Environmental Management and Health

Fluoride Problems in Sri Lanka

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Tube well water is a problem in Sri Lankan districts with high groundwater fluoride.

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Introduction

Construction of tube wells with hand pumps in rural community water supply programmes in Sri Lanka has drastically increased since the beginning of the last decade. At present, there are over 13,000 tube wells with hand pumps on the island, mostly in the dry zone. With the increasing number of tube wells, the problems of the quality of tube well water have also become more significant.

One of the main water quality problems is the high fluoride content in groundwater, especially in low lying areas of the dry zone.

Although rural water supply projects based on tube wells have provided safe drinking water to the rural community, in the areas with fluoride-rich groundwater these projects have been of limited benefit to the people because of the unsolved fluoride problem. Excess fluorides in drinking water have resulted in severe tooth mottling or dental fluorosis[1].

The tube well rehabilitation programme has been able to provide solutions in many parts of the country for some water quality problems such as high iron. However, it has not been possible in Sri Lanka till now to rehabilitate or to find successful solutions to bring down the high fluoride levels in the groundwater of the tube wells.

In view of the dangerous health implications of high fluoride in water, it is high time the authorities paid more attention to the fluoride problem in tube wells and to work out rehabilitation methods to overcome the problem.

It is the aim of this article to discuss the fluoride problem in tube wells in Sri Lanka with special emphasis on the experience gathered during the implementation of rural water supply and sanitation projects in Matale and Polonnaruwa districts where 1,700 tube wells with hand pumps have been constructed in the rural areas during the last five-year period.

Fluoride Geochemistry and Its Impact on Human Health

Fluorine, being one of the most reactive elements, is associated with the many types of minerals in the earth's crust. Some of the common fluoride-bearing minerals are fluorite, cryolite and fluor apatite, among others. The chemistry of the fluoride (F^-) ion is very similar to that of the hydroxyl (OH^-) ion and therefore exchange between these two ions is very common in the natural environment.

Human teeth and bones are composed mainly of hydroxyl apatite. When fluoride is present, substitution of OH^- by F^- results in the replacement of hydroxyl apatite in teeth and bones by fluor apatite, which is the main cause of dental and skeletal fluorosis.

Drinking water is one of the principal sources of fluoride for the human body. Fluoride in surface and groundwater is mainly derived from the leaching of rocks and soils rich in fluoride-bearing minerals. This situation is particularly important in Sri Lanka where the vast majority of the population depend on groundwater, mainly from shallow dug wells and deep boreholes with hand pumps.

According to the World Health Organization (WHO) International Drinking Water Standards (Geneva, 1971) the impact of high fluoride on human health is given in Table I.

Geology and Water Supply Boreholes

Geologically, more than 90 per cent of the country consists of crystalline rocks of Precambrian age. Among these, charnockites, quartzites, marble, granites and a variety of gneisses are the major constituents. The abundant fluoride-bearing minerals in these rocks are mica, hornblende, apatite and, less frequently, fluorite, tourmaline and topaz.

Table I. *Impact of Fluoride on Health (After World Health Organization, Geneva, 1971, International Drinking Water Standards)*

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	Promoted dental health resulting in healthy teeth, prevents tooth decay
15.-4.0 mg/l	Dental fluorosis, skeletal fluorosis (pain in back and neck bones)
Greater than 10.0 mg/l	Crippling fluorosis

Groundwater in the crystalline rock terrain of Sri Lanka mainly occurs within:

(1) the weathered overburden of the basement rocks;

(2) basement rocks, the secondary porosity being due to fractures, joints, faults, fissures and solution cavities.

Due to the undulating ground surface and the presence of ridges and valleys, the country can be divided into a large number of separate basins and independent aquifers. However, fracturing and jointing of the basement rocks sometimes tend to interconnect the overburden and basement aquifers and also separate basins.

The water supply boreholes in crystalline terrains are drilled through the weathered overburden until a water-bearing fractured or jointed zone is encountered. The upper parts of the boreholes are cased in the weathered overburden up to the hard rock with PVC or other types of well casings. In areas with thick weathered overburden (more than 10 m), screens are used at the lower part of the overburden, if a sufficient amount of good quality water is found within the overburden. The average depth of boreholes in crystalline rock areas of Sri Lanka is about 50m.

