Iodine in the environment and endemic goitre in Sri Lanka

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Abstract: The prevalence of endemic goitre is extremely high in certain parts of Sri Lanka where rates as high as 44% have been observed. With nearly 10 million people at risk the aetiology of endemic goitre in Sri Lanka needs to be clearly ascertained. The endemic goitre belt of Sri Lanka coincides with the wet climatic zone, indicating an apparent relationship of iodine geochemistry with climatic factors. However, the fact that there is a correlation of only –0.64 between the iodine content and the prevalence of goitre suggests the existence of other factors such as humic substances in the soil, clay minerals and soil pH that exert an influence on the bioavailability of iodine.

Iodization of salt used in food is the most convenient method of goitre prevention.

It has been estimated that out of a population of 17 million in Sri Lanka, nearly 10 million people are at risk of goitre (Fernando *et al.* 1987). The association between iodine and goitre was one of the earliest demonstrated links between a trace element in the environment and human health and nutrition. However, there is still very little information on the geochemistry of iodine and its effect on the prevalence of endemic goitre in Sri Lanka. The few studies carried out (Mahadeva & Shanmuganathan 1967; Weerasekera *et al.* 1985; Chandrajith 1987; Fernando *et al.* 1987, 1989; Balasuriya *et al.* 1992; Dissanayake & Chandrajith 1993) have shown that the endemic goitre belt of Sri Lanka lies in the wet climatic zone and that the climate has a marked influence on the geochemical distribution of iodine in the environment.

Geochemistry of iodine

Iodine with a large univalent anion does not usually enter crystal lattices of minerals on account of its large size. Ionic substitution of iodine is therefore unlikely and its geochemistry is mainly governed by the surface chemistry of geological materials. Fuge & Johnson (1986) in a review of the geochemistry of iodine have noted that iodine is particularly concentrated in the biosphere with strong affinities for organic matter. The easy transfer of iodine to the atmosphere and the mechanical and chemical removal from soil by groundwater tend to deplete soil of iodine. The geochemical cycle of iodine in the soil is critically important in the geographical distribution of goitre.

Levels of iodine in soil and water in Sri Lanka

Due to errors in analytical procedures, accurate data on iodine in soils and water are lacking. The earlier surveys used tedious colorimetric methods. Balasuriya *et al.* (1992) studied 609 samples of drinking water collected from scattered sources of the eight districts of Kandy, Matale, Kalutara, Anuradhapura, Polonnaruwa, Colombo, Puttalam and Gampaha using the Orion electrode method of analysis. Figure 1 illustrates the locations of these districts and the endemic goitre region of Sri Lanka as known at present. Table 1 shows the data obtained by them for iodine in water. It is seen that the Anuradhapura and Polonnaruwa Districts had higher water iodine levels while the Gampaha and Kalutara Districts had the lowest levels. It was also noted that tube wells had in general more iodine than dug wells.

Table 1. *Mean and median concentrations of water iodide by district (after Balasuriya* et al. *1992)*

District	Mean $\mu g\, l^{-1}$	Median $\mu g\, l^{-1}$
Kandy	30.96	19.1
Matale	16.91	11.1
Kalutara	15.50	12.2
Anuradhapura	119.03	101.6
Polonnaruwa	47.21	33.0
Colombo	16.86	11.4
Puttalam	34.68	21.6
Gampaha	11.90	5.0

