated areas can have several thousand ppm, a level where skeletal fluorosis may begin. Fourth, the ability to excrete fluoride in urine is significantly decreased among individuals with impaired kidney function. This creates a double-whammy for the elderly, for not only do they already have high accumulated levels of fluoride in their bone, but because kidney function declines with age, they have a reduced ability to remove the new fluoride entering their system. Finally, fluoride appears to interfere with the process of bone turnover (i.e. bone remodeling), wherein the mineral portion of bone is broken down by one type of cell and rebuilt by another. Specifically, fluoride may cause an irregular mineralization, where the density of trabecular bone (which comprises the majority of the spine) can increase at the expense of reductions in cortical bone (which comprises the majority of the extremities). Since the integrity of cortical bone is critical to hip strength, fluoride's ability to reduce cortical bone density has been seen as a key mechanism explaining the link between fluoride and hip fractures. In the past, for example, when high doses of fluoride were given as an experimental drug to osteoporotic patients, fluoride was consistently found to both decrease cortical bone density and increase the rate of hip fractures. Even when fluoride increases bone density, as it often does with trabecular bone, it can simultaneously make your bone more brittle and subject to fracture. (Hileman, 1998).

MAIN FOCUS OF THE REVIEW

Issues and Controversies

In tropical countries like India and China the level of fluoride recommended in drinking water varies with region but is still low as recommended in USA. The various levels of fluoride have been found to cause several ailments although the amount is still lower than the recommended one. Excess of fluoride in supplied drinking water leads to several skeletal disorders some of which are discussed below.

Fluorosis

Fluorosis is a crippling and painful disease caused by excessive ingestion of fluoride through water and/or food. Fluoride can enter the body through drinking water, food, toothpaste, mouth rinses and other dental products; drugs, and fluoride dust and fumes from industries using fluoride containing salt and or hydrofluoric acid. The upper limit ofoptimum fluoride level in drinking water for a tropical country like India is 0.5 ppm or 0.5 mg/l. China fixed 0.7 ppm as upper safe limit in drinking water. It is the total daily intake through water and food thatdetermines the development of fluorosis.

Fluorosis takes 4 forms dental, genu valgum, skeletal and neurological.

Dental Fluorosis

All children living in endemic areas of fluorosis consuming water containing more than 1.5 ppm of fluoridehave been found to develop dental fluorosis.(Truman et al, 2002 and Griffin et al, 2001). Dental fluorosis mainly involves enamel and mottling is one of the earliestrecognizable features. Permanent teeth are affected which become rough, opaque and chalky white with pittingand chippings. Brown, black or yellow pigmentation is also deposited on the teeth.

Genu Valgum

Genu valgum, commonly called "knock-knee", is a condition in which the knees angles inside and touch one another when the legs are straightened. (Prival, 1972, Singh and Jolly, 1970). These are the

deformities of limb bones, and found in children inendemic areas with fluorine toxicity. It occurs only in poorly nourished children whose diet is low in calcium intake.These changes are not seen in endemic regions of Punjab and Rajasthan in India, where intake of dairyproducts containing calcium is higher. (Krishnaramachari and Krishnaswamy, 1974).

Calcium is very essential for humans. 99% of calcium in the body is in the bones and it constitutes 2% ofbody weight. At birth the body content of calcium is 30 grams and in adults it reaches upto 1200 grams. 180 milligrams aday should be retained during growth. Calcium binds with fluoride in the gastrointestinal tract and such a compound iseliminated through the feces. A diet poor in calcium increases body's retention of fluoride. Fluoride increasesbone metabolism and the diets deficient in calcium intake provokes parathyroid hyperactivity. This in turnmobilizes calcium from bone to maintain the serum levels, which causes weakening of bones thereby causingosteoporosis. Weight bearing lower limb bones suffers leading to grotesque deformities. These deformities inlower limb bones are called as 'genu valgum' and these are not seen in individuals living in high endemicregions of fluorosis in Punjab since their diet contains adequate calcium. Daily calcium requirements ofpreschool children are 500-800 milligrams and for adolescents it is 1200-1500 milligrams a day. (Singh et al, 1963).