High Fluoride in Groundwater in Sri Lanka

In the compilation of the Hydrogeological Atlas of Sri Lanka, Dissanayake and Weerasooriya[2] delineated the fluoride zones of Sri Lanka (see Figure 1) based on the fluoride content in dug well water samples. Higher fluoride concentrations were observed in groundwater in the north central and eastern regions of the country whereas the central and south western coastal regions had relatively low fluoride concentrations. Data collected by the National Water Supply and Drainage Board of Sri Lanka[3] based on water supply boreholes has also shown a similar distribution pattern. Out of the 1970 water samples collected, 400 contained fluoride greater than 1.5 mg/l. These results have highlighted the areas where there is high risk from fluorosis and associated health problems to the local community.

The levels of fluoride in groundwater in various districts of Sri Lanka correspond well with the incidence of dental caries and dental fluorosis. Dental health surveys conducted in three districts in the country[2,4] have correlated the fluoride level in groundwater and dental health of the population between seven and 20 years of age (see Table II). When comparing the fluoride-rich and fluoride-poor areas with climatic, geomorphological and geological factors prevailing in the country, low fluoride concentrations in groundwater are common in the wet zone where annual average rainfall in general exceeds 5,000 mm and high fluoride is common in the dry zone.

Physiographically, high fluoride zones lie within the low plains of the island whereas the low fluoride areas are mostly confined to the central highlands.

This situation, though possibly caused by many other factors, appears to be partially explained by the fact that, in the elevated wet zone areas with high rainfall, fluoride is leached from primary and secondary minerals in rocks and soils whereas, in the dry zone, evaporation tends to bring soluble ions upwards by capillary action. The slow rate of groundwater movement in the low plains also tends to increase the fluoride concentration because the contact time of groundwater with a particular geological formation is comparatively long.

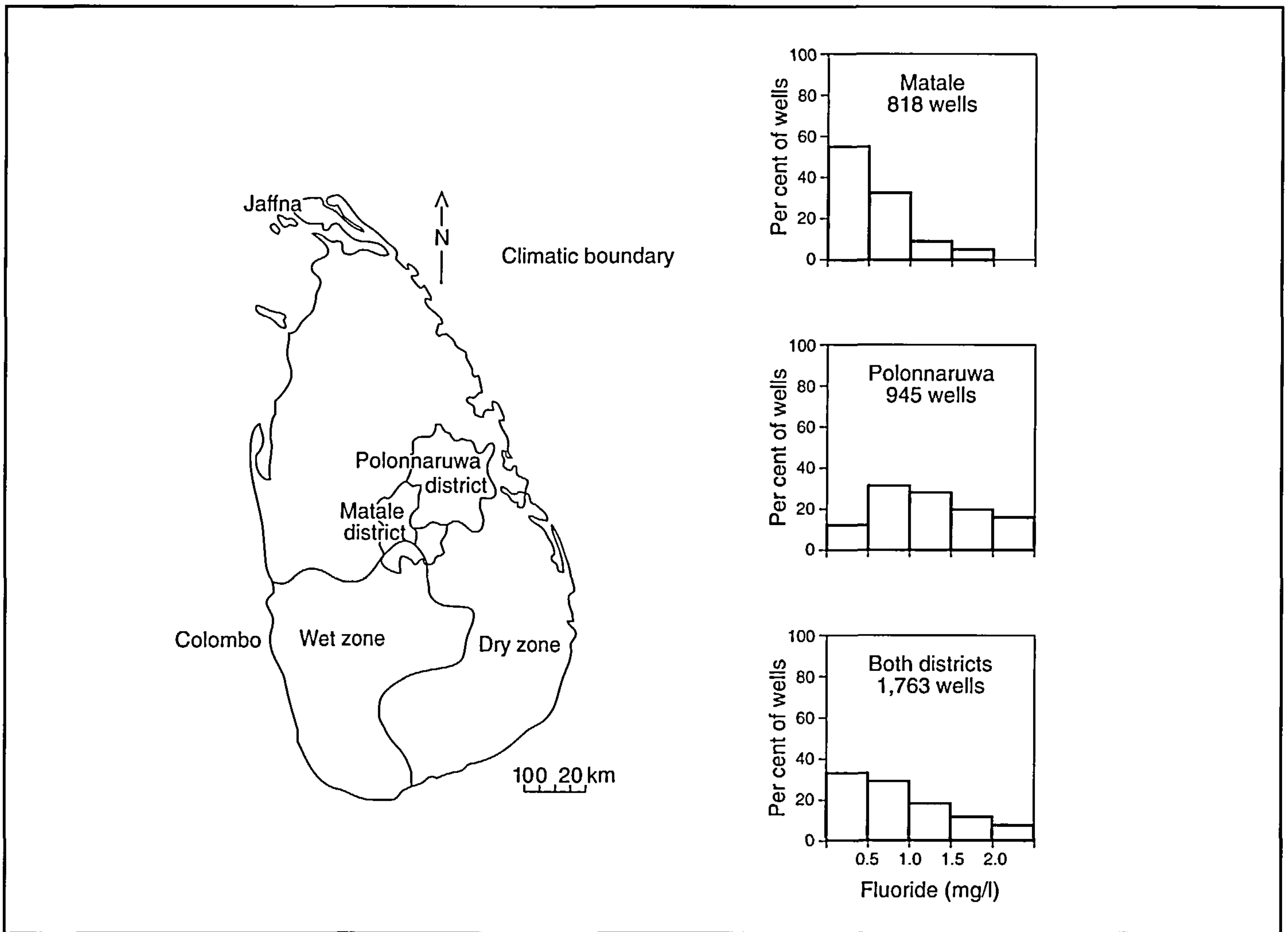
Geologically, high fluoride concentrations are observed in tube well water in association with rock types such as charnockites, hornblende-biotite gneiss, intrusive granites, granitic gneiss, granulites and calc gneiss, whereas low fluoride concentrations in tube wells have been observed in association with quartzite and marble[3,6].

