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GENERAL ARTICLE

WATER QUALITY IN THE DRY ZONE OF SRI LANKA - SOME INTERESTING HEALTH ASPECTS

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Abstract: Dental fluorosis and kidney diseases are commonly observed in many parts of the dry zone of Sri Lanka, notably in the North Central Province. Chronic Renal failure (CRF) has recently shown a marked increase in some areas in the Anuradhapura and Polonnaruwa districts. Geochemically, the groundwater in these areas is generally of the Na/K type with the Cl^- sub-type predominating possibly due to the increasing drought conditions and salt build up. The Total Dissolved Solids (TDS) and the electrical conductivity are also correspondingly high. A unique feature of the dry zone is that in a large number of areas, the fluoride levels in the groundwater are higher than the recommended danger levels of the World Health Organization (WHO), and in some wells values as high as 10 mg/l F^- have been recorded. The WHO stipulates that a F^- concentration of 1.5 mg/l is the upper limit. The abundance of fluoride in the groundwater and the higher intake of water have resulted in dental fluorosis being largely prevalent in children. It is also presumed that skeletal fluorosis is more common than hitherto believed.

Though the incidence of CRF is increasing, the exact cause of the disease is not known to any degree of certainty. Since the affected people are mostly from the farming community, the contamination of drinking water possibly by agrochemicals is considered a possibility. Among the other possibilities are: (a) the use of inferior quality aluminium vessels which may react with fluoride (b) genetic factors (c) alcohol consumption (d) deficiency of some essential trace nutrients (e) excess of a toxic trace element (f) some organic matter in the water.

The abundance of high fluoride in all areas and total dissolved solids in the groundwater, and the high saline nature of the water may well turn out to be a major factor in the incidence of CRF. Studies carried out on the health effects of excess fluoride in drinking water have indicated the detrimental effect it could have on the kidneys. However, this needs further investigations before any firm conclusions can be drawn.

INTRODUCTION

Sri Lanka has two marked climatic zones, the dry and the wet zones separated by an intermediate zone (Figure 1). Even though the geological formations do not differ significantly in the dry and wet zones, the degree of rock weathering and leaching out of certain elements in the wet zone in contrast to the dry zone where evaporation and accumulation of salts on the surface have resulted in differing hydrogeochemical characteristics. These features are illustrated in figure 2.

Approximately 75% of the population of Sri Lanka live in a rural environment with a close association with the immediate physical environment, obtaining their drinking water directly from the ground. The chemistry of the groundwater must therefore, have an important bearing on the health of the population.

It is the aim of this paper to highlight the importance of groundwater geochemistry in public health as exemplified by two case studies from the dry zone of Sri Lanka.

THE CHEMISTRY OF THE GROUNDWATER OF SRI LANKA

Dissanayake and Weerasooriya produced the first Hydrogeochemical Atlas of Sri Lanka.[2] They classified the groundwater of Sri Lanka into 4 main types (Figure 2).

1. calcium type
2. magnesium type
3. sodium/potassium type
4. non-dominant cation type

Each type was further sub-divided into Cl^-, SO_4^{2-}, HCO_3^- and the Non-Dominant Anion (NDA) types.

The calcium type of water is distributed mainly in the northern, central and in some parts of the southern, eastern and north central regions. The Cl^- type predominates in the northern parts whereas the HCO_3^- type is prevalent in the central regions. Salinity and the presence of carbonate rocks influence the prevalence of these two types of water.

The magnesium type is distributed in relatively smaller areas in the southern parts notably around the Embilipitiya Region. The sodium/potassium type is distributed widely in Sri Lanka, very significantly in the northwestern , north central, eastern provinces and parts of the southeastern dry zone . It has been observed that the Cl^- type predominates in these regions probably due to the effect of salinity caused by excessive evaporation and salt accumulation.

The Non-dominant cation type of water is distributed mainly at the periphery of the central highlands and in some parts of the north central and southern regions, the HCO_3^- and NDA sub-types being more prevalent.

