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NEUTRON EVAPORATION FROM THE SURFACE OF NEUTRON STARS

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Abstract : It is shown that a newly born neutron star could cool more rapidly by neutron evaporation than through neutrino emission. The mass loss due to neutron evaporation is estimated.

1. Introduction

In current supernova scenarios a neutron star is born in a highly excited state, with an energy of excitation exceeding the energy of the final equilibrium state by more than 10^{53} ergs, ie. a temperature at birth few times 10^{11} °K.[1,3] It is generally believed that this excitation is dissipated by neutrino and antineutrino emission.[4,5] In this note, it is pointed out that around temperatures of the order 10^{11} °K a more efficient mechanism for cooling is evaporation of neutrons. It is shown that a newly born neutron star at a temperature $\sim 10^{11}$ °K will emit a burst of neutrons lasting for about 1 sec and cools to a temperature $\lesssim 10^{10}$ °K.

2. The Equations

We assume that neutrons in the star behave as a noninteracting nearly degenerate fermi gas. Since the neutron star matter is highly conducting, the surface temperature immediately after birth could also be few times 10^{11} °K (10^{11} °K $\simeq$ 10 MeV). At these temperatures the matter at the surface of the star will consist predominantly of neutrons. Neutrons in the surface region having energies near the fermi level can leave the star if they have sufficient kinetic energy to overcome the potential barrier resulting from nuclear and gravitational forces. Because of the strong interaction, the energy Φ_n necessary to evaporate a neutron from the surface must at most be of the order of binding energy per nucleon of the most stable nucleus ^{56}Fe $\sim$ 10 MeV. To escape from the gravitational confinement of the star, the evaporated neutrons must do an additional amount of work,

$$\Phi_g = GM/R,$$

where G = gravitational constant, M = mass, R = radius of the star. For a neutron star of 1 M and radius 10 km, $\Phi_g \simeq$ 14 MeV.

Thus the total work function is,

$$\Phi = \Phi_n + \Phi_g \qquad 24 \text{ MeV.} \qquad (1)$$

The flux of evaporated neutrons leaving the surface can be calculated as follows. The rate at which the neutrons in the momentum range $p + dp$ and p will strike unit area on the surface of the star near any point P is,

$$(4\pi^3\hbar^3)^{-1} f v_x dp$$

where f = fermi distribution function, v_x = the component velocity of a neutron in the radial direction (chosen to be the x direction) at P. Neutrons with normal component of momentum,

$$P_x > P_o = 2m(\Phi + \mu)^{1/2},$$

will escape from the star. Hence the radial current density leaving the surface of the star is,

$$J = (4\pi^3 n^3 m)^{-1} \int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{P_o}^{\infty} [\text{Exp}(\mu - 1)/kT + 1]^{-1} p_x dp_x dp_y dp_z \qquad (2)$$

where $E = 1/2m(p_x^2 + p_y^2 + p_z^2)$, μ = chemical potential characterizing the distribution f. Performing the first integration in (2) we get,

$$J = (4\pi^3 n^3)^{-1} kT \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \ln(1 + e^{-s})\, dp_y dp_z \qquad (3)$$

where

$$s = 1/kT \quad [\Phi + (p_y^2 + p_z^2)/2m]$$

Evaluating the resulting double integral in (3) approximately, we obtain,

$$J = AT^2 e^{-\Phi/kT} \qquad (\star)$$

where $A = (mk^2/2\pi^2\hbar^3)$.

Emitting neutrons will carry away mass and thermal energy from the star. If N = number of neutrons in the star at time t and ρ = density which is assumed to be constant through out the evaporation, then the total flux of neutrons escaping from the star at time t is,

$$-dN/dt = 4\pi AR^2T^2e^{-\Phi/kT}$$

$$= 4\pi AT^2 (3mN/4\pi\rho)^{2/3} e^{-\Phi/kT} \quad (5)$$

For a neutron star of $1M_o$ and radius 10km at 10^{11} °K the expression (5) gives $dN/dt = -10^{59}$ sec^{-1}. However, because of cooling and decrease in surface area from loss of mass, the star will not emit neutrons continously at a rate comparable to the above. It will be shown that a newly born neutron star could emit a flash of neutrons resulting in a significant drop in temperature and loss of mass.