Fluoride in the Matale and Polonnaruwa Districts

The Danish International Development Agency (DANIDA), through the Ministry of Local Government Housing and Construction of Sri Lanka, began implementing the Rural Water Supply and Sanitation Project in 1981 in the two districts of Matale and Polonnaruwa (see Figure 2). Under the water supply component of the project, 1,700 boreholes with hand pumps had been completed by the end of 1989.

The whole of Polonnaruwa district and about two-thirds of Matale district fall within the dry zone, and one-third

Figure 1. *Fluoride Zones in Sri Lanka*



of the area of Matale district (the southern part) falls in the wet zone.

Geologically, both districts consist of Precambrian crystalline rocks, mainly charnockites, quartzites, marble and varieties of gneisses.

Water samples collected from the boreholes indicate the levels of fluoride in groundwater in the two districts (see Figure 2). The frequency distribution of the fluoride content of the borehole water samples in the Polonnaruwa district shows a high variation, whereas a much smaller variation can be seen in the Matale district. Thirty-five per cent of the water samples in the Polonnaruwa district have fluoride contents greater than 1.5 mg/l and only 4 per cent of the samples in Matale district show fluoride above 1.5 mg/l. On the other hand, 10 per cent of the boreholes in the Polonnaruwa district and 55 per cent in Matale district have fluorides less then 0.5 mg/l. Matale and Polonnaruwa district possess similar geological conditions since the same lithological units run through both districts (see Figure 4). It is, therefore, likely that the difference is related to the different climatic conditions prevailing in the two districts. As indicated earlier, the entire Polonnaruwa district falls within the dry zone, whereas the southern part of Matale district extends into the wet zone.

Table II. *The Fluoride Concentration in Groundwater and Related Dental Health in Three Districts of Sri Lanka*

	Anuradhapura district (dry zone)	Polonnaruwa district (dry zone)	Kandy district (dry zone)
Dental fluorosis (%)	77.5	56.2	13.0
Dental caries (%)	26.2	26.5	95.9
Fluoride levels (ppm)	4.70-0.10	13.1-0.50	3.70-0.02

Source:[5]

Fluoride Content in Relation to Rock Types

Water samples collected from boreholes located on different rock types have also shown interesting results (see Figure 3). High fluoride concentrations were observed in boreholes located in charnockitic gneiss, calc gneiss, biotite gneiss and on granulite. No fluoride values above 1.5 mg/l have been observed in boreholes drilled in quartzite and no values above 2.0 mg/l in marble.