Magnesium has peculiar relationship with fluoride. Magnesium forms 0.05% of body weight and is essential forhumans. Magnesium helps in elimination of fluoride from the body by competing with calcium. Dailyrequirement of magnesium is 350-500 milligrams. Fluorosis incidence is less in villages whose water contentof magnesium is high compared to those with lower levels of magnesium and similar levels of fluoride in drinking waters. Adequatemagnesium lessens the fluoride toxicity and vice versa. Hence magnesium supplementation should help inendemic regions with fluorine toxicity.

Vitamin C in abundance is also mentioned as a helpful adjunct in fluoride elimination from the body. But do not use ascorbic acid as a vitamin C source for an adjunct to any of the fluoride detox methods.Daily requirement of Vitamin C is 40 milligrams and vitaminsupplementation should be beneficial for individuals living in endemic regions. (Srirangaredy and Srikantia, 1971).

Skeletal Fluorosis

Endemic skeletal fluorosis is a chronic metabolic bone and joint disease caused by ingesting large amounts of fluoride either through water or rarely from foods of endemic areas. In China and India, for example, the high levels of skeletal fluorosis are believed to come from drinking water as well as inhaling coal being used as an indoor fuel source.It is a debilitating disease, especially in latter stages. While in the beginning, the achy joints and stiffness may resemble arthritis, advanced fluorosis causes severe deformities as the ligaments of the neck and vertebrae calcify (harden), muscle tissue wastes away, and movement becomes more and more limited.

Scientific surveys indicate that any water supply containing more than 1 ppm of fluoride could be a risk for skeletal fluorosis. In the United States, 1 ppm is the average amount of fluoride being purposefully added to drinking water. But in addition to consuming fluoride through drinking water, it is also heavily absorbed in hot showers, and can be found in food at 180x the amount in drinking water. Fluoride is a cumulative toxin which can alter accretion and resorption of bone tissue. It also affects the homeostasis of bone mineral metabolism. The total quantity of ingested fluoride is the single most important factor which determines the clinical course of the disease which is characterized by immobilization of joints of the axial skeleton and of the major joints of the extremities. A combination of osteosclerosis, osteomalacia and osteoporosis of varying degrees as well as exostosis formation characterizes the bone lesions. In a proportion of cases secondary hyperparathyroidism is observed with associated characteristic bone changes. Contrary to earlier thinking, severe crippling forms of skeletal

fluorosis are seen in paediatric age group too. Increased metabolic turnover of the bone, impaired bone collagen synthesis and increased avidity for calcium are features in fluoride toxicity. Osteosclerotic picture is evident when small doses of fluoride are ingested over a long period of time during which calcium intakes are apparently normal while osteoporotic forms are common in paediatric age group and with higher body load of the element. Alterations in hormones concerned with bone mineral metabolism are seen in fluorosis. Kidney is the primary organ of excretion for fluorides. (Applbaum, 2010). Age, sex, calcium intake in the diet, dose and duration of fluoride intake and renal efficiency in fluoride handling are the factors which influence the outcome. Serum parameters rarely help in the diagnosis. Elevated urinary fluoride and increased bone fluoride content are indicators of fluoride toxicity. Fluorosis is a preventable crippling disease. No effective therapeutic agent is available which can cure fluorosis. Industrial fluorosis is on the increase on a global basis. Bone density measurement is a tool for early diagnosis.

In the early clinical stage of skeletal fluorosis, symptoms include pains in the bones and joints; sensations of burning, pricking, and tingling in the limbs; muscle weakness; chronic fatigue; and gastrointestinal disorders and reduced appetite. During this phase, changes in the pelvis and spinal column can be detected on x-rays. The bone has both a more prominent and more blurred structure. (Teotia et al, 1971).

