Status of chronic fluoride exposure and its adverse health consequences in tribal people of scheduled area of Rajasthan, India

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Abstract: In India, Rajasthan is the largest state being consists of total number of 33 districts. Eight of these, namely, Banswara, Chittourgarh, Dungarpur, Pali, Pratapgarh, Rajasthan, Sirohi, and Udaipur districts have been included in scheduled area of Rajasthan. This is the most backward and under developed tribal area where >70% tribal populations are residing. This area, though, several communicable and non-communicable diseases are endemic. But, recently a single factor, fluoride (F) is causing a dreaded fluorosis disease which is deteriorating the tribal health. Though, diverse sources of F exposure are available in the scheduled area. However, fluoridated drinking water and industrial F pollution are the major sources of F exposure. In this area, almost all the drinking water sources contain F in the range of 0.1-21.6 ppm which is higher than the maximum permissible limit (1.0-1.5 ppm). Drinking of such water for prolonged period is injurious to human health. The tribal people of this area are consuming this water for both drinking and cooking for last > 40 years. Due to low nutritional status, tribal people are highly susceptible to F toxicosis as compared to non-tribal subjects of this area. Hence, thousands of tribal people (> 69%) of this area are suffering with chronic F poisoning. Dental fluorosis is the most common in tribal individuals of all age groups. At > 3.0 ppm concentration of F in the potable water, the tribal people are severely afflicted with skeletal fluorosis and revealed various bone deformities; crippling, banding of waist (kyphosis), curvature of the extremities (genu-varum and genu-valgum), and neurological complications (paraplegia and quadriplegia). Among fluorosed tribal subjects, other health consequences such gastrointestinal discomforts, frequent urination, low IQ in children, sterility, repeated abortion, still birth, etc. are also prevalent which are also the resultant of chronic F intoxication. In this communication, sources of F exposure and its diverse adverse health consequences (fluorosis), susceptibility of F toxicity in tribal
individuals, F exposure and erythrocyte genetic disorders, fluorosis and tribal economy, and prevention and control of F intoxication are considered and briefly and critically reviewed. Simultaneously, research gaps have also identified and highlighted. Findings of this review are significant and useful in framing and implementation of health plan for the preservation of tribal health from chronic F poisoning in scheduled area of Rajasthan.

**Keywords:** Adverse health consequences; Drinking water; Fluoride exposure; Osteo-dental fluorosis; Scheduled area; Susceptibility; Tribal economy; Tribals; Rajasthan; India.