It is important to note that groundwater in crystalline terrains travels through fractures and other weak zones of the different rock types before it is tapped by a borehole located in a particular rock type. Therefore the chemical quality of groundwater does not completely represent the solution chemistry of minerals in the rock in which the borehole is drilled. Hence it could be assumed that the absence of or low fluoride concentration in groundwater trapped in some rock types could be due to some fluoride absorption property of those rocks[7]. Geologically, both Matale and Polonnaruwa districts possess almost similar geological conditions, and the same rocks extend from Matale to Polonnaruwa district (see Figure 4).

The wells located on the same rock type but in the two climatic zones (dry and wet) have also shown noteworthy resuts (see Figure 5). All tube well water samples except from quartzites have shown fluoride levels below 0.5 mg/l when located in the wet zone. In quartzite too, 93 per cent of the samples were in the same range with only 7 per cent showing values between 0.5 and 1.0 mg/l of fluoride. In the dry zone the values of fluoride concentration were in a wide range for all rock types with the exception of quartzite and marble.

It can therefore be assumed that, on the regional scale geomorphological and climatic formations are more important with respect to higher concentrations of fluoride in groundwater then the mere lithological composition of the area.

Geographic Distribution

The area-wise distribution of fluoride concentrations in groundwater on a regional scale appears to be well correlated