Each emitted neutron will take away from the star an amount of thermal energy equal to its kinetic energy plus the work done against the potential barrier. That is the average energy removed from the star per emitted neutron is ($< E > + \Phi$). Where $< E >$ = average kinetic energy of the emitted neutrons. The quantity $< E >$ can be calculated by finding the velocity distribution function for the emitted neutrons. To find this velocity distribution function, consider neutrons just inside a small region on the surface of the star. The number of neutrons in this region with the component of velocity normal to the surface (chosen to be the x component) between $v_x + dv_x$ and v_x is,

$$n(v_x) = (4\pi^3\hbar^3)^{-1} m\, dv_x \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} dv_y dv_z \, [\mathrm{Exp}\,(E-\mu)/kT + 1]^{-1} \quad (6)$$

If u_x is the normal component of the velocity of a neutron after emission,

$$1/2\,(mu_x^2) = 1/2\,(mv_x^2) - \mu - \Phi \quad (7)$$

Subsitituting (7) in (6) and evaluating the integral (6) approximately we get,

$$n(v_x)dv_x \quad (m^2kT)\,(2\pi^2\hbar^3)^{-1}\,\mathrm{Exp} - (mu_x^2/2kT - \Phi/kT)\, du_x \quad (8)$$

and the velocity distribution function for the radial component of the velocities of the emitted neutrons is,

$$f(u_x)\, du_x = (mu_x/kT)\,\mathrm{Exp} - (mu_x^2/2kT)\, du_x \quad (9)$$

and the average kinetic energy of neutrons associated with the radial component of the velocities is,

$$< mu_x^2/2 > = m/2 \int_0^{\infty} f(u_x)\, u_x^2\, du_x^2 \quad (10)$$

$$= kT$$

The component velocities parallel to the surface do not change upon emission ie,

$$< mu_y^2 /2 > \quad = \quad < mu_z^2 /2 > \quad = \quad kT/2 \qquad (11)$$

Therefore $< E > = 2kT$ and the average energy carried away per neutron emitted is $(2kT + \Phi)$. If U is the heat content of the star, the rate of dissipation of thermal energy by neutron emission is,

$$-W_n = dU/dt = dn/dt\ (2kT + \Phi) \qquad (12)$$

Using (5) the above result can also be written as,

$$W_n = 4\pi AR^2T^2\ (2kT + \Phi)\ e^{-\Phi/kT} \qquad (13)$$

Now we compare the cooling due to neutron emission with that due to neutrino emission. The neutrino processes important in the initial cooling of neutron stars is supposed to be the modified URCA and the inverse process[4] and the neutrino luminosity from the above processes is estimated to be[4]

$$W_\upsilon \qquad \alpha\ T^8 \qquad (14)$$

where $\alpha = 3 \times 10^{-67} M\ (\rho_n/\rho)^{1/3}$, ρ_n = nuclear matter density. The Table 1 gives W_n (equation 13) and W_υ (equation 14) at different temperatures for a neutron star $1m_o$ and radius 10 km. It is seen at temperatures close to 10^{11} °K the energy carried away by neutrons is comparable to the losses due to neutrino and antineutrino emission, (at these temperatures the energy lost from the surface as thermal radiation is $\sim 10^{41}$ erg $sec^{-1} << W_n$). The rate of cooling and mass lost due to neutron emission can also be determined easily. It turns out that at temperatures $\sim 10^{11}$ °K, the rate of cooling resulting from neutron emission is faster than that from neutrino emission, as the former process is also accompanied by a change in volume of the star.