It is clear from the above description that the Na/K type of water is markedly present in the dry zone of Sri Lanka. Evaporation under strong conditions of drought brings about an accumulation of salts in the upper soil layers and this factor is largely responsible for the abundance of Na/K type water in the dry Zone of Sri Lanka.[2] Further, the Total Dissolved Solids (TDS) in the groundwater in these parts are also high, on account of the higher soluble contents of the water.

THE FLUORIDE PROBLEM IN THE DRY ZONE OF SRI LANKA

One of the most interesting aspects of the groundwater chemistry in the dry zone of Sri Lanka, is the discovery of high concentrations of fluoride in both dug wells and in deep wells.[3] (Figures 3 and 4). Fluoride, though considered an essential ion in human health, becomes toxic when ingested in excessive doses (Table 1). It should however be mentioned that the WHO recommended danger level of 1.5 mg/l is not suitable for Sri Lanka. Being a country located in the humid tropical zone, the water consumed per individual is much higher than that in the

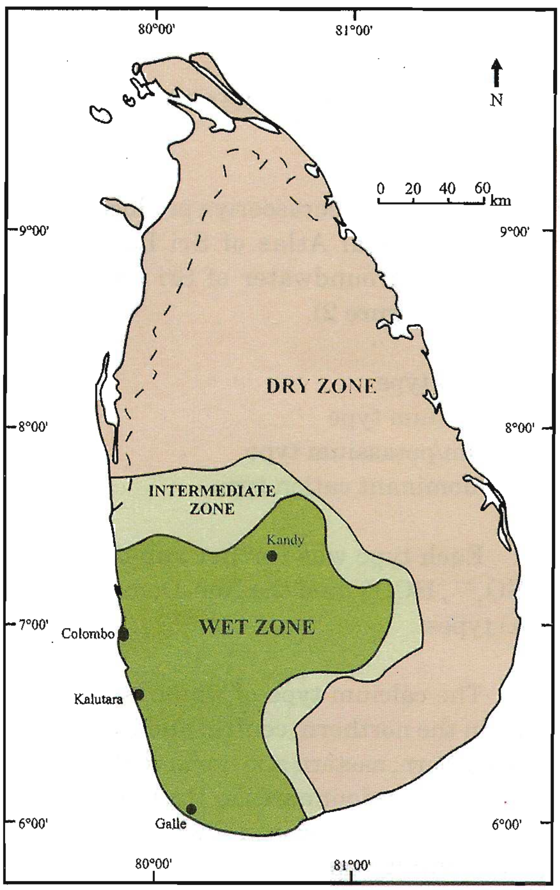

Figure 1: The climatic zones of Sri Lanka.

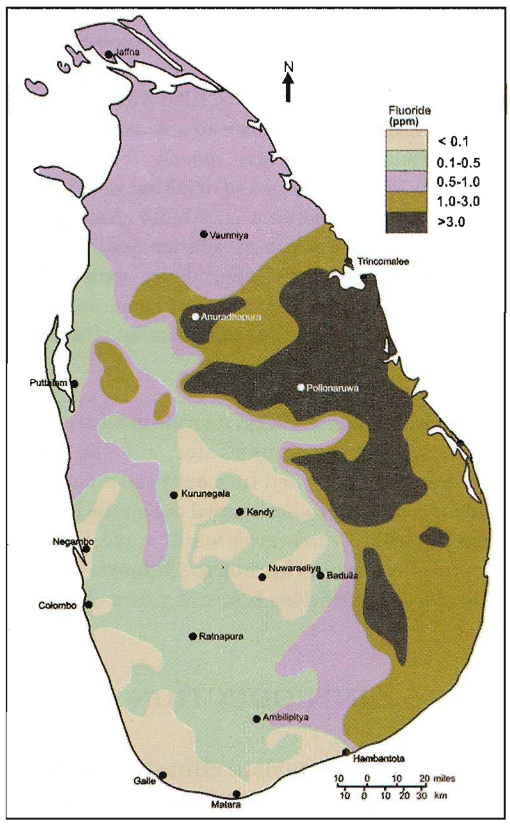

Figure 2: The geochemical classification of the groundwater of Sri Lanka (Dissanayake and Weerasooriya, 1985).