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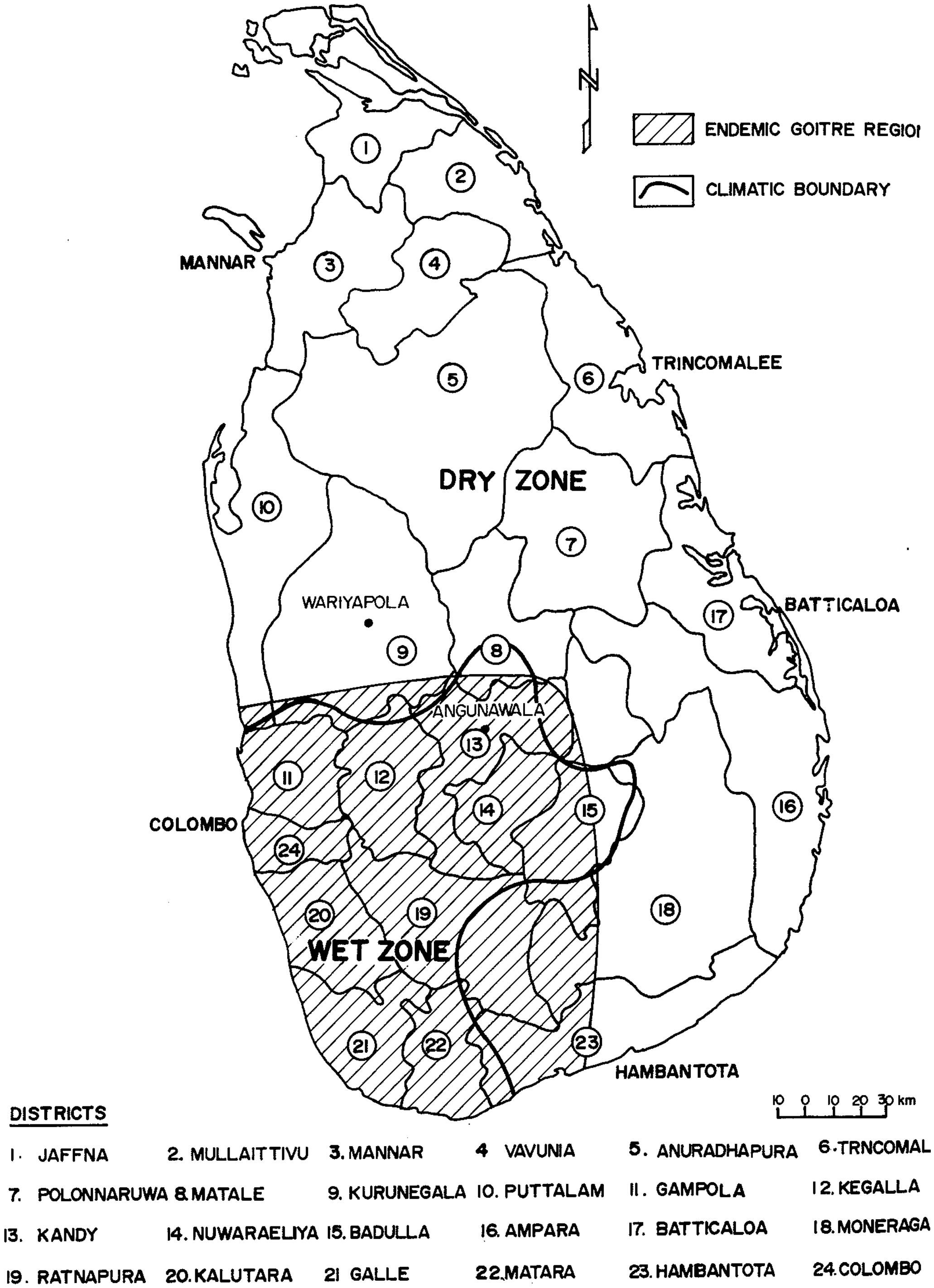


Fig. 1. The endemic goitre belt of Sri Lanka.