The heat content of the star is the same as that of a degenerate fermi gas ie,

$$U = \pi^2k^2T^2N/4\mu \qquad (15)$$

Thus equation (12) becomes,

$$(\pi^2k^2/4\mu)\ d/dN(T^2N) = 2kT + \Phi \qquad (16)$$

The solution of equation (16) with the initial condition $N = N_o$ when $T = T_o$ $(T, T_o < a)$ is,

$$N = N_o\ (a - T_o)\ (a - T)^{-1}\ (b + T_o)\ (b + T)^{-1} \qquad (17)$$

where $a = 8\mu\ /\pi^2 k$, $b = \Phi\ /2k$ ($\mu\ \sim\ 100$ MeV). Substituting (17) into (14) we get after some approximations,

$$dT/dt \qquad -BT^2\ e^{-\Phi/kT} \qquad (18)$$

$$\text{where } B = mk^2\ /n^3\ (3m/4\pi\rho)^{2/3}\ (a + b + 2/3T_o)\ N_o^{-1/2} \qquad (19)$$

Equation (18) describes the rate of cooling of the star due to neutron emission and solving (18) with the initial condition $t = 0$, $T = T_o$ we obtain,

$$t = k/B\Phi\ (e^{\Phi/kT} - e^{\Phi/kT_o}) \qquad (20)$$

The above equation indicates that a neutron star of $1M_o$ and radius 10 km at 10^{11} °K, cools to 10^{10} °K in about 1 sec. It takes much longer to cool through the same temperature range via neutrino emission. From (14) and (15) we obtain the equation

$$\pi^2 k^2\ /4\mu\ d/dt\ (T^2 N) \ = \ -\alpha\ T^8 \qquad (21)$$

that describes cooling of the star due to neutrino emission. The solution of (21) ie,

$$t = (\pi^2 k^2 N/2\mu\ \alpha)\ (T^{-6} - T_o^{-6}) \qquad (22)$$

shows that a neutron star of $1M_o$ and radius 10 km takes $\sim\ 10^3$ sec to cool through the same temperature range. At lower temperatures ($kT << \Phi$) cooling from neutron emission becomes insignificant because of the damping of the rate of cooling by the exponential factor in (18). The above analysis indicates that in the temperature range 10^{11} – 10^{10} °K, the cooling is predominantly from emission of neutrons. In this temperature range, the rate of neutron evaporation is only slightly affected by neutrino cooling and a significant portion of the mass of the star is lost as evaporating neutrons.

T°K	W_n erg sec^{-1}	W_ν erg sec^{-1}
10^9	2.8×10^{-36}	5×10^{38}
10^{10}	2.8×10^{43}	5×10^{46}
10^{11}	5.5×10^{53}	5×10^{54}
10^{12}	1.4×10^{56}	5×10^{62}

Table 1

3. Conclusions

The conclusion we draw from the above discussion is that a neutron star $\sim 1M_\odot$ and radius $\sim$ 10 km will emit a flash of neutrons immediately after its birth, if the surface temperature is around 10^{11} °K. The duration of the flash is about 1 sec and approximately 10% of the mass of the star gets evaporated. As the neutron flash is emitted just after the birth, it should interact with matter ejected in the supernova explosion (neutron emission will probably continue until the outer shell of ejected matter has moved to a distance $10^3 - 10^4$ km). This effect could have important consequences, neutron and proton (protons from decay of emitted neutrons) bombardment of the ejected matter may be efficient in synthesising heavy elements.[6] The flux of protons may also be a source of cosmic rays.

It is very important to note that the process depends entirely on evaporation of neutrons from the surface and does not involve mass transport from inside. The star wears away from the surface due to loss of neutrons.

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CHEMICAL CONSTITUENTS OF SOME SPECIES OF HOLOTHURIANS FOUND IN SRI LANKA