**Introduction**

In India, more than 700 endogamous tribes inhabit the forest and remote areas of different states and union territories. Many of these tribes are still in primitive form and mostly they live in isolated form. In the country, though, many survey reports on their socio-economic status, education, literacy, habits, behaviours, traditions, culture, etc. are available. However, scientific health surveys, especially on chronic F poisoning in various tribal populations of different states are still too limited. In the state of Rajasthan, most of the tribal people are residing and restricted in the forests and remote hilly areas of south east region. These people are the weakest section of the modern society and suffering from several communicable and non-communicable diseases.1-18 Recently, water-born F induced dreaded hydrofluorosis disease, has been emerged out in the scheduled area of Rajasthan19-22 which is immensely deteriorating the health of tribal people. Before the four decades, this tribal areas was completely free from fluorosis disease but endemic of water-born parasitic disease, dracunculiasis being caused by infection of human nematode, *Dracunculus medinensis*.23, 24 Thousands of tribal people of this area were infected with this parasite. In the year of 1986, to overcome dracunculiasis disease burden as it was serious and highly painful health problem in tribals, a guinea-worm eradication program was commenced. There is no doubt that the program was successful, but in lieu of dracunculosis, fluorosis disease developed among the tribal people.25, 26 Besides the water born hydrofluorosis, in certain remote tribal areas of Dungarpur, Chittourgarh, Pali, Sirohi, and Udaipur districts of the scheduled area, the industrial F pollution is also causing neighbourhood and industrial fluorosis in the tribal subjects and their domesticated animals, respectively.27-29 Interestingly, medical and health, veterinary, and pollution departments are unaware about these health threats in the scheduled area of Rajasthan.
In India, except few studies on chronic F poisoning among tribals, no extensive epidemiological survey studies have been performed so far in various tribal populations of different states and union territories where drinking water is containing F toxicant beyond the maximum permissible limit 1.0 ppm or 1.5 ppm. In spite of having a number of sources of industrial F emissions in the remote areas of many states and union territories of the country where tribal populations are also endemic, but studies on chronic industrial F intoxication in the tribal people are also wanting. However, in the state of Rajasthan, F distribution in drinking waters and endemic fluorosis in several tribal villages of Banswara, Chitourgarh, Dungarpur, Pratapgarh and Udaipur districts of the scheduled area have been well studied. Findings of these studies are significant, unique and useful in the preparation and implementation of health plan for the preservation of tribal health from chronic F poisoning. In the present review, sources of F exposure and its diverse health consequences (fluorosis), susceptibility of F toxicosis in tribals, chronic F exposure and erythrocyte genetic disorders, fluorosis and tribal economy, and prevention and control of F intoxication in tribal populations of scheduled area of Rajasthan are considered and briefly and critically reviewed. Simultaneously, future research scopes on F toxicosis in the scheduled area have also been identified and focused. This review is very important and may draw an attention of the government medical and health and public health engineering departments and non-government organizations (NGOs) to solve the endemic fluoride and fluorosis health problem in the scheduled area of Rajasthan (India).

Scheduled area and its tribes

Rajasthan is the largest state in India which is eco-geologically separated by Aravali Mountains into two different regions. In the western region, desert environment is located where in the eastern region, the humid environment exists. It has total number of 33 districts. Eight of these, namely Banswara, Chittourgarh, Dungarpur, Pali, Pratapgarh, Rajasamand, Sirohi, and Udaipur districts are located in its south eastern part and have been included in the scheduled area of Rajasthan (Figure 1). This is the most backward and underdeveloped area of Rajasthan which is characterised with preponderance of diverse tribal communities or populations. As per Census of 2011, total population of scheduled area is 64, 63,353, out of which scheduled tribe population is 45, 57, 917 which is 70.43% of the total population of the scheduled area. Three districts of this area, namely Banswara, Dungarpur and Pratapgarh are known as full tribal districts and remaining are partial tribal districts. In the scheduled area,
the most dominating endogamous tribes are Bhil, Damor, Meena, Garasiya, Kathudia and Sahariya. Later three tribes are still primitive.

**Socio-economic and nutritional status, and habits of tribal people**

The socio-economic status of tribal people of scheduled area of Rajasthan is poor. In this area, the literacy rate is relatively very low and health education is the almost negligible. In general, tribal people prefer to live in the forest and remote areas of Arawali hills in isolated form. Financially, the tribal people are not well and mostly depend on animal husbandry, traditional agriculture, and forest yields. However, for the daily income, they prefer to do labour work. In this area, the nutritional status of tribal people is very poor. In their staple diet, the main food stuffs are maize, barley, rice, onion, garlic, and with or without pulses and vegetables. Occasionally, they consume meat, milk, curd, cooking oil, ghee, seasonal fruits, and vegetables. Most of these people are habitual for consuming of local made wine, tea, smoking, and tobacco whereas young tribals of both sexes frequently consume Supari (betel nut) and tobacco containing flavoured Pan Masala and Gutkha. In general, tribal people are shy, conservative, highly orthodox, and superstitious, and have deep faith in their local deities and they believe that they will keep them healthy and away from various diseases. Mostly, tribal people generally used their own traditional methods for the treatment of various diseases including fluorosis. One of the methods, which is cruel, terrible, and very painful method, they stained with hot iron rods on the patient's forehead, hands, feet, back, and stomach for the treatment of diseases. Many times patients die by this method due to secondary infection. This practise is still prevalent in the scheduled area of Rajasthan.