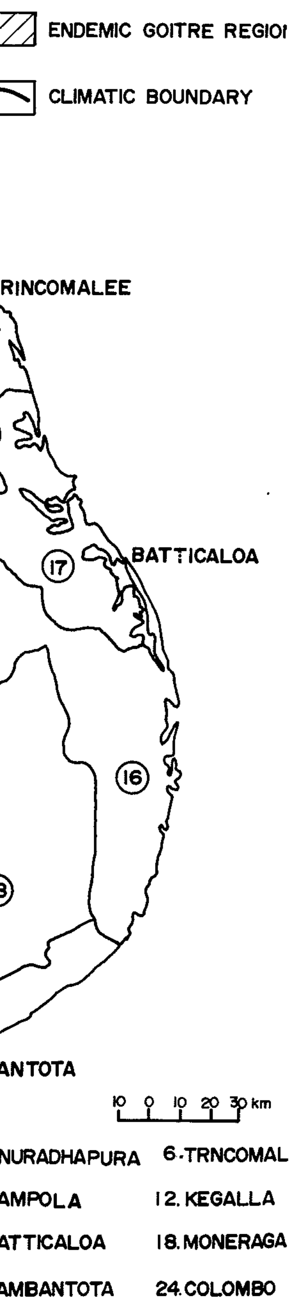


Table 2. *Geochemical data for water in the endemic goitre area around Angunawela–Daulagala in the Kandy District (No. samples = 60)*

Parameter	Minimum	Maximum	Mean
pH	5.85	8.2	7.7
Alkalinity ($mg\,l^{-1}$)	30	420	138
F ($\mu g\,l^{-1}$)	44	700	297
Cl ($mg\,l^{-1}$)	6	108	35
I ($\mu g\,l^{-1}$)	15	150	55
NO_3 ($mg\,l^{-1}$)	1.5	15	8.5
Na ($mg\,l^{-1}$)	27	1016	512
K ($mg\,l^{-1}$)	0.55	9.4	7.3
Ca ($mg\,l^{-1}$)	1.35	1616	50
Mg ($mg\,l^{-1}$)	0.23	16.64	5.9
Mn ($\mu g\,l^{-1}$)	1	208	53
Fe ($\mu g\,l^{-1}$)	520	2430	1166
Hardness ($mg\,l^{-1}$)	7	341	82
Co ($\mu g\,l^{-1}$)	1	23	11

*Sample size, 11.

Table 3. *Geochemical data on the soils in the endemic goitre area around Angunawela–Daulagala in the Kandy District*

Parameter	Minimum	Maximum	Mean	Standard deviation
pH	3.8	6.8	5.2	0.7
E.C. ($mhos\,cm^{-1}$)	159	310	236	28
F ($mg\,kg^{-1}$)	0.4	44.9	10.2	6.5
Cl ($mg\,kg^{-1}$)	0.6	4.3	1.6	0.8
I ($mg\,kg^{-1}$)	0.04	6.6	1.9	1.2

Dissanayake & Chandrajith (1993) studied the geochemistry of endemic goitre in a village in the Central province near Kandy where a 40% rate of endemic goitre had been reported. Chandrajith (1987) analysed a total of 120 soil and water samples collected from 60 locations using the Orion electrode for iodine. The authors also analysed the samples for pH, alkalinity, F^-, Cl, NO_3^-, Na^+, Ca^{2+}, Mg^{2+}, Mn^{2+}, Fe and total hardness.

Table 2 shows the data obtained in the study of Dissanayake & Chandrajith (1993). A comparison of the iodine levels obtained from the two studies mentioned above shows that in general the water iodine levels of Sri Lanka are higher than the value of $10\,\mu g\,l^{-1}$ regarded as the value below which goitre becomes endemic for Sri Lanka as suggested by Mahadeva & Shanmuganathan (1967). They are also considerably higher than those found in other endemic goitre regions such as northern England, southwest England and Wales as reported by Fuge (1989).

Figure 2 shows the spatial distribution of iodine in soils in the Angunawela–Daulagala area, a region of high endemic goitre in the Kandy District (Fig. 1). The soils for the endemic region have an average of $1.9\,mg\,kg^{-1}$ iodine (Table 3) with 27% below $1.0\,mg\,kg^{-1}$. Only 15% of the soil samples analysed had more than $3\,mg\,kg^{-1}$ iodine.

In contrast, soils in Wariyapola, a non-goitre region in the Dry Zone of northwest Sri Lanka (Fig. 1) had on the average more than $9\,mg\,kg^{-1}$ of iodine. The frequency histogram for both areas is shown in Fig. 3. The distribution of iodine in the soils is unimodal with peaks at 32% for both areas.