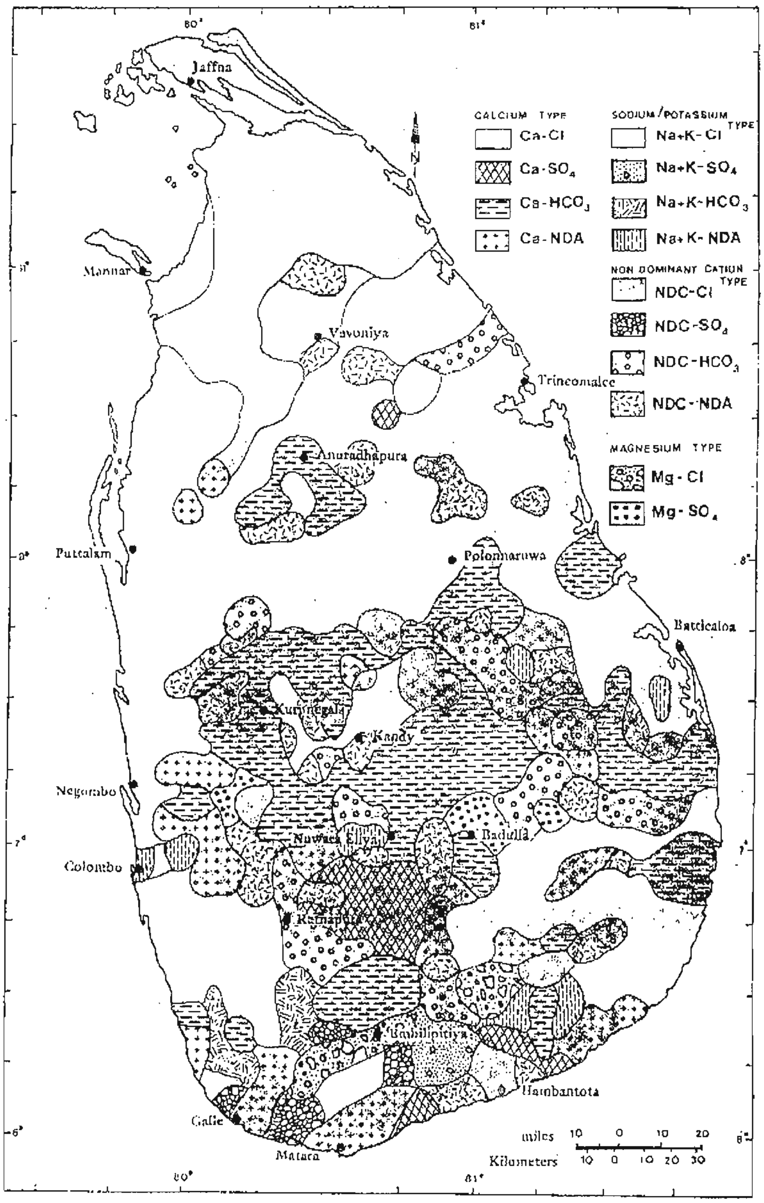

Figure 3: The distribution of fluoride concentrations in the groundwater of Sri Lanka as obtained from dug wells.(Dissanayake and Weerasooriya, 1985)

more temperate lands. Even with a low-fluoride in water, dental fluorosis was still common in some parts of the dry zone. Considering the rather high fluoride levels in the dry zone in Sri Lanka, and also the population exposed to this danger, over a million people, mostly children, are at risk from dental and skeletal fluorosis . Since the "optimum range" of fluoride varies within a narrow range, there is indeed a real risk of dental fluorosis assuming epidemic proportions. The North Central Province in particular, is highly vulnerable to such a risk, as observed by the very high incidence of dental fluorosis in the Anuradhapura, Polonnaruwa, Medawachchiya areas among many others. Fluoride values reaching as much as 10 mg/l have been reported in some of these areas.