**Sources of F exposure in scheduled area**

In general, F is present in varying amount in water, foods, soil, and air. In the scheduled area of Rajasthan, though, both natural and anthropogenic myriad sources of F exposure are available. However, the commonest and principal source of F exposure for tribal individuals as well as for their domesticated animals is drinking of groundwater. In the villages of scheduled area of Rajasthan, water of almost all the drinking groundwater sources, mainly hand-pumps and bore-wells are contaminated with F toxicant and is found beyond the maximum permissible limit (1.0- 1.5 ppm) as per standards of ICMR and WHO. Consumption of such water for long-time for the drinking and cooking is harmful to tribal
health and causes mild to severe diverse adverse health consequences in the form of fluorosis.33

Fluoride in drinking water in all the 8 districts of scheduled area of Rajasthan is varied between 0.1-21.6 ppm. In the districts of Banswara, Chittourgarh, Durgapur, Pali, Pratapgarh, Rajasamand, Sirohi and Udaipur, F content in the potable water is found in the range of 0.1–4.6 ppm, 0.0–6.6 ppm, 0.1–10.8 ppm, 0.0–14.0 ppm, 0.1–4.7 ppm, 0.0–4.5 ppm, 1.0–16.0 ppm and 0.1–21.6 ppm, respectively39-52 (Figure 2). Exposure of such fluoridated water for prolonged period is not safe and injurious to human and animal health.36, 53

Besides the F in drinking water, F is also found in various food chains and webs as well as in the agriculture or crop yields (food grains, cereals, pulses, vegetables, fruits etc.) cultivated in F containing soil and irrigated by fluoridated groundwater.54 In the scheduled area, domesticated animals are also afflicted with chronic F toxicosis.55-67 Therefore, milk and meat of these fluorosed animals contained F in varying amounts and are the sources for F exposure for tribal individuals.68-73 Apart from these, wine, tea, smoking, and tobacco and Supari (betel nut) containing flavoured Pan Masala and Gutkha are also sources of F exposure for tribal individuals as these items contained ample amount of F.

In scheduled area, some industries such as Hindustan Zinc Smelter, Superphosphate Fertilizer Plants, Rock Phosphate Minings, Chemical Fertilizers, Bricks kiln and Cement production are discharging F in both gaseous and particulate/dust forms into surrounding environments and pollute the soil, agriculture crops, vegetations, and freshwater reservoirs. Therefore, industrial F emission is one of the potential sources of F exposure causing F toxicosis among tribal people as well as in their domesticated animals.27-29 In fact, inhalation of these dust particles is relatively more dangerous and injurious to human and animal health.

**F induced adverse health consequences in tribal people**

It is well established, over F exposure or excessive ingestion and inhalation of F for long-time causes mild to severe toxicosis and ultimately develops the fluorosis disease. F is not only affects or damages the hard tissues (teeth and bones) but also affects the various soft tissues or organs of the body. Once F inters into body, it absorbed by digestive and respiratory tract and finally reaches to various tissues or organs of the body through blood circulation. More than 50% absorbed F excreted through excretory products (faeces and urine) and perspiration, while rest is retained in the body and accumulates gradually in both
hard and soft tissues. However, due to its greater affinity with calcium, it accumulates maximum in the calcified or hard tissues such as osteal and dental tissues as compared to non-calcified tissues or soft organs. Accumulation of F, interfere the physiology of diverse biological systems which triggers the genesis of various adverse or toxic effects in the body. These F induced pathological or toxic changes are collectively referred as fluorosis. These changes in teeth and bones are, generally, permanent, irreversible and untreatable and could be visible by neared eyes. However, F induced changes in soft tissues are reversible and disappeared on removing of source of F exposure.