The content of iodine in the soil and other factors such as geology and climate show a clear relationship with the incidence of goitre. The Wariyapola region located in the Dry Zone of Sri Lanka consists mostly of reddish-brown earth, and is characterized by flat topography with a few inselbergs. The area is underlain mainly by biotite gneisses, for which no iodine data are available. Fuge & Johnson (1986), however, quote a figure of $0.04\,mg\,kg^{-1}$ for biotite gneisses and 0.38 for amphibolites. The iodine content of soils is expected to be greater than that in rocks and Fuge & Johnson (1986)

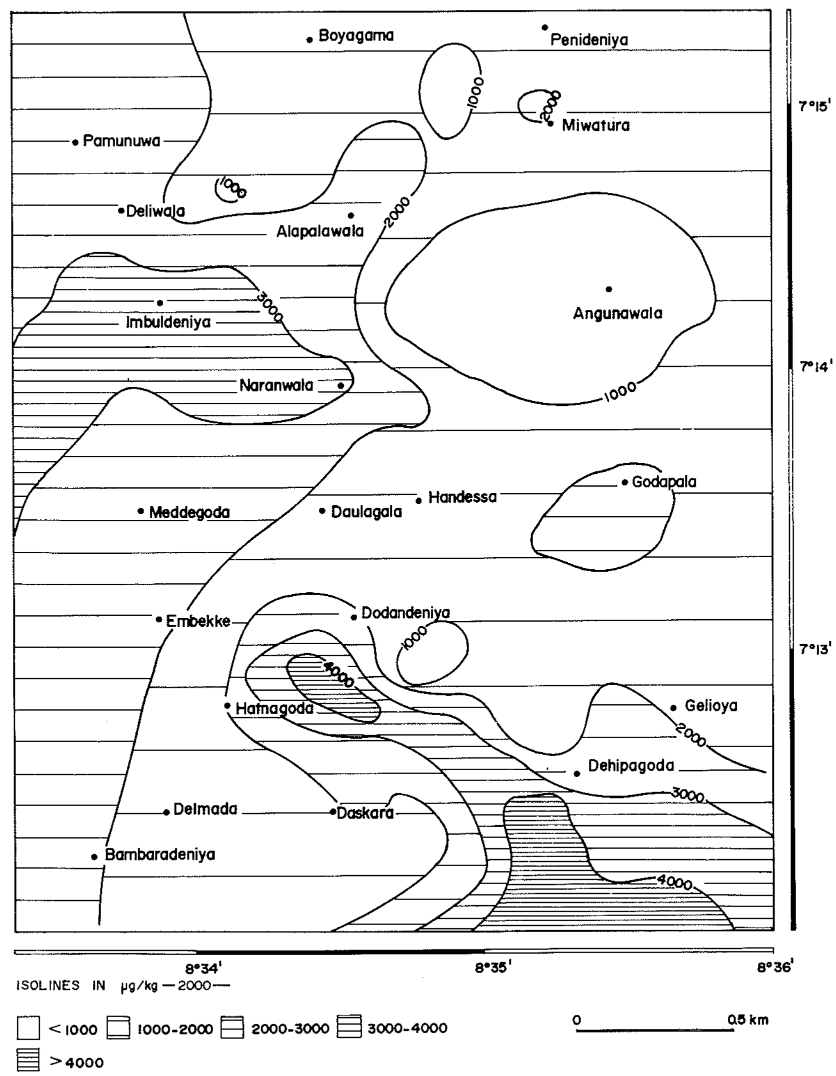


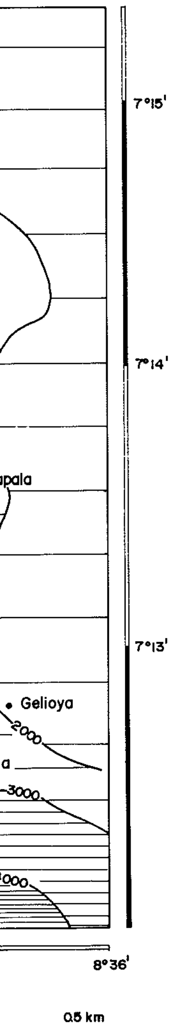
Fig. 2. The spatial distribution of iodine in soils in the endemic goitre area around Angunawela–Daulagala in the Kandy District.

record a range of 4–8 $mg\,kg^{-1}$ as a mean value for iodine in soils.