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Abstract : The sodium, potassium, calcium, iron, magnesium and phosphorus contents of the **six** Holothurian species *Holothuria scabra, Holothuria atra, Holothuria nobilis, Holothuria leucospilota, Bohadschia marmorata* and *Sticopus chloronotus* were determined. *H. scabra* has the highest sodium (4.29%), potassium (1.05%), calcium (7.91%) and magnesium (5.21%) contents. *B. marmorata* has the lowest amounts of sodium (0.30%) and calcium (2.05%). *H. atra* has the lowest amount of magnesium (0.73%) and *S. chloronotus* has the lowest amount of potassium (0.10%). *H. scabra* has the highest amount of the trace elements copper (9 ppm) and nickel (36 ppm), while *B. marmorata* contains the highest amount of manganese (7 ppm) and zinc (340 ppm). Of the two commercial species, *H. atra* (61 - 65%) has a higher protein content than of *H. scabra* (36 - 38%). The effect of processing on the mineral and protein contents of *H. atra* and *H. scabra* is also reported. Processed *H. atra* and *H. scabra* from the Northern coast of Sri Lanka have a higher protein content (73 – 76%) than the processed *H. scabra* (59%) from the South Pacific Islands. A possible method of differentiating *H. scabra* and *H. atra* on the basis of the mineral content is also suggested.

1. Introduction

The Holothurians are soft, cylindrical-bodied, usually dull dark-coloured and often warty species much like cucumbers (therefore called sea cucumbers) belonging to the Invertebrate class Holothuroidea (or Holothurioides) of the phylum Echinodermata.[2]

Holothurians are marine species of economic importance and their export provides valuable foreign exchange to Sri Lanka. Processed Holothurian, *Beche-de-mer* is considered a delicacy by the Chinese and as a result is exported to the countries where the Chinese population is relatively high.[3] The prices of the exported animals depend on qualities such as size, appearance, odour, colour, moisture content and resistance to spoilage. Thus knowledge of the amounts of moisture, protein, carbohydrates, fat, amino-acids and minerals present in different species of Holothurians found in Sri Lanka would be useful in evaluating their food value and the market potential. Holothurians are also used in making poultry feed.[3] The water extract of *H. scabra,* obtained during processing is used to relieve pain and to cure paralysis by some villagers in the Northern part of Sri Lanka.[3]

Of the species known, *H. scabra* is the most commercially popular. In northern Sri Lanka, this species is largely available in the coastal area of Mandaitivu, Nainativu and Mannar. Another commercially popular species *H. atra* is also available in the northern coastal area. The latter is plentiful in the coastal area of Point Pedro.

The mineral, fat, protein and moisture contents of *Beche-de-mer* processed from *H. scabra* from the South Pacific Islands have been reported.[10] Recently a group of workers have reported[4,5] the protein, fat, and saponin contents of some species of Holothurians found in Sri Lanka. In our earlier communication,[1] we reported the mineral and iodine contents of six species of fresh Holothurians found in the coastal area of Jaffna. In this paper, we report our results on the chemical constituents of the commercially popular species *H. scabra* and *H. atra* along with those of the other species. The effect of processing on the mineral content is also reported.

2. Experimental Methods and Materials

Fresh samples of *H. scabra* used in this study were collected from Mandaitivu during the months December 1982 and June 1984 and from Mannar in October 1983. *H. atra* used for this study was collected from Mandaitivu in March 1983 and June 1984 and from Point Pedro during the months of March and June 1983. Also samples of *B. marmorata, H. nobilis* and *S. chloronotus* collected from Trincomalee and *H. leucospilota* collected from Mandaitivu were analysed for comparison purposes. The different species were identified by reported methods.[3]

Processing[3] of Holothurians was carried out as follows: The specimen was first boiled in water for 30 min removed from water and allowed to air dry for 3 h. Then the dried specimen was kept under a soil bed overnight for fermentation. The outer body wall cover was removed by washing with water and the processes of boiling and air drying were repeated twice.

After the above treatment, the air-dried samples were dried in an oven 105°C to constant weight. The ash content was determined by ashing weighed quantities of oven dried samples at 450°C in a Muffle furnace until constant weight was obtained.

2.1 Preparation of Test Solutions

Oven dried samples of known weights were ashed at 450°C and dissolved (quantitatively) in a known volume of 0.6M HCl and the resulting solutions were used to determine sodium, potassium, calcium, magnesium, iron and trace elements.