In the second clinical stage, pains in the bones become constant and some of the ligaments begin to calcify. Osteoporosis may occur in the long bones, and early symptoms of osteosclerosis (a condition in which the bones become more dense and have abnormal crystalline structure) are present. Bony spurs may also appear on the limb bones, especially around the knee, the elbow, and on the surface of tibia and ulna.

In advanced skeletal fluorosis, called crippling skeletal fluorosis, the extremities become weak and moving the joints is difficult. The vertebrae partially fuse together, crippling the patient.

Neurological Stage of Fluorosis

This is a late stage of skeletal fluorosis where spinal nerves in the spinal cord are compressed causingparalysis. This is a crippling stage and some of them can only be cured by surgery.

Problems

Fluoride Content of different sources of Water Supplies in the Endemic Regions in India

There are three kinds of water sources available namely rainwater, surface water and ground water.Rainwater is clean and ideal for drinking and cooking. Since rainfall is uneven, storage of rain water becomes a majorproblem. Large storage reservoirs are needed which are very expensive to build and maintain. Rainwaterharvesting in bunds and tanks will help in keeping ground water levels higher. (Short et al, 1937). Surface water sources aretanks, dams, canals and rivers. The fluoride content of Nagarjunasagar reservoir and its canals is low andsuitable for drinking and cooking since the fluoride content ranges between 0.4-0.5 ppm. Tank waters areusually contaminated with biological and chemical pollutants. Such water should not be used without treatmentand disinfection. Fluoride content of tank water is higher than rainwater and is in the range of 1.4 ppm. Riversare not perennial and their fluoride content varies from 1.0 ppm in Alairvagu to 7 ppm in stream near Sivannagudem. The fluoride content of river waters in Nalgonda, PedaVagu, ChandurVagu, Chinnakaparthi stream, Kodabakshupallivagu etc are also higher and not suitable for drinking.Ground water sources are wells and boreholes. Fluoride content of well water can vary greatly depending onthe geological structure of the aquifer and the depth at which water is drawn. The fluoride content is unevenlydistributed in ground water both vertically and horizontally and hence every sample has to be tested beforeuse. The fluoride content of granite rocks in Nalgonda varies between 325 to 3200 ppm with a mean of

1440ppm. (Short et al, 1937). The fluoride content of soils in these districts varies between 28 to1780 ppm and of groundwaters ranges between 0.4 to 20 ppm. The reasons adduced for this high level of fluoride inground waters of these regions are the low calcium content of rocks and soils and the presence of high levels ofbicarbonate in soils and waters. Borehole content of fluoride is even higher and they may have abnormal concentrations of trace elements and hence may not be suitable for drinking. If all the sources of waters inthe region are not suitable for use one has to consider defluoridation of waters to reduce its fluoride content.