Figure 2. *Fluoride Content in Tube Wells of Matale and Polonnaruwa Districts*

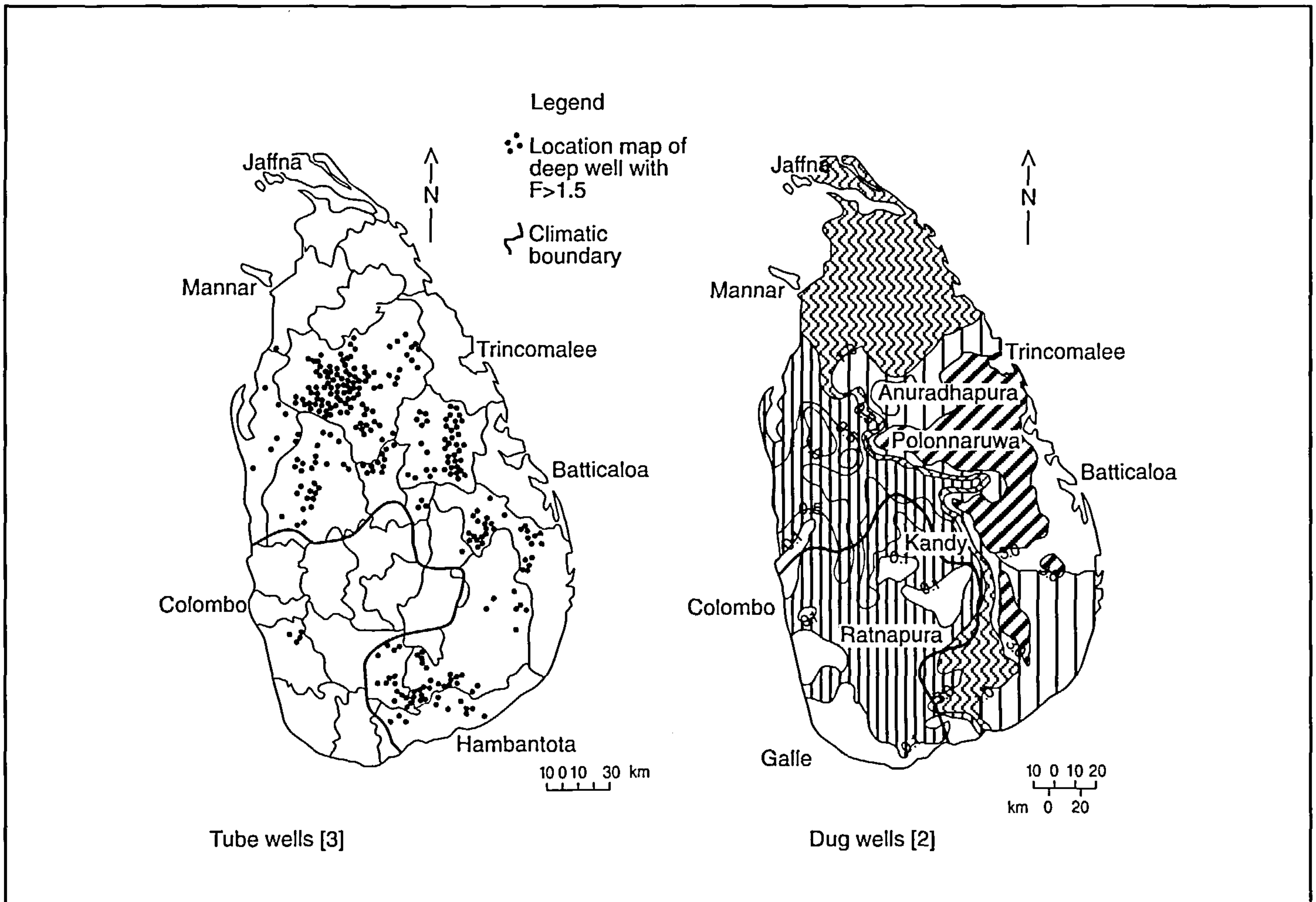


Figure 3. *Fluoride Content in Tube Wells on Different Rock Types*