Those F induced changes are the resultant of consumption of F containing water are collectively known as hydrofluorosis which is more common and rampant not only in the tribal people but also in their domesticated animals of schedule area of Rajasthan.\textsuperscript{26,33} When these changes are the resultant of industrial F pollution, then these are referred as neighbourhood and industrial fluorosis in human and animals, respectively.\textsuperscript{27-29} Both forms of fluoroses are prevalent and hyperendemic in the scheduled tribal area of Rajasthan.

\textit{Dental defragment (dental fluorosis)}

F induced dental mottling or changes (dental fluorosis) are the earliest sign of chronic F intoxication which are visible, sensitive, and indexive. Clinically, dental fluorosis is characterised by diffuse hypocalcification which is generally appeared in the form of bilateral, striated and horizontal opaque brownish pigmented streaks on teeth surface. In tribal children and adolescents, these pigmented streaks are relatively more contrast in appearance and sharply visualized on their anterior teeth incisors (Figures 3 and 4). No doubt, in the scheduled area of Rajasthan, dental fluorosis is rampant. As the increasing of age and F content in drinking water and its duration of exposure, dental fluorosis becomes more advance and severe being characterized with development of diastema (gaps) between teeth, pronounced loss of the tooth-supporting alveolar bone occurs with recession and swelling of the gingival tissues and excessive abrasion or irregular wearing of the teeth (Figures 5 and 6). This worst condition of dental fluorosis is more prevalent and common in tribal people of higher age groups (> 55 years) and residing in those villages where drinking water contain F > 2.0 ppm.

Recently, in the scheduled area of Rajasthan, a large survey studies were conducted in tribal villages of Banswara, Chittourgarh, Dungarpur, Pratapgarh, and Udaipur districts of scheduled area of Rajasthan for the evidence of F intoxication in tribal as well as in non-
subjects. F in drinking water of these villages contained F between 0.1 and 21.6 ppm. Studies revealed that out of 9429 children and 10315 adolescents and old tribal subjects, 6496 (68.8%) and 7472 (72.4%) were found to be afflicted with mild to severe dental fluorosis, respectively. In many villages, 70-100% tribal children are found to be afflicted with dental fluorosis with varying grades. Findings suggest that tribal children are relatively more prone to F poisoning. Interesting, most of the tribal children in the scheduled area are unknown about the cause of dental fluorosis.

Whatsoever, dental fluorosis causes tooth loss and decay which creates a problem in mechanical digestion of food among the tribal subjects. Opaque appearance of dental fluorosis also causes aesthetic changes may trigger social constraints as well as behaviours in young tribal subjects. It may also cause psychological effect and lead to low confidence in tribal children and adolescents. In fact, dental fluorosis is not only affecting the quality of life but also affecting the oral hygiene and health in tribal individuals of both sexes. Recently, a study was conducted in F endemic areas of Eastern Africa revealed that the prevalence of tooth decay / loss and oral leukoplakia increased with severity of dental fluorosis. Study also revealed that increased esophageal cancer risks are found to be associated with moderate and severe dental fluorosis in subjects having more tooth loss/decay. Therefore, it may possible that tribal people are also at high risk for leukoplakia and esophageal cancer. However, in India, for its confirmation, such studies are needed in tribal individuals residing in F endemic areas. Scientific survey studies on dental fluorosis in relation to quality of life, social constraints, and oral hygiene and health are also highly suggestive in the tribal villages of Rajasthan. Findings of these studies are useful in making of health policy for the prevention of dental fluorosis as well as for better oral health and hygiene in tribal individuals.

**Skeletal deformities (skeletal fluorosis)**

Excessive F intake alters the equilibrium between formation and resorption of bones. This physiological process is accomplished by involvement of certain regulatory determinants and signalling pathways, thereby leading to various bone deformities known as skeletal fluorosis which is very painful and more dangerous than dental fluorosis. Skeletal fluorosis is highly significant since it diminishes the mobility at a very early age by producing gradually varying changes in bones such as periosteal exostosis, osteosclerosis, osteoporosis and osteophytosis. These changes appear clinically in the form of vague aches and pains in the body and joints and these changes can be seen and identified in the
radiographs of various bones of fluorosed subjects (Figures 7-12). The excess accumulation of F in muscles also diminishes or restricts the movements and the condition leads to crippling or disabilities. In advanced stage of skeletal fluorosis, neurological complications such as paraplegia and quadriplegia and the syndromes of genu-valgum and genu-varum are also the resultant of chronic F exposure and this is a worst condition or stage of skeletal fluorosis.