Flourosis in India

In India, which is highly endemic for fluorosis, over 50% of ground water sources have excess fluoride in thistropical country and it affects more than 150000 villages. Optimum fluoride level for India is 0.5 ppm or 0.5mg per liter. China fixed the upper limit of safe water content of fluoride as 0.7 ppm. The supply of waterwith permissible levels of fluoride though desirable cannot obviously be made available to the vast numbers ofpeople exposed to the risk of fluorosis in various endemic regions around the world nor can they beshifted to other areas. That is why various water-purifying plants have been pressed into service. These defluoridation plants are of two basic types, namely the ones based on exchange process or adsorption andsecond based on addition of chemicals to water being treated to remove excess fluoride. A variety ofmaterials have been tried, although their use has not made any appreciable difference to the incidence offluorosis. Such was the case even when small portable units of water defluoridation were tried in endemic areas. In recent years W.H.O, was emphasizing effective and less expensive methods that are suitable forindividual households or small communities for cooking and drinking water if their fluorine content is morethan 5 ppm. One such method using bone char seemed to be promising. Another one such method that is beingtried in various parts of India based on method of defluoridation known as Nalgonda technique which involvesaddition of aluminum salts to remove fluorides, lime for rapid settling and bleaching powder for disinfectionfollowed by rapid mixing, flocculation, sedimentation and filteration. (Daver, 1945). Scientists are concerned about the use ofaluminum, which has the property of increasing the absorption of fluoride from the gut and also the suspicionthat aluminum toxicity may cause Alzheimer's disease. One other method that was suggested was that,wherever possible, surface waters should be supplied from nearby dams if any and also to collect rainwater byharvesting it. Studies in the highendemic areas of Andhra Pradesh, India proved that there were occasional sources of water, which were good for drinking in these regions. (Daver, 1945 and Siddiqqui, 1970). For example Yellareddyguda and Yedavalli villages of Nalgonda district are known to have a very highincidence of fluorosis. Out of ten water samples tested in the former village one source was very goodaccording to W.H.O. guidelines. It was true of latter village. First ever cases of endemic fluorosis in the worldwere reported from Podili, Darsi and Kanigiri areas of Prakasam district of Andhra Pradesh in 1937. It was found that 7 out of 18water sources tested in these regions were good and safe for drinking. Hence one should search for this kindof sources and villagers should be informed about it. This of course would need a very large study of all thevillages affected with fluorosis but it would be very useful for those living in these endemic regions.

Endemic fluorosis is widely prevalent in tropical countries like India and cases have been reported from all states except north east and Himachal Pradesh. It is estimated that 25-30 million people are living in endemic areas of fluorosis in the country and naturally they run the risk of contacting skeletal fluorosis and half a million people are crippled because of it. Skeletal fluorosis is a crippling disability and has a major public health and socioeconomic impact affecting millions of people in India. There is no known medical or surgical therapy especially if skeletal fluorosis is allowed to develop to the stage when it becomes a crippling disability and hence its prevention should be the only aim. In order to

prevent the skeletal fluorosis it becomes necessary to understand all aspects of fluoride metabolism and the factors which govern its development. The report of endemic skeletal fluorosis in Podili, Darsi and Kanigiri areas of Andhra Pradesh in 1937 contained the description of neurological manifestations of fluorosis, which occurs in the late stages of fluoride intoxication. (Sidiqqui, 1955, 1970). Surprisingly the fluoride levels of drinking water in these areas were not very high and were in the range of 1-3 ppmand rarely did they exceed 6 ppm. Same is true of other Indian states such as Punjab, Rajasthan and Uttar Pradesh etc. A study from Rajasthan revealed that the people drinking 6 ppm of fluoride in water developed skeletal fluorosis in 63% of individuals. In Uttar Pradesh, the incidence of skeletal fluorosis was 57% drinking 3.2 ppm of fluoride in water while it was 71% in Punjab consuming 9.7 ppm of fluoride in water. World Health Organization monograph No.59 of 1970 on 'fluorides and human health' states that skeletal fluorosis would not develop in individuals who are consuming water containing 5 ppm of fluoride and with fluoride levels in water of 8 ppm there is only 10% chance of them developing skeletal fluorosis. Hence the reasons adduced for such severe manifestations of fluorosis in India were the following: (a) high atmospheric temperatures in summer going up to 115-116*F , (b) Strenuous physical labor and lastly (c) poor nutrition deficient in calories and also in their content of Vitamin C. Climate and occupation do play a role by influencing the fluid intake. Increased water intake naturally leads to ingestion of larger amounts of fluoride. The plane of nutrition appears to play a crucial role and, epidemiological studies in endemic regions in India and Japan suggested that the incidence and severity of fluorosis be related to the dietetic content of protein, calcium and vitamin C. It is not known how a balanced diet reduces the toxicity of fluoride, although a diet having adequate calcium and vitamin C has been found to be effective in this regard. It is true that lower limb deformities that are seen in individuals in endemic areas of Nalgonda are not seen in fluorotic regions of Punjab with same levels of fluoride in drinking water supplies. This may be because the people's nutrition is better in Punjab especially as per their calcium intake. The role of nutrition in skeletal fluorosis has been well highlighted by the Chinese study in endemic areas where drinking water contains 4 ppm of fluoride. Malnourished individuals whose diet was deficient in proteins and calcium had an incidence of 69.2 % of skeletal fluorosis as compared to 43.8 % in the well nourished group. World Health Organization monograph on fluorides published in 2002 also confirmed that nutrition doesplay a role in fluoride toxicity. This is especially true of growing children and adolescents if their diets are deficient in calciumcontent and their intake of fluoride from water and food is very high. There is increased bone metabolism in cases of fluorosisand in order to maintain extracellular calcium level body provokes parathyroid hyperactivity. This weakens the bonesespecially the weight bearing lower limb bones. This in turn causes genu valgum and forward bowing the leg bones. Whatwas not realized in 1937, (Short et al, 1937) was that all the ten cases recorded had poor renal functions. It is now known that diseased kidneyscannot handle fluoride excretion and hence fluoride is retained in the body leading to the development of skeletal fluorosis. Itis also realized in recent years that presence of abnormal amounts of certain trace elements can influence fluoride toxicitysome beneficial and others detrimental. A study with18 water samples from Podili, Darsi and Kanigiri regions showed that except foursamples all were from the same well waters which people were consuming for decades and centuries. Four were borehole waters,which are usually bad as compared to the ground waters from wells. Only 7 of the 18 water sources were good for humanconsumption according to WHO guidelines. Even today fluoride levels in drinking waters in areas of Prakasam district of Andhra Pradesh, are not high. (Krishnaramachari and Krishnaswamy, 1974). The concentrations of some elements like chromium and uranium were very high in these samples and these are known to be nephrotoxic. Highincidence of renal disease noted in people who developed the severe forms of fluoride intoxication in these areas may be dueto these