Geochemically, the F^- ion (radius 1.36 A) is similar to that of the OH^- ion (radius 1.40 A) and this facilitates an easy exchange between them . Some fluorides therefore, tend to enter the aqueous phase easily. Previously, 2230 water samples from the Vedavati river catchment in a drought-prone hard rock area in Peninsular India were studied for their fluoride and other major constituents. Carbonate concretions are typical of arid and semi-arid regions and the leaching out of fluoride from these are controlled by (a) pH of the draining solutions, (b) alkalinity (c) dissolved CO_2 and the pCO_2 in the soil. Figure 5 illustrates the mechanism of fluoride migration in such dry terrains such as those in the more northerly regions of Sri Lanka .The geochemical pathways of fluoride is strongly influenced by processes involving absorption-desorption and dissolution-precipitation reactions. It is important to realise therefore that the degree of weathering and the amount of leachable fluoride in a terrain is of greater significance in the fluoride concentration of water than the mere presence of fluoride-bearing minerals in soils and rocks. The "soil-water" and the "rock-water" interactions and the residence time of fluoride are two important factors in the concentration of fluoride in water. The geochemical environment of surface dug wells and those in the deeper bore holes are different. Whereas the shallow dug wells tend to have lower concentrations due to leaching and rapid groundwater circulation and lower residence times, the "water-rock interaction" in the deep bore holes is enhanced by longer residence times. It is therefore common to observe higher fluoride concentrations in water obtained from deep wells. However, it should be mentioned that not all deep wells are rich in fluorides. Some dug wells do have higher concentrations of fluoride as compared to the deep wells.

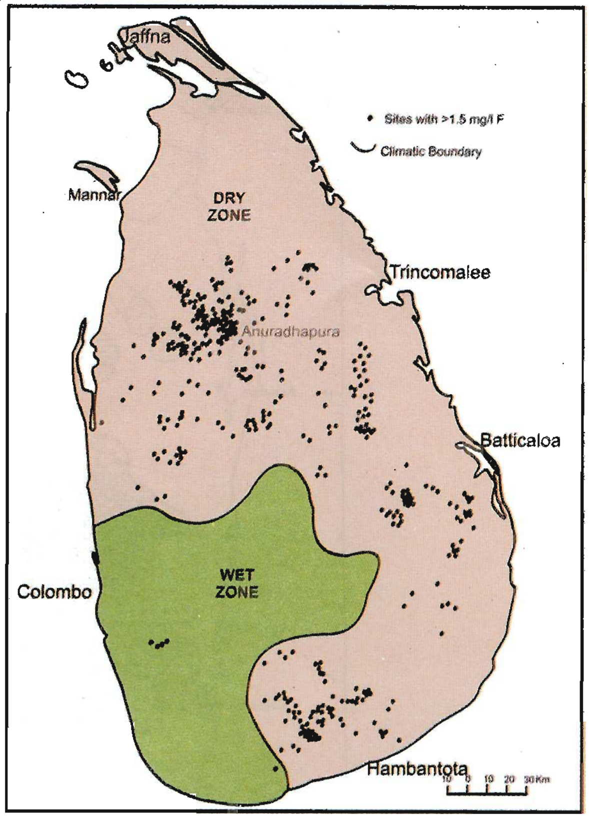

Figure 4: Distribution of fluoride in the deep wells of Sri Lanka (Dissanayake, 1991)

Table 1: Impact of fluoride on health

Concentration of fluoride	Impact on health
Nil	Limited growth and fertility
0.0 – 0.5 mg/l	Dental caries
0.5 – 1.5 mg/l	Promotes dental health resulting in healthy teeth; prevents tooth decay
1.5 – 4.0 mg/l	Dental fluorosis (mottling of teeth)
4.0 – 10.0 mg/l	Dental fluorosis, skeletal fluorosis (pain in the back and neck bones)
> 10.0 mg/l	Crippling fluorosis

Source : WHO (1971)