In scheduled area, many tribal people are suffering with crippling and bedridden, hunch-backed (kyphosis) and bow legs (genu-varum) deformities. However, cases of scissor-shaped, knock-knee (genu-valgum) leg deformities\(^7^8\) and neurological complications (paraplegia and quadriplegia) are also prevalent in tribal subjects of both sexes. In general, these bone abnormalities (Figure 13-17) are prevalent and more common in subjects of higher age groups at 1.5 ppm F concentration in drinking water\.\(^{34, 35}\) As increasing of F concentration in drinking water, skeletal fluorosis becomes more severe and developed even in children, adolescent and adult individuals. A large survey study conducted in the scheduled area revealed more than 27% tribal subjects are suffering with skeletal fluorosis\.\(^{34, 35}\) In the scheduled area of Rajasthan, the most common skeletal deformity among tribals of all age groups is the bow legs (genu-varum syndrome) and the rarest is knock-knee (genu-valgum syndrome) deformity. Interestingly that genu-valgum syndrome is found to be more prevalent among the tribal children of state of Madhya Pradesh and Chhattisgarh\.\(^{30-32}\) Why this syndrome is not common among tribals of Rajasthan is yet not clear. It may be possible the variation in nutrition or nutrients in food and continuity of F exposure. However, for the scientific justification of it, more comparative studies in different area having variable F concentration in drinking waters.

**Other health consequences (non-skeletal fluorosis)**

In the scheduled area, besides the teeth and bone deformities, the most common F induced health consequences such as intermittent diarrhoea or constipation, abdominal pain, flatulence, urticaria, polyurea and polydipsia in the tribal people have also been observed\.\(^{34, 35}\) However, cases of repeated abortions, sterility, reluctance to reproductive functions and erectile dysfunction in male individuals have also been observed in the F endemic villages. F induced these changes in the soft tissues or organs are generally referred as non- skeletal fluorosis and are the earlier signs of chronic F intoxication in both humans\.\(^{25}\) and domestic
animals. These health consequences are temporary and can be reverse after removal of source of F exposure.

In F endemic Rajasthan, low memory, learning ability, intelligence quotient (IQ) and cognition in school going chronic F exposed children have also been reported. Several studies have revealed a significant relationship between F toxicity, dental fluorosis and neurotoxicity or impaired cognition in children. In fact, F is potential to impair the function of central nervous system. But involvement of exact mechanism at the molecular level is yet not clear. It has long been suspected that F may contribute to the formation of kidney stones. A study also conducted in F endemic tribal areas of southern Rajasthan suggested that a high intake of F provoked nephrolithiasis in tribal populations. However, more such studies are needed to allow unanimous acceptance of the role of F in stone formation in kidney as well as in reducing of IQ in children, especially in Rajasthan where the drinking water contains a high amount of F. Many studies revealed that F induced the hypothyroidism in human population but not a single case of goitre has been detected and reported in tribal populations of scheduled area of Rajasthan. Nevertheless, in the absence of research studies, it is difficult to say that these fluoride-borne health complaints are present in tribal people. Therefore, there is a need for detailed research on the correlation of F with memory, learning ability, intelligence quotient (IQ), cognition, stone formation in kidney and gall bladder, and reproductive and endocrine functions in tribal and non-tribal subjects of F endemic scheduled area of Rajasthan.