elements in abnormal concentrations aggravating fluoride toxicity.

Next report of fluorosis cases from Andhra Pradesh was from villages of Nalgonda district in 1945. (Daver, 1945). Observations confirmed the role of malnutrition and occupation, which aggravate the fluoride toxicity. A farm laborer is more likely to develop fluorosis than sedentary worker drinking the same well water. Obvious inference is that the laborer consumes more water and naturally more prone to develop fluorosis. Similarly malnourished laborers were more likely to get fluorosis. Next detailed study of fluorosis cases from Nalgonda came in 1955 who confirmed that intake of calcium by villagers of Nalgonda was very low, in the range of 300 milligrams per day. (Sidiqqui, 1955). In contrast the daily intake of calcium by the individuals living in high endemic regions of Punjab was 900 milligrams. (Singh, 1967). This fact alone explains the presence of cases of endemic genu valgum in Nalgonda villages, which is not found in Punjab. These studies did not report cases of endemic genu valgum though the intake of calcium was low. It appears that in the past two decades, people's nutrition have further deteriorated. What transpired in these two decades was that phosphate fertilizers were increasingly used for cultivation, more borewell water used for drinking and cultivation with the availability of electricity and sale of commercial dairy products diminished the use of pure dairy products in the villages. Phosphate fertilizers are major source of fluoride contamination in agricultural soils. They are manufactured from rock phosphates which generally contain 3.5% of fluorides. The final product contains 1.3- 3% of fluorine. Cultivation of crops using under tanks which collected the rain water which has low levels of fluoride has been replaced by deeper wells and bore wells resulting in increased fluoride content of water used for cultivation. The incidence of fluorosis varied in villages of Andhra, which had similar fluoride levels in drinking waters. Some studies proved that the levels of magnesium in water supplies made the difference in the incidence of fluorosis. (Pandit et al, 1940). Higher levels of magnesium were beneficial and vice versa. Experiments in fluorotic dogs, laboratory animals and humans proved the beneficial role of magnesium compounds in fluorosis. (Philips, 1934).