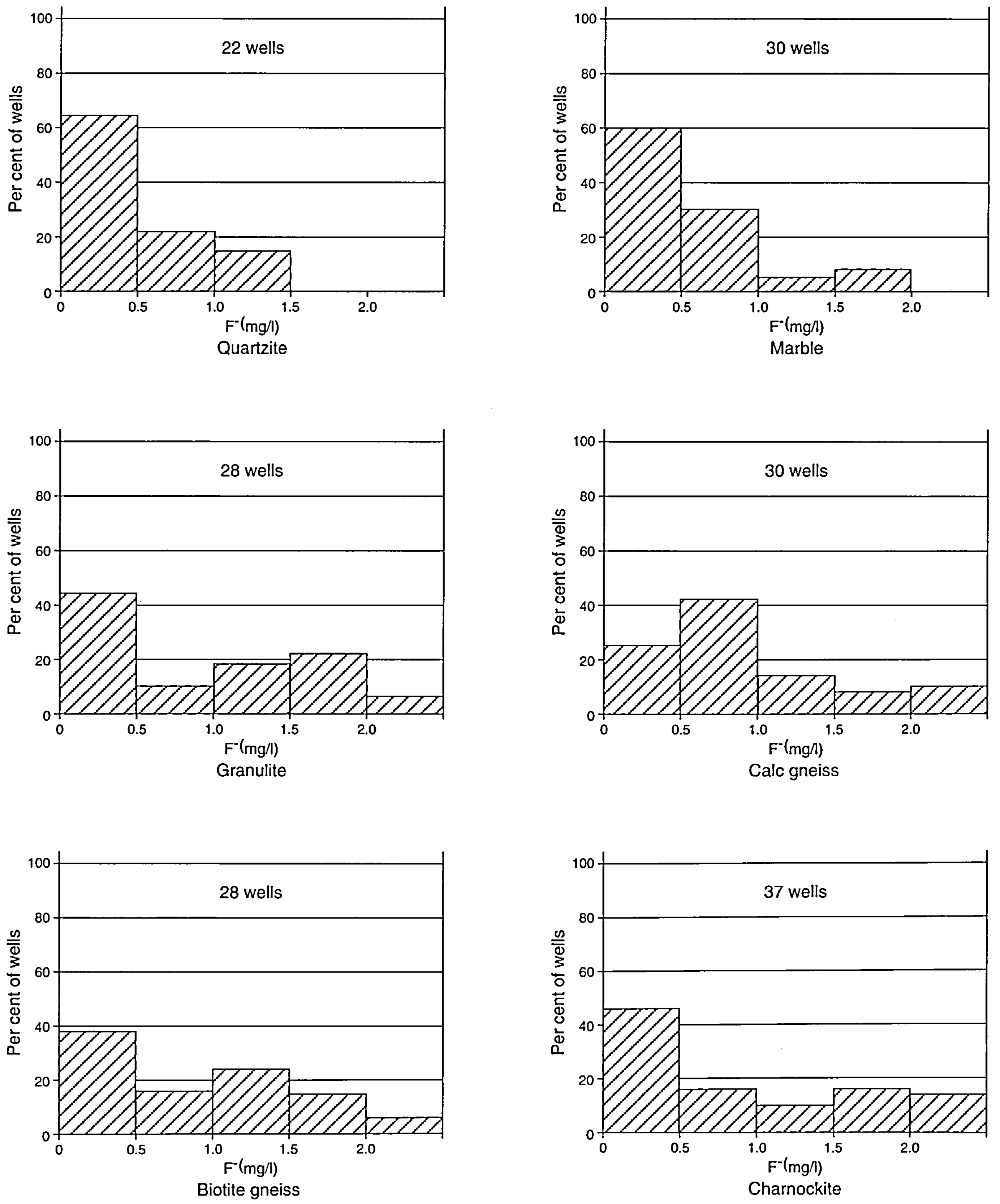


Figure 4. *Distribution of Rock Types in Matale and Polonnaruwa Districts*

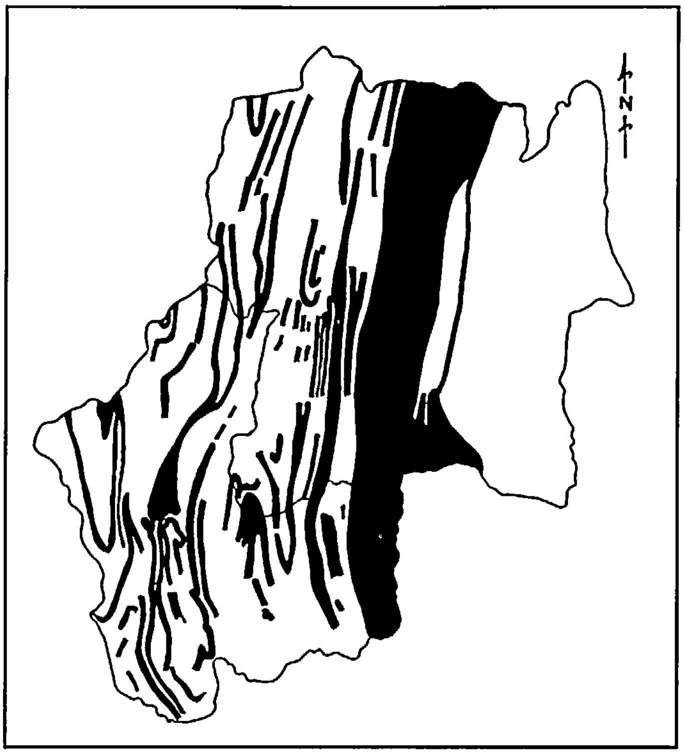
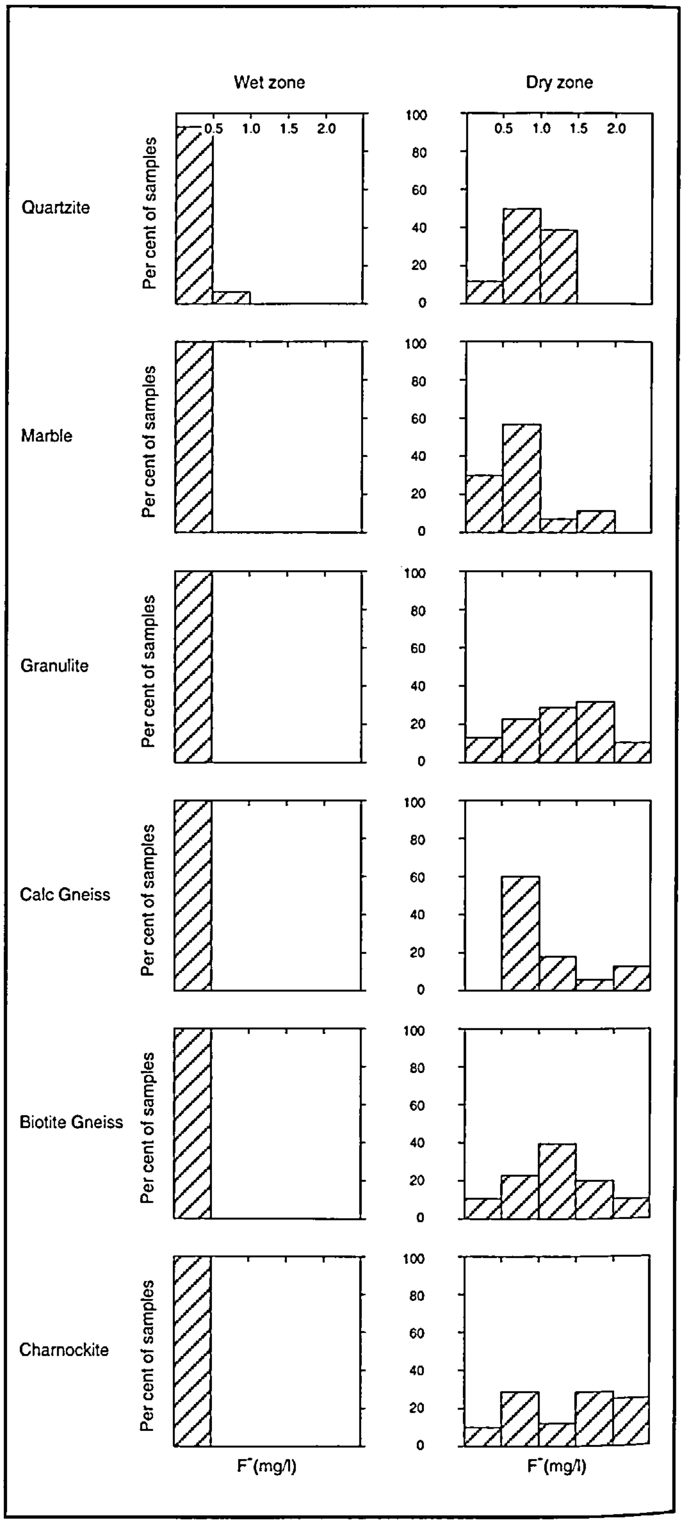