2.1.1 Determination of the Amounts of Sodium and Potassium

Sodium and potassium contents of test solutions were determined Flame Photometrically[7] using a Corning 400 Flame Photometer. The Flame intensities for sodium were corrected for interference by calcium by the standard addition method.[13]

2.1.2 Determination of the Amounts of Calcium and Magnesium

Calcium and magnesium contents of test solutions were determined titrimetrically[11] using EDTA with potassium cyanide as the masking agent. Patton Reeders indicator was used for calcium determination.

Magnesium content of test solutions was estimated as follows: The total amount of magnesium and calcium present was determined[11] by titrating a known volume of test solution with standard EDTA solution with Eriochrome Black T as indicator and using potassium cyanide as masking agent.[11] Magnesium content was obtained by subtracting the amount of calcium present from this value.

2.1.3 Determination of Iron

Iron content of test solution was determined colorimetrically.[6] 1,10—Orthophenanthroline was used as the complexing agent and the colour intensity was measured using a Corning Model 252 Colorimeter with a 490 nm filter.

2.1.4 Estimation of Protein Content

The total nitrogen content of oven dried samples of holothurians was determined by the Kjeldhal method[6] and protein content was calculated by multiplying the total nitrogen content by 6.25.

2.1.5 Determination of Trace Elements

The trace elements copper, manganous, nickel, zinc, cadmium, cobalt and chromium were determined[6] using the test solution (prepared as described above) on a Varian Model 1257 Atomic Absorption Spectrophotometer.

2.1.6 Determination of Lead

Oven-dried samples were subjected to wet oxidation with concentrated nitric acid and concentrated sulphuric acid as reported previously.[6] The resulting solution was used to prepare the test solution. The amount of lead present was determined using a Corning Model 252 Colorimeter after complexing with dithizone.[6]

2.1.7 Determination of Phosphorus

Accurately weighed oven-dried samples (1–2g) were ashed with magnesium nitrate[6] and the ash was dissolved in 1M H_2SO_4 (10 ml) and the solution made up to 50 ml. Phosphorus content of this solution was determined[6] by measuring the intensity of the colour produced on complexing with vanadomolybdate reagent using a Corning Model 252 Colorimeter with 430, 470 and 490 nm filters.

2.1.8 Determination of Iodine

Iodine content of accurately weighed oven dried samples was estimated by the alcoholic potash method.[8]

2.2 Identification of aminoacids and carbohydrates

Methanol extracts of fresh samples of *H. scabra* and *H. atra* were used for the identification of carbohydrates and aminoacids. Carbohydrates and aminoacids were separated from the methanol extract by using the cation exchange resin, Zeocarb 225. The aminoacids and carbohydrates present were tentatively identified[12] by comparing with authentic samples using paper chromatography.

2.3 Separation of spicules and their analysis

Spicules were separated[3] from the flesh of the specimen by adding saturated solution of sodium hypochlorite. The mixture was left overnight and decanted (The spicules will float in the liquid – the flesh will be at the bottom). The spicules were separated from the decanted solution by centrifuging and decanting the supernatant liquid. The spicules were washed with distilled water until no more chloride ions are detected in the washings. The spicules were then weighed, ashed and dissolved in 0.6M HCl and the estimation of the minerals were carried out as before.

3. Results and Discussion

The habitats of the six holothurian species studied are given in Table 1 and their localities are given in Table 2. Of the six species studied, *H. atra* is the smallest (usually 8 – 15 cm in length) and *H. leucospilota* is the largest (30 – 80 cm). Our results on the estimation of the amounts of sodium, potassium, calcium and magnesium present in six species of Holothurians are given in Table 3. The amounts of iron, phosphorus and iodine are given in Table 4. Of the six species investigated, *H. scabra* contains the highest amounts of sodium, calcium and magnesium. But *H. atra*, and the non-