Soils are known to contain very low percentages of water soluble iodine. Magomedova *et al.* (1970) observed that for some soils in the USSR, only 1–12% of the total iodine was water soluble. Whitehead (1973) noted that only 24% of the total iodine could be extracted by boiling water while Fuge & Johnson (1986) recorded that 80% of the soils analysed, had less than 10% cold water extractable iodine. The iodine content of groundwater is therefore expected to be very low and this is seen in the case of the endemic goitre region of Angunawela.

The high rainfall of the Wet Zone takes away the iodine in the groundwater to deeper levels, while in the Dry Zone evaporation tends to bring up the iodine to surface soil layers, aided by capillary action. Some island-wide goitre surveys carried out earlier by Wilson (1954) and Mahadeva & Shanmuganathan (1967) had indicated that goitre is prevalent in areas where the rainfall is highest. Table 4 shows the mean iodine content of soils in relation to the incidence of endemic goitre.

Salt and seafood including dry fish are the main sources of iodine in the diet. According to Mahadeva *et al.* (1968) the iodine content of



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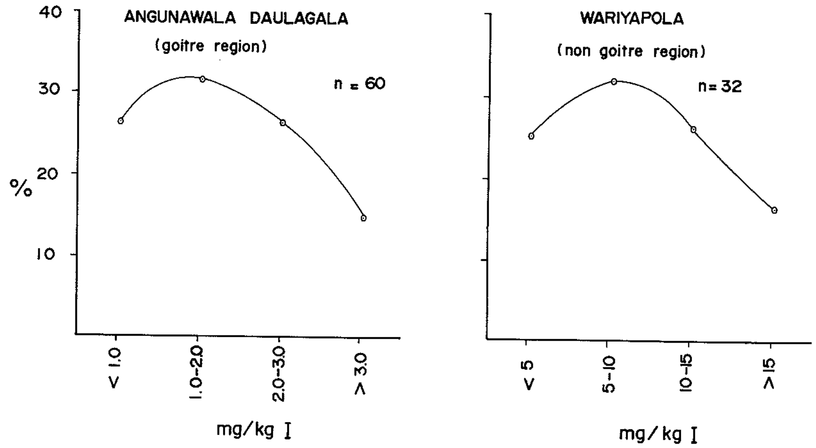

Fig. 3. Frequency histograms for the distribution of iodine in soils in an endemic goitre region and a non-goitre region in Sri Lanka.

Table 4. *Incidence of endemic goitre in relation to the iodine content in soils*

Area	Population suffering from goitre (%)	Mean iodine content ($mg\,kg^{-1}$)	Reference
Taranaki (New Zealand)	4	14	Hercus
Auckland (New Zealand)	4	12	*et al.*
Dunedin (New Zealand)	19	3.2	(1931)
Clutha Valley (New Zealand)	40	0.4	
South Canterbury (New Zealand)	62	0.3	
Angunawala–Daulagala (Sri Lanka)	45*	1.9	present
Wariyapola (Sri Lanka)	12*	9.4	study

*Dr K. B. Heath, pers. comm.

Table 5. *Consumption of salt in different countries*

Country	Salt consumption (g per person per day)	Reference
South India	18	Pasricha (1966)
Taiwan	10	Kung-pei Chen (1964)
USA	10	Johnson (1951)
USA	20	Black (1952)
UK	15–20	Davidson *et al.* (1975)
Sri Lanka	07	Mahadeva & Karunanayake (1970)

local food varies from one area to another, the Dry Zone crops having higher quantities of iodine.