Susceptibility of F toxicity in tribals

A large survey study was carried out among 18662 and 8808 subjects of both sexes belonging to scheduled tribe (ST), scheduled caste (SC), and other backward class (OBC) and general caste (GC) populations residing in the tribal villages of Banswara, Chittourgarh, Dungarpur, Pratapgarh, and Udaipur districts of scheduled area of Rajasthan for the evidence, prevalence and severity of F toxicity in the form of dental fluorosis (DF) and skeletal fluorosis (SF). Findings of this study indicate that the prevalence and severity of osteo-dental fluorosis is much variable in the subjects belonging to different populations (Table 1). The highest prevalence of DF (69%) and SF (27.02%) was found in the subjects of ST followed by SC and OBC and GC population (Figure 18). Similarly, the severity of DF and SF was also found maximum in tribal people compared to their counter parts. It is evidently cleared that tribal people have less tolerance and are relatively more susceptible to F. That’s why
tribal people are severely afflicted with osteo-dental fluorosis in the scheduled area of Rajasthan. Interestingly, in the studies conducted in tribal and non-tribal subjects living in different villages having almost the similar F concentration in their drinking waters, revealed relatively a higher prevalence and magnitude of osteo-dental fluorosis in tribal subjects. Higher susceptibility and low tolerance with F toxicity in tribal people are mainly due to their poor nutritional status. Further, this finding is lend to supported by earlier studies.86, 87

It is well known that besides the F concentration in drinking water, some other determinants are also involved to govern or accelerate the F toxicity. The frequency and duration of F intake or exposure are the major factors for the controlling of severity of chronic F toxicosis. However, age, sex, habits, nutrition and other food constituents, chemical constituents of drinking water, environmental factors, individual susceptibility, biological response, tolerance and genetics are also determinants of fluorosis.88-92 Nevertheless, the prevalence and severity of fluorosis in tribal people are relatively higher than non-tribal individuals due to poor nutritional status and having certain bad habits. In fact, in their diets or foods have inadequate amount of calcium and vitamin C nutrients as these are antagonistic to F toxicity.86, 87, 92 Most of the tribal individuals are also habitual for the regular consumption of local wine, tea, smoking and tobacco and betel nut (Supari) containing Pan-Masala and Guthaka. These food items are additional sources of F exposure because of these contain high amount of F which leads to aggravate the fluorosis. Hence, the tribal people are severely afflicted with osteo-dental fluorosis in very young age.34, 35

Chronic F exposure and erythrocyte genetic disorders

According to research studies, not only fluorosis disease is prevalent in the state of Rajasthan, but people of different populations living in its desert and hilly-plain areas have genes of blood-borne genetic diseases such as sickle cell anemia, β-thalaseamia, and glucose-6-phosphate dehydrogenase (G-6-PD) enzyme deficiency (Figure 19). After over of certain age, letters die due to anemia and other serious complications. Although treatment of these sickle cell and β-thalaseamia diseases is possible, but it is not accessible to everyone due to being more expensive. The genes of these diseases are widely present in the tribals of scheduled area of Rajasthan, on the other hand these people also have F induced fluorosis disease. Research studies also show that due to the toxic effect of F, various changes in blood parameters are possible and accelerate the haematological degeneration leading to death of
erythrocytes and causing a mild to severe anaemia. Therefore, the possibility cannot be
ruled out that tribals who have genes for sickle cell anemia and β-thalasaemia diseases may
die more quickly from the effects of F toxin. Although, it is not possible to confirm the above
statement due to lack of research. Therefore, there is an urgent need for deep and factual
detailed research among the tribals of this area to confirm and understand it, which will prove
to be a new information of F intoxication in humans.