Dietetic content of protein, calcium and vitamin C have been found to reduce the toxicity of fluoride, although the underlying mechanism is not known. Presence of certain trace elements like silicon, molybdenum, copper, calcium and magnesium might either mitigate or potentiate the effects of fluoride toxicity. Excess of silicon and molybdenum seems to aggravate fluoride toxicity and optimum contents of copper, calcium and magnesium are beneficial. Dietary practice like parboiling of rice, which is prevalent, especially in south Asia with fluoride rich water, may further increase the fluoride burden to the people.

Solutions and Recommendations

All the above observations may be utilized in the prevention or lessening the effects of fluoride toxicity in endemic areas.

Improving the nutritional status especially of children and adolescents, identifying foods high in fluoride content which needs be avoided by the population at risk, educating the people and communities against indiscriminate use of fluoride rich pesticides and fertilizers and parboiling of rice in safe water are some of the healthy practices to be followed to mitigate the effect of fluorosis. It may be noted that tea is very rich in fluoride content, which varies from 250-400 ppm, and each cup adds 0.5 mg of fluoride and obviously should be avoided in these areas. One other aspect, which has not been studied, is the fluoride content of foodstuffs grown in these areas, which have high fluoride in water sources. Some studies investigated the fluoride content and seven trace elements levels in the foodstuffs that are eaten in three villages namely Yellareddyguda, Yadavalli and Naibai in Nalgonda district. (Pandit, 1940). These results should be compared with similar studies in foodstuffs cultivated in non endemic regions. Certain plants have a high predilection to absorb fluoride in large amounts

such as gladiola and tea. Information about other plants is not available. Further work needs to be done which can only be accomplished with a dedicated team attached to a major teaching hospital. One should know that even animals in the endemic regions suffer from the same problems, as human beings.

Hence the factors which govern the development of skeletal fluorosis are (a) the prevalence of high levels of fluoride intake through water and food; (b) continued exposure to fluoride; (c) strenuous manual labor; (d) poor nutrition; (e) impaired renal function and lastly (f) abnormal concentrations of certain trace elements. (Tusl, 1970). In regions having very high fluoride content the disease may affect younger age groups including children. Obviously the longer the exposure to fluoride the higher will be its incidence. Farm laborers engaged in manual works are more prone to fluorosis than those belonging to sedentary occupations. Some constituents of water accounting for its hardness or alkalinity also seem to promote the incidence of fluoride by affecting the amount of fluoride absorbed from the gut. The most important factor, which throws light on the development of fluoride toxicity, is the status of the kidney. Abnormal concentrations of certain trace elements will also affect fluoride toxicity. Calcium and magnesium are beneficial while selenium, chromium and uranium are bad and not much is known about the role of other elements. (Ventateshwarli and Rao, 1957).

In order to plan alleviation of endemic skeletal fluorosis in fluoride-laden areas one has to consider all the factors that govern the development of skeletal fluorosis. (Wadhwani, 1952, 1970).

Prevention and Management of flourosis

Some of the methods to prevent fluorosis are:

- Planning the optimum diet content of calcium, magnesium and vitamin C.
- Planning supply of water containing optimum levels of fluoride. After extensive study the Department of Health and Human Services, U.S., recommended 0.7 mg/liter of fluoride as the safest level to prevent fluorosis.
- Other precautions to be taken are avoiding tea drinking in these areas as tea has exceptionally high content of fluoride.
- Parboiling of rice with fluoride containing water should be avoided.

Management of fluorosis:

- Provide surface water from nearby dams if any.
- Harvest rainwater.
- Look for sources of water, which are good as per WHO guidelines for drinking and cooking.
- Provide nutritious food to children and adolescents preferably from local foodstuffs.
- Need to establish a laboratory to estimate Fluoride levels in every district. This laboratory should bewithin easy reach of villagers.
- Setup a major laboratory to estimate trace elements and Fluoride levels in Foodstuffs. There is also a need to have a ward for studying the fluorosis cases.