commercial species *H. leucospilota* and *S. chloronotus* contain relatively high amounts of iron and phosphorus. *H. scabra* from the Mandaitivu coast and *S. chloronotus* from Trincomalee have appreciable amounts of iodine while *H. atra, H. leucospilota* and *B. marmorata* do not have detectable amounts of iodine. It is interesting to note that seaweeds from the Mandaitivu coast also have high iodine content.[9] *H. scabra* from the South Pacific Islands[10] has higher amounts of sodium and iron than the Holothurian species from Sri Lankan coast but its calcium and phosphorus contents are much lower. Tables 3 and 4 also show the amounts of the same minerals present in different species of Holothurians after processing. Processing removes 87 – 90% of sodium and potassium from both *H. scabra* and *H. atra*. Relatively smaller amounts of calcium, magnesium, iron and phosphorus are lost during processing and iodine is lost completely. However there is a large difference in the amount of calcium, magnesium and phosphorus lost by *H. atra* and *H. scabra*. Table 5 gives the percentage of the original amounts of the minerals remaining in the animals after processing to the original value.

Table 1. The habitats of the holothurian species studied.

Species	Habitat
Holothuria scabra	Found among eel grasses in the shallow waters and in sandy bottom in deep waters.
Holothuria atra	Found among coral reefs and clear sand. It is usually found coated with sand with few naked patches.
Holothuria leucospilota	Found in deep sea (about 10 m depth).
Holothuria nobilis	Found in muddy bottom (4 - 8 m depth).
Sticopus chloronotus	Found in deep waters on pebble stone grounds (6-12 m depth).
Bohadschia marmorata	Found in deep sandy bottom where the bed can be easily seen from the surface of the water.

Table 2 : Details of the species used in the study.

Species	Locality	Month of collection	Weight of whole sample–(g)	Length of sample–(cm)	Moisture (%) in body	Weight of body (g) (without alimentary canal)
Holothuria scabra (I)	Mandaitivu	December 1982	314	21	83.10	144
Holothuria scabra (II)	Mandaitivu	June 1984	386	30	82.51	178
Holothuria scabra (III)	Mandaitivu	June 1984	188	22	82.63	95
Holothuria scabra (IV)	Mannar	October 1983	465	28	85.31	206
Holothuria atra (I)	Mandaitivu	April 1984	68	13	85.97	24
Holothuria atra (II)	Mandaitivu	April 1984	106	12	85.90	38
Holothuria atra (III)	Point Pedro	March 1983	125	15	83.21	55
**Holothuria leucospilota*	Mandaitivu	–	–	–	–	–
**Holothuria nobilis*	Trincomalee	–	–	–	–	–
**Bohadschia marmorata*	Trincomalee	–	–	–	–	–
**Sticopus chloronotus*	Trincomalee	–	–	–	–	–

*Samples from Miss P. Elanganayagam, Department of Zoology. Sun dried mixture of several animals was used (moisture content of these sun dried samples ranged from 15 – 17 %).

Table 3.

Sodium, Potassium, Calcium and Magnesium contents of Holothurians, [g/100g oven dried samples]

Species	Ash		Sodium		Potassium		Calcium		Magnesium	
	a	b	a	b	a	b	a	b	a	b
1. *Holothuria scabra* [I]	53.23	19.61	3.92	0.39	0.74	0.09	6.76	2.73	4.39	0.98
2. *Holothuria scabra* [II]	53.89	22.75	4.29	0.48	1.05	0.14	7.91	3.11	5.21	1.17
3. *Holothuria scabra* [III]	48.14	14.82	2.36	0.24	0.66	0.07	5.85	2.63	4.18	0.89
4. *Holothuria scabra* [IV]	45.81	15.17	3.70	0.40	0.30	0.02	4.28	1.84	2.12	0.54
5. *Holothuria atra* [I]	20.36	3.12	1.05	0.11	0.15	0.02	2.07	0.42	0.73	0.23
6. *Holothuria atra* [II]	21.76	3.65	1.50	0.17	0.16	0.02	2.49	0.57	0.77	0.26
7. *Holothuria atra* [III]	22.50	3.86	1.14	0.15	0.18	0.03	2.58	0.64	0.95	0.34
8. *Holothuria scabra*[10] [South Pacific Islands)	–	37.9	–	3.43	–	–	–	1.65	–	–
9. *Holothuria leucospilota*	22.35	–	0.55	–	0.24	–	2.17	–	2.13	–
10. *Holothuria nobilis*	22.00	–	0.83	–	0.17	–	2.49	–	2.04	–
11. *Bohadschia marmorata*	29.40	–	0.30	–	0.23	–	2.05	–	2.30	–
12. *Sticopus chloronotus*	36.47	–	1.90	–	0.10	–	3.00	–	1.56	–

a – ash and minerals in unprocessed samples.

b – ash and minerals in processed [as described earlier] samples

Table 4.