Figure 5. *Comparison of Fluoride Content in Groundwater from Different Rock Types Under Dry and Wet Zone Conditions*



with the climatic and geomorphological and drainage factors of the two districts. The fluoride content is generally low in the southern wet and elevated part, whereas comparatively high values are common in the northern and north-eastern dry plains. It has also been observed that the fluoride contents in groundwater gradually increase when moving away from the regional drainage divide of the area running NE-SW (see Figure 6). When considering the surface water flow pattern and the topography of the area, it can be expected that the groundwater flow also generally follows the same direction as the surface water flow. This situation possibly causes the increase of fluoride content away from the drainage divide in the direction groundwater flow and therefore for the present geographic distribution of fluoride concentrations.

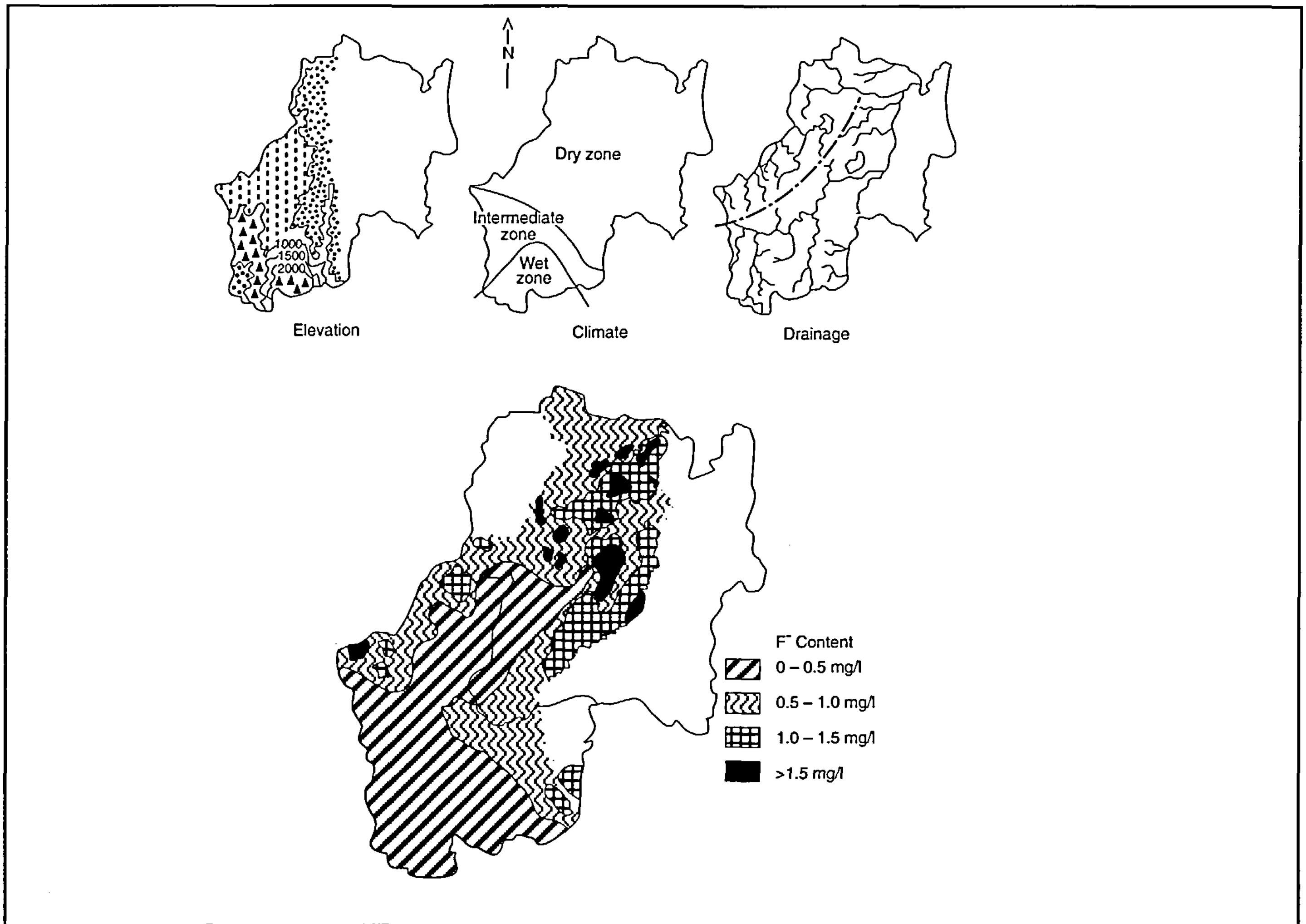
Aquifer Permeability and Fluoride Content