FUTURE RESEARCH DIRECTIONS

Fluorosis in all over the world has been usually misdiagnosed with arthritis, osteoporosis and other well known skeletal disease. Our knowledge and understanding towards this disorder is limited. There is a need for further investigation of the medical and anatomical mechanism underlying this condition. At the same time policies and recommendations regarding the level of fluoride in drinking water should be taken into account after excessive research. Nutraceutical aspects of the disease also need to be looked into before decision making.

CONCLUSION

The risk of skeletal fluorosis depends on more than the level of fluoride in the water. It also depends on nutritional status, intake of vitamin D and protein, absolute amount of calcium and ratio of calcium to magnesium in drinking water, and other factors. In parts of India, China, Africa, Japan, and the Middle Fast, large numbers of people have skeletal fluorosis from drinking naturally fluoridated water. In India about a million people have this disease. Most of the victims live in areas where the water fluoride level is 2 ppm or above, but some cases are found in communities with natural fluoride levels below 1 ppm. In the U.S., more than a dozen cases of skeletal fluorosis have been reported. Some have occurred at high fluoride levels, others at levels lower than 4 ppm when aggravating conditions were present, such as diabetes or impaired kidney function. In setting the recommended maximum contaminant level for fluoride in drinking water in 1986, EPA considered only crippling skeletal fluorosis as a health effect and established little or no margin of safety, even for this disease. (A margin of safety is a difference between the maximum contaminant level and the level at which health effects first occur in the most susceptible individuals.) According to a Department of Agriculture survey, about 3% of the U.S. population drinks 4 L or more or water per day. Therefore, about 3 % of the people who live in areas where the water contains the natural fluoride level of 4 ppm allowed by EPA such as certain communities in Texas or South Carolina are ingesting at least 16 mg of fluoride a day, not including the fluoride they derive from other sources, such as toothpaste, food, or air. Several states of India and other tropical countries have acute level of fluoride in water.

Since fluorosis is a preventive and not a curable disease, proper amount of nutrients with essential trace elements like calcium, magnesium and Vitamin D and supply of clean drinking water with 0.7mg/L of fluoride are some of the recommended preventive measures of fluorosis.

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KEY TERMS AND DEFINITIONS

Flouride: It is a poisonous compound of pale yellow-green colour, present naturally in low concentration in water, food and air. At high concentrations it is a toxin.

Skeletal flourosis: A bone disease which occurs when high concentration of fluoride gets accumulated in bones leading to their deformity.

Genu valgum: It is a skeletal disorder commonly known as knock-knee. Affected persons can't stand straight. Their knees appear to be bending towards each other giving the lower limb a V-shaped structure while standing.

Dental flourosis: Disease associated with discolouration and rupture of teeth caused due to exposure to excess fluoride.

Trace elements: Dietary minerals that are needed in very less amount for proper growth and development of an individual.

Remineralization: A process which is used in tooth therapies. In this process the mineral used in therapy gats absorbed in the teeth with time contributing to the re-structuring of teeth.

Bone remodeling: A natural and life long process in which the old and mature bone tissues are removed by the new ones. An imbalance in this natural process leads to a bone disease called osteoporosis.

Arthritis: It is a type of disorder associated with the joints of bones. It causes inflammation, pain and weakening of at joints.

Osteoporosis: A progressive disease associated with decreased bone mass density caused due to imbalance in the bone remodeling process. It make the bone weaker and hence prone to fractures.

Osteomalacia: Softening of the bones caused by defective bone mineralization and also due to inadequate amounts of available phosphorus and calcium. It leads to increased fragility and excessive flexibility of the bone so that the patient can't even move their limbs.

Osteosclerosis: Hardening of bone caused due to elevated bone density. It usually causes stiffness in the bone.

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