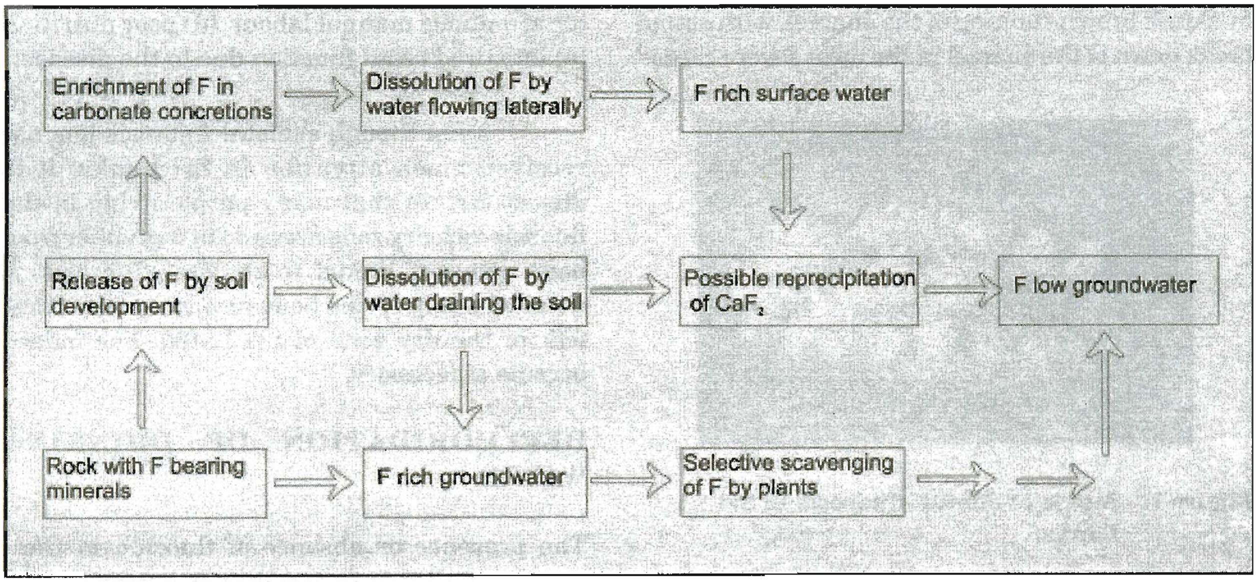

Figure 5: Mechanism of fluoride migration in arid and semi-arid areas (Ramesam an Rajagopalan, 1985).

DENTAL FLUOROSIS

The outermost layer of the exposed tooth is a hard, thin, translucent layer that envelopes and protects dentin, the main portion of the tooth structure (Figure 6). Enamel, dentin and cementum are all composite materials composed of the mineral hydroxyapatite (HA), protein and water. Enamel is the hardest substance found in the human body and has ~ 90% mineral , 1% organic matter and 3 % water. On account of its hardness, it is also brittle. Enamel has the carbonate-rich apatite arranged in rods or prisms 4-5 um in diameter. These are held together by a cementing substance and surrounded by an enamel sheath. The rods that make up enamel are formed by cells known as ameloblasts.

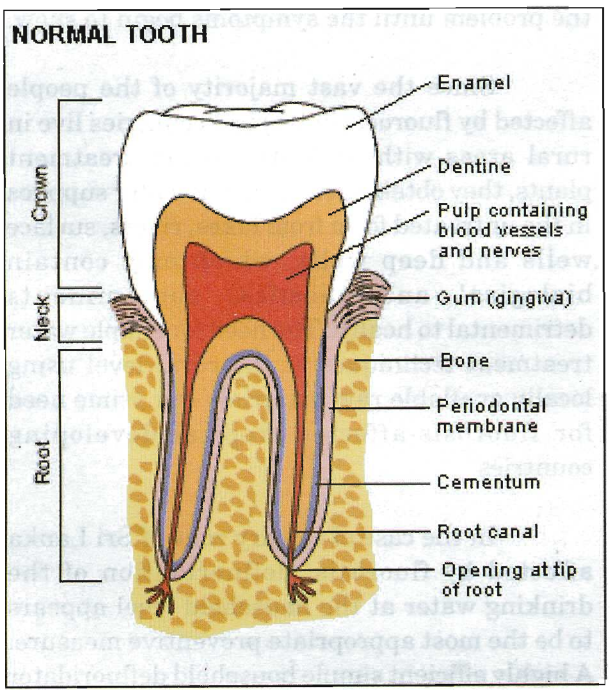

Figure 6: Structure of a normal tooth.

The mineral apatite $Ca_5(PO_4)_3(OH,F,Cl)$ has varying amounts of fluorine, chlorine or the hydroxyl group, though in some cases one of these may approach the 100% level, and according to the major presence of F^-, Cl^-, or OH^-, they are termed fluorapatite, chlorapatite and hydroxyapatite respectively.