The iodine content in the local salt used for cooking is low when compared to that in other countries (Table 5). The salt used for cooking in Sri Lanka is known to contain about 498 mg 100 g^{-1} wet weight iodine (Mahadeva *et al.* 1968). The washing of the salt prior to cooking and excessive heat applied during the cooking result in major losses of iodine.

Factors affecting the endemicity of goitre in Sri Lanka

The analysis of the data for water as obtained by Balasuriya *et al.* (1992) show that the rank order correlation between iodine and the prevalence of goitre was only –0.64. The fact that the Kalutara District which has a very high prevalence of goitre (≃44%) is located near the sea further suggests that some factors other than the iodine content may contribute to the aetiology of goitre

Fig. 4. Typical case of goitre in Sri Lanka.

in Sri Lanka, bearing in mind that the sea is a rich source of iodine.

From among the factors other than nutritional iodine deficiency, goitrogens, which affect the utilization of iodine by the thyroid gland, are of extreme importance. The high rate of goitre among certain villagers (Fig. 4), whose lifestyles and dietary patterns are no different from those who live in non-goitre regions, point to a major role played possibly by goitrogens yet unknown in Sri Lanka. It is apparent that the utilization of iodine by the thyroid gland is obstructed by a goitrogen that may well be environmental in origin.

Even though iodine may be found in sufficient concentrations in soil and water, its bioavailability may be seriously hampered if the iodine is fixed by substances prevalent in the environment.

Organic matter

The ability of the soil to retain iodine is related to a large number of complex interrelated soil characteristics and described by Fuge & Johnson (1986) as Iodine Fixation Potential (IFP). They defined IFP of a soil as the total amount of iodine that can be fixed by the various fractions in a soil and which is a characteristic of the soil in a given environment.

Organic matter in soils is known to trap and absorb iodine resulting in higher concentrations of iodine in soils rich in organic matter. This fact was demonstrated by Johnson (1988) who observed that surface soil samples (0–20 cm) show good correlation between organic content and total iodine ($r_{sp} = 0.70$).

Humic substances in the organic matter play a major role in the speciation and geochemical mobility of chemical elements (Dissanayake 1991). Iodine in view of its large ion could well be fixed by the humic substances resulting in a lowering of the bioavailability. The nature and extent of organic matter in the soils of the endemic areas are therefore worthy of further detailed investigation.

Soil pH

It has been suggested that highly acidic soils tend to be low in iodine due to the I^- ion being easily oxidized to I_2 which is then easily volatilized (Fuge 1990). The soil pH also influences the soil anion exchange capacity, which directly affects the iodine content. The study of Dissanayake & Chandrajith (1993) also showed that in the endemic goitre region around Kandy the soil pH was low ranging from 3.8–6.7 with a mean of 5.2. Figure 5 illustrates the correlation of I^- with other chemical parameters in hand pump wells,