**Fluorosis and tribal economy**

The tribal people of schedule area are economically dependent mainly on labour
work, agricultural or crop yields, and animal husbandry business. In this area, several
communicable and non communicable diseases are endemic which are curable except
certain lethal erythrocyte genetic diseases such as sickle cell anaemia, β-thalassaemia, and
glucose-6-phosphate dehydrogenase (G-6-PD) enzyme deficiency. In the state of
Rajasthan, the government is providing free medicines for the treatment of these diseases
except erythrocyte genetic diseases. Hence, tribal people have less economic burden and
losses due to these diseases. But, the fluorosis disease may cause a serious economic burden
in tribal people. In fact, F induced skeletal deformities; crippling, genu-varum syndromes,
kyphosis, and para and quadriplegia etc. are permanent, irreversible, and remain life-long in
fluorosed subjects. These deformities not only restrict the movement but also reduce the
working capacity in tribal people who are suffering with skeletal fluorosis. In general, these
fluorosis affected people are physically weak, anaemic, inactive, and lethargic and are mostly
unable to do labour work for daily income. In this way, skeletal fluorosis directly or
indirectly adversely affects the daily income of the tribal people.

The tribal people of this region are also financially dependent on agricultural
production or crop yields and animal husbandry business. Due to irrigation with fluoridated
water in agriculture, the yield letter is low due to which the tribals do not get the economic
benefits they should get from agriculture. On the other hand tribal people also suffer
economic losses due to reduced in milk yield in domesticated animals exposing with dietary
fluoride, fluoridated water and industrial F pollution. Whatever the case, F poisoning
adversely affects both agricultural production and animal husbandry, further weakening the
economic condition of the tribal people. In the absence of research studies, it is difficult to
say how much economic loss is caused to the tribals due to F poisoning or fluorosis.
Therefore, more scientific research studies are absolutely needed to know this. This will be a new field of F research.

**Prevention and control of chronic F intoxication in the scheduled area**

Fluorosis in the scheduled area of Rajasthan is not only adversely affecting the health of the tribal people and their economically important domestic animals but also affecting their economy or financial status. Relatively, tribal people are more sensitive, susceptible, and prone to fluorosis, hence these financially poor people of this area are severely afflicted with osteo-dental fluorosis. Once F induced deformities appeared in bone and teeth they are never reversible and even untreatable. But, chronic F intoxication or fluorosis in tribal people could be checked or controlled by adopting and implementation the following possible and recommended ways: (a) regular supplying or providing of F free treated drinking water, (b) checking the entry of F in the body through any sources or food items such as wine, tea and rock salt, and tobacco and betel nut containing items, (c) providing nutritious foods containing ample amount of calcium and vitamin C nutrients and antioxidants, and (d) awakening in tribal people with the help of well trained students and teachers towards preventive measures of chronic F poisoning. Recently, diverse ways for the prevention and control of chronic F poisoning humans are well stated and also briefly and critically reviewed.\(^{100}\)

It is possible, at both community and domestic levels for the regular supply and availability of F free drinking water in tribal scheduled area by adopting a defluoridation technique. Though, several defluoridation techniques are available. However, the Nalgonda defluoridation technique is an ideal as it is simple, effective, and low-cost \(^{101}\) which can be used. Although, this technique is affordable and gives good results but its success rate at the community level in tribal areas or villages is poor. At many places in several villages of scheduled area of Rajasthan, this technique is totally failure at the community level due to lack of public participation, a lack of responsibility for its supervision, and a lack of proper monitoring and maintenance. Instead of defluoridation technique, the harvesting and conserving of rainwater is a better option for regular obtaining low F or F free water. In scheduled area, some perennial large freshwater sources or reservoirs are also available which are mostly free from F contamination.\(^{34, 35}\) Water of these sources can be used to regular supply to tribal people after proper treatment. In this backward and undeveloped area, tribal people are not health conscious and unaware about the health education and chronic F
poisoning. Therefore, there is an urgent need to conduct public awareness campaign on a large scale to prevent fluorosis in this area, so that not only the tribals but also their domestic animals can be saved from this water-borne dangerous disease.