The yield of wells is an indication of the permeability of the formation on which the wells are located. The higher the yield of the wells, the higher the permeabilities of the geological formations.

The average yields of 170 randomly selected wells with different fluoride content were compared (see Figure 7). It was observed that there is an inverse relationship with the average yield of the tube wells and the fluoride content of the water, higher fluoride contents being common in the wells with low average yields.

This may be explained by the fact that the contact time of water with mineral constituents is comparatively greater in aquifers with low permeability enabling more fluorides to come into the solution from such aquifers.

Figure 6. *Geographic Distribution of Fluoride in Groundwater: A Comparison with Geomorphology, Climate and Surface Drainage*



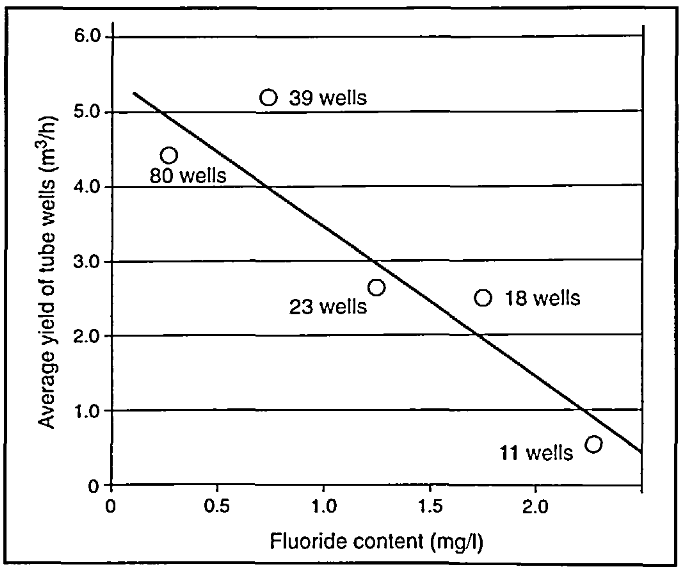
Conclusions

High fluoride concentrations in groundwater are one of the main water quality problems facing rural water supply projects dependent on groundwater, especially in the dry zone areas of Sri Lanka.

The prevalence of dental fluorosis in the country shows a direct correlation with the fluoride content in the groundwater of the areas concerned.

Although the sources for fluoride in groundwater are the different minerals of the geological formations, the climatic, geomorphological and drainage factors appear to play a major role in the occurrence and distribution of fluorides on a regional scale.

Figure 7. *Variation of Fluoride in Groundwater with Aquifer Permeability*



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Further Reading

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