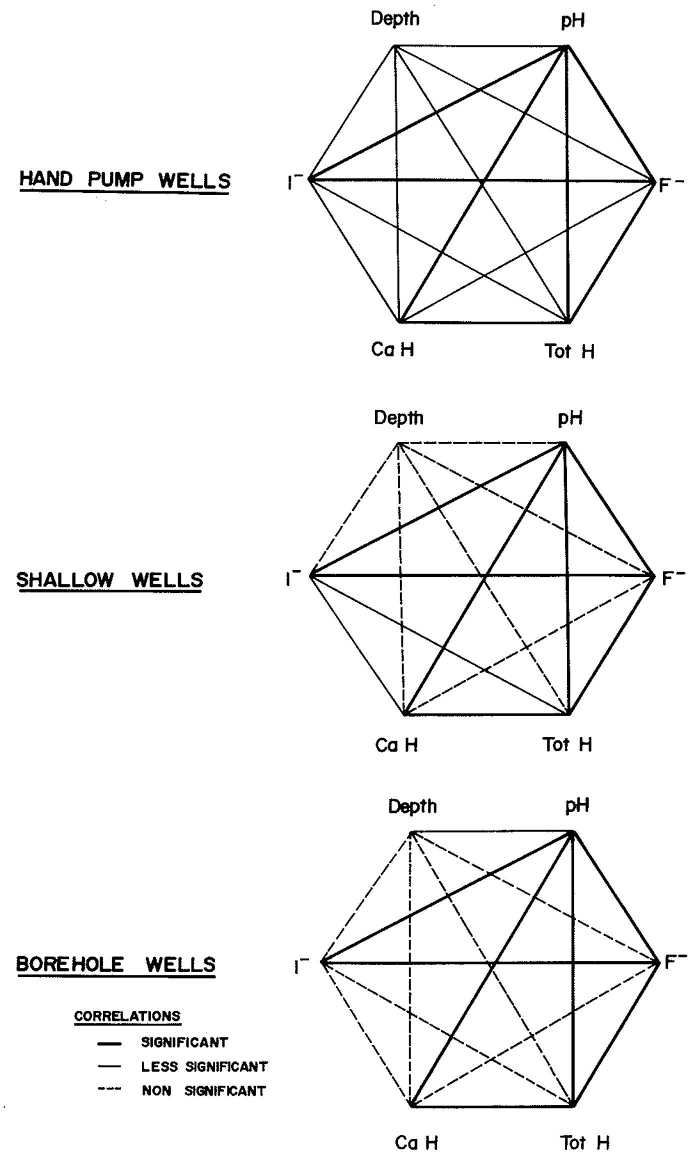

Fig. 5. Correlations of iodide with other parameters in the wells of the Kandy District (after Perera *et al.* 1992).

shallow wells and boreholes in the Kandy District as observed by Perera *et al.* (1992), from a study of about 200 wells. It is seen that the pH and the F^- correlate significantly with that of the I^- ion in the water.

Climatic influence

The geographical distribution of endemic goitre in Sri Lanka is clearly influenced by the climate. The high prevalence of goitre in the wet climatic zone appears to indicate a strong leaching effect of iodine from soils due to the heavy rainfall. The higher levels of iodine as found in the Dry Zone exemplified by the Anuradhapura District indicate a process of concentration.

Effect of clays

As in the case of the organic matter present in the soil, clays also have a marked tendency to adsorb ions. Iodine is strongly sorbed in or on clays and colloids and the presence of clays in the soils markedly affects the bioavailability of iodine. Whitehead (1979) has suggested that iodine in soils is retained mainly due to Al and Fe oxides and organic matter based on a good correlation between iodine and the sesquioxides present in soil.

Interestingly, the different clay mineral provinces of Sri Lanka also coincide with the climatic zones. The wet zone consists mainly of gibbsite and kaolinite while the Dry Zone has the montmorillonite type of clays. The geochemistry of iodine in the soils is therefore governed to a marked extent by the combined effect of the climate and the clays bearing in mind that a low pH favours the uptake of iodine by iron and aluminium oxides.

Prevention of goitre

The most convenient method of prevention of goitre is the iodization of the salt used in food. This practice has now been introduced in Sri Lanka, particularly in the endemic areas. However, due to the fact that the vast majority of the population that appears to undergo iodine deficiency disorders (IDD) in Sri Lanka are among the low income rural groups, a major awareness programme on the use of iodized salt is necessary. Such a venture must necessarily involve a concerted and coordinated effort by public health workers, manufacturers of salt, distributors and finally consumers. It is also of vital importance to monitor the progress of such a community health programme continuously.

Conclusions

Several factors govern the geochemical pathways of iodine and the incidence of goitre. Among the factors most clearly seen in Sri Lanka are climate, geology, nature of soil inclusive of organic matter, clay content, pH and food. The fact that the iodine contents of soil and water do not show marked correlation with the endemicity of goitre in Sri Lanka indicates a multifactorial aetiology which may include goitrogens, which affect the utilization of iodine by the thyroid gland.

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