Conclusions

In the state of Rajasthan (India), the maximum tribal populations, >70% are living in the most backward and under developed area known as “scheduled area” where several communicable and non-communicable diseases are still prevalent and endemic. Recently, a water-born fluorosis disease is also emerged out in this area due to chronic F exposure through fluoridated drinking groundwater and industrial F pollution and creating a health problem. Thousands of tribal people of all age groups of this area are suffering with this dreaded fluorosis disease. Due to this endemic disease, besides the dental deformities, tribal individuals are also severely afflicted with skeletal deformities; crippling, banding of waist, curvature of the extremities and neurological complications. These people are also suffering with F induced health complaints; gastrointestinal discomforts, frequent urination, sterility, low IQ in children, repeated abortion, still birth, etc. Disability or crippling deformity is the worst condition of chronic F poisoning. Fluorosis is not only affecting the tribal health but also affecting their economy in different ways. Tribal people are more vulnerable and have less tolerance to F poisoning due to their poor nutrition status. To overcome this F health burden in tribal population, regular providing of F free drinking water, improving the quality of food and generating the general awareness are highly suggestive. However, to control the fluorosis and other endemic diseases and for the better healthy life of tribal individuals of the most backward and underdeveloped scheduled area of Rajasthan, the commencement of well health plan is still needed.

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References


Table 1. Severity of dental and skeletal fluorosis in subjects belonging to different populations inhabiting scheduled area of Rajasthan, India (Source: Choubisa et al. 2007)

<table>
<thead>
<tr>
<th>Population</th>
<th>Dental fluorosis (DF)</th>
<th>Skeletal fluorosis (SF)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DF +ve subjects</td>
<td>Questionable</td>
</tr>
<tr>
<td>ST</td>
<td>7534/10886 (69.0)</td>
<td>951 (12.6)</td>
</tr>
<tr>
<td>SC</td>
<td>1546/2700 (37.2)</td>
<td>213 (13.7)</td>
</tr>
<tr>
<td>GC</td>
<td>1944/5035 (38.6)</td>
<td>285 (14.6)</td>
</tr>
<tr>
<td>Total</td>
<td>11004/186621 (59.0)</td>
<td>1449 (13.1)</td>
</tr>
</tbody>
</table>

Figures in parentheses indicate percentage
ST, Scheduled tribe; SC, Scheduled castes; GC, General castes
Groups between prevalence of
(a). Dental fluorosis and severe dental fluorosis r = + 1 (highly positive)
(b). Skeletal fluorosis and grade III skeletal fluorosis r = + 1 (highly positive)
Figure 1. Map showing scheduled area of Rajasthan (as per notification of Government of India, 2018).
Figure 2. Map showing F distribution in eight districts of scheduled area of Rajasthan (India).
Figures 3-6. Polymorphism and severity of dental fluorosis in tribal individuals. Children showing pitting or patches fine dots and bilateral stratified deep brownish yellow streaks on teeth (Figures 3 and 4). Excessive abrasions of enamel and exposure of cementum and dentine material with deep-brownish.
Figures 7-12. Fluoride induced radiological changes (periosteal exostosis, osteosclerosis, osteoporosis and osteophytosis) in cervical spines (Figure 7), bony cage with radiolucent lungs and clavicular involvement (Figure 8), radius-ulna (Figure 9), tibia fibula (Figure 10), vertebral column or dorsal spines (Figure 11) and pelvis bones (Figure12). Calcification of interosseous membrane (arrow) between radius and ulna bones and ligaments and tendons are also appearing.
Figures 13-17. Tribal individuals suffering with severe skeletal fluorosis having various bone deformities such as kyphosis, invalidism, genu-varum (outward bowing of legs at the knee), genu-valgum (inward bowing of legs at the knee), crossing or scissor-shaped legs and crippling with paraplegia and quadriplegia
Figure 18. Prevalence of fluorosis in different scheduled tribe (ST), scheduled caste (SC), and general caste (GC) populations or ethnic groups of scheduled area of Rajasthan, India. (Source: Choubisa et al. 2007)

Figure 19. Prevalence (%) of sickle cell haemoglobin (Hb-S), β-thalassaemia trait, and G^d^ genes in subjects belonging to scheduled tribe (S.T.), scheduled caste (SC) other backward caste (OBC), and general caste (GC) populations of desert and humid environments.