When fluoride is present in the water ingested, some of it is incorporated into the apatite crystal lattice of the tooth enamel during its formative stages, the enamel becomes harder and discoloration results (Figure 7). Clinically the appearance of enamel fluorosis is known to vary with the amount of fluoride ingested during early childhood, appearing in its mildest forms as a white flecking of the enamel coalescing to become more visible in its moderate forms and marked by a dark brown staining of the enamel, with actual break down of the enamel in the most severe cases.[1]

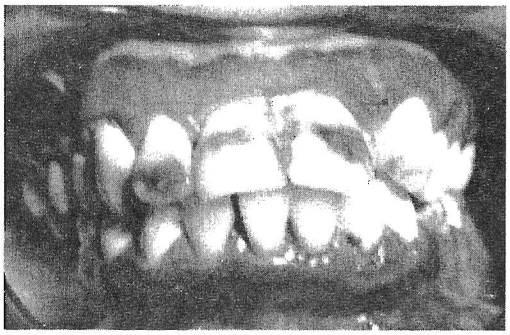

Figure 7: A case of dental fluorosis in Sri Lanka.

The high incidence of dental fluorosis in the dry zone of Sri Lanka has its inherent sociological problems. Since it is the school - going children in the low income rural areas of the dry zone who are most affected, one often comes across deep psychological instabilities which affect their studies. There are even cases where children have used sand paper in an attempt to get rid of the unsightly stains of the teeth. It is of interest to note that from among a total of 518, 14-year old students in Uda Walawe, 43.2% had dental fluorosis.[10]

SKELETAL FLUOROSIS

If the levels of fluoride ingestion continue to rise, a serious debilitating disease which affects the bones (Figure 8),termed "skeletal fluorosis" results, which may even cause neurological complications. About 96-99% fluoride retained in the body combines with mineralized bones and when the ingestion is > 4 mg, 50% is retained by the skeleton and the rest is excreted through urine. The skeletal fluoride concentration is known to increase almost proportionately to the amount of fluoride ingested and its duration.[9]

In endemic regions, crippling skeletal fluorosis occurs between the ages 30 to 50 years. It has been observed that new comers to a hyper endemic region may develop symptoms within years of their arrival.[8] The main factors which influence the development of skeletal fluorosis are: (a) high fluoride intake (b) continual exposure to fluoride (c) strenuous manual labour (d) poor nutrition (e) impaired renal function due to the disease.

Even though skeletal fluorosis has not received much attention in Sri Lanka, it is almost certain that many people living in the fluoride-rich dry zone areas do in fact suffer from bone diseases linked to skeletal fluorosis. A detailed study of the bone diseases of the rural folk in the dry zone of Sri Lanka has indeed become a necessity.

DEFLUORIDATION OF DRINKING WATER

The presence or absence of fluoride in their water supplies is generally not known by the public, particularly in developing countries where, in most cases, the drinking water is obtained direct from the ground. Unlike in the case of excessive dissolved iron in the dug and deep wells, where a colour and an objectionable taste is imparted, fluoride imparts neither colour nor taste. Only chemical analyses can detect its presence and the concentration. This is a major reason why such a high percentage of the population living in fluoride-rich areas and who are affected by fluorosis are not even aware of the problem until the symptoms begin to show.

Since the vast majority of the people affected by fluorosis in tropical countries live in rural areas without central water treatment plants, they obtain their domestic water supplies in the untreated form from lakes, rivers, surface wells and deep wells, which may contain biological and chemical contaminants detrimental to health. The need for simple water treatment techniques at the rural level using locally available raw materials is a prime need for fluorosis-affected tropical developing countries.

In the case of the dry zone of Sri Lanka affected by fluorosis, defluoridation of the drinking water at the household level appears to be the most appropriate preventive measure. A highly efficient simple household defluoridator using burnt bricks was employed in many areas with high fluorosis in Sri Lanka.[5] This defluoridator is suitable for developing countries and is especially suited on account of its easy installation, maintenance, low cost and ready availability of the defluoridating raw material used, i.e. burnt bricks, thus achieving Village Level Operation and Maintenance (VLOM) status.

CHRONIC RENAL FAILURE (CRF) IN THE NORTH CENTRAL PROVINCE

It has been observed that there is a marked increase in chronic renal failure among people in the North Central Province, notably in the Medawachchiya AGA Division (Anuradhapura District). During the period January 2001 to December 2002, this area recorded the highest number of renal patients, as shown by the records at the General Hospital, Anuradhapura. It is now known that CRF is markedly increasing in other areas such as Polonnaruwa, Padaviya, Girandurukotte, and Ampara. It is very likely that there are other villages in the dry zone with increasing numbers of CRF patients. The faculties of Medicine and Science of the University of Peradeniya, the Renal Unit of the General (Teaching) Hospital, Kandy, Provincial Ministry of Health, North Central Province (NCP) are presently carrying out a study on the causes of the CRF in the affected areas.

The rate at which people succumb to CRF has caused great concern in the medical circles. The Polonnaruwa General Hospital records that 20% of the deaths at the hospital are due to CRF and is the leading cause of death at Polonnaruwa. In the Kandy Nephrology Unit, 35-40% of the kidney patients are from the NCP. As reported, the disease affects mostly men in the 21-82 group with the average age between 30-50 years.[4] While 95% of the patients are farmers, the male –female ratio of those affected by CRF is 5:2.

Up to now however, there is no definite conclusion as to the cause of the CRF. Drinking water quality has an obvious effect and it has been observed that CRF is prevalent among people who use surface dug wells, agrowells, and deep bore wells for their drinking water supplies. However, those using shallower dug wells appear to be affected more than the others.

Being mostly farmers, the use of agrochemicals has also been considered as a possible cause. There are also suggestions that the poor quality aluminium vessels used to collect and store drinking water are a contributory factor, bearing in mind that aluminium is a toxic element when ingested in higher concentrations. Other factors such as genetic causes, food, alcohol, etc., are also being considered. One major factor that is worthy of detailed investigation is the high fluoride contents in the groundwater of the affected areas. The majority of these wells have fluoride concentrations of 0.7 mg/l or more and this is considered sufficient to cause damage to the kidneys, particularly when there is continuous ingestion of fluoride. It is known that kidneys are among the most sensitive body organs in their histopathological and functional responses to excessive amounts of fluoride.[7]

It may also be possible that fluoride combines with another element such as sodium, also found in high concentrations in the water. Sodium fluoride has significant toxic effects on the kidneys and in fact it is even used as a rat poison.

Among the features that are worthy of note are :

1. All areas affected by CRF are located in the dry zone .
2. The water tends to be more saline with high electrical conductivity, indicative of an abundance of electrolytes.
3. The fluoride concentrations of the groundwater are markedly high.
4. The dry zone soils , due to the effect of drought and evaporation, tend to accumulate salts in the soils which then pass into the groundwater.
5. The prevalence of dental and possibly skeletal fluorosis in the affected areas.

The continuous ingestion of fluoride-rich, salt-rich water could well affect the kidneys resulting in CRF. However, it is very clear that more detailed investigations, both geological and medical, are necessary to unravel the cause of the CRF in the dry zone of Sri Lanka.

CONCLUSION

Geochemically , the dry zone of Sri Lanka has some unique features. The marked drought conditions alternating with seasonal rainfall and excessive evaporation cause salts to accumulate in the surface soil layers. The groundwater in the dry zone of Sri Lanka is therefore markedly of the Na/K type and with high contents of total dissolved solids. Further, the fluoride concentrations in the groundwater is generally high (reaching nearly 10 mg/l in some cases). These geochemical features have a major impact on the health of the population of the dry zone, bearing in mind that the majority of them obtain their drinking water direct from the groundwater through surface and deep wells. On account of the high fluoride concentrations in the water, dental fluorosis is common among children and over a million people are at risk. In areas where fluoride ingestion is even higher, skeletal fluorosis is a distinct possibility. Chronic renal failure, now causing serious concern in the NCP can also be attributed to the quality of the groundwater from which drinking water is obtained. Even though the cause of CRF is still uncertain, excess fluorides and salts in the groundwater may well turn out to be contributory factors.

Acknowledgement

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