Iron, Phosphorus and Iodine contents of Holothurians [mg/kg oven dried samples]

Species	Iron		Phosphorus		Iodine	
	a	b	a	b	a	b
1. *Holothuria scabra* [I]	81	43	777	653	51	no detectable amount
2. *Holothuria scabra* [II]	90	51	865	700	54	" "
3. *Holothuria scabra* [III]	59	31	733	630	34	" "
4. *Holothuria scabra* [IV]	40	18	281	223	no detectable amount	
5. *Holothuria atra* [I]	146	66	1092	28	" "	" "
6. *Holothuria atra* [II]	233	104	1116	691	" "	" "
7. *Holothuria atra* [III]	452	194	985	625	" "	" "
8. *Holothuria scabra*[10] [South Pacific Islands)	–	226	–	96	–	–
9. *Holothuria leucospilota*	413	–	1255	–	no detectable amount	–
10. *Holothuria nobilis*	336	–	666	–	6	–
11. *Bohadschia marmorata*	86	–	577	–	no detectable amount	
12. *Sticopus chloronotus*	251	–	1037	–	150	–

a – minerals in unprocessed samples
b – minerals in processed samples.

Table 5. Percentage of the original amounts of minerals present after processing.

Species	Na	K	Ca	Mg	Fe	P
Holothuria scabra [I]	9.9	12.2	40.4	22.3	53.1	84.1
Holothuria scabra [II]	11.2	13.3	42.2	22.5	56.7	80.92
Holothuria scabra [III]	10.2	10.6	45.0	21.3	52.5	86.0
Holothuria scabra [IV]	10.8	6.7	43.0	25.8	45.0	79.4
Holothuria atra [I]	10.5	13.3	20.3	31.5	45.2	57.5
Holothuria atra [II]	11.3	12.5	22.9	33.8	44.6	61.9
Holothuria atra [III]	13.2	16.7	24.8	35.8	42.9	63.5

One of the reasons for the greater loss of alkali metals during processing could be the higher solubility of their salts. Another possibility is that these salts are present in relatively large amounts in the outer skin and spicules which are removed during the processing. The difference in the loss of calcium, magnesium and phosphorus between *H. scabra* and *H. atra* could be attributed to the difference in the distribution of these elements in the animal body wall, the skin and spicules of *H. atra* containing relatively larger amounts of the minerals than *H. scabra.* Table 6 gives the amount of minerals left in the animal after each stage in processing for the two species *H. scabra* and *H. atra.*

The trace elements present in different species of holothurians were also estimated using an Atomic absorption spectrophotometer. The elements chromium and cobalt could not be detected in any of the species. The Table 7 shows the amounts of copper, manganous, zinc, lead, nickel and cadmium present in four species.

Table 6

Effect of processing on the mineral contents of *H. scabra* and *H. atra*; [g/100g oven dried samples]

Stage in processing	Ash	Na	Ca	Mg	K	Fe	P
1. *Holothuria scabra* [I]							
Fresh	53.23	3.92	6.76	4.39	0.74	0.0081	0.0777
After 1st boil	44.10	2.95	6.04	3.05	0.447	0.0067	0.0798
After fermentation	33.35	1.04	4.95	2.37	0.324	0.0084	0.0779
After 2nd boil	25.69	0.47	3.28	1.27	0.210	0.0047	0.0674
After 3rd boil	19.61	0.39	2.73	0.98	0.091	0.0043	0.0653
2. *Holothuria atra* [II]							
Fresh	21.76	1.50	2.49	0.77	0.160	0.0233	0,1116
After 1st boil	14.32	1.23	1.74	0.49	0.093	0.0165	0.0957
After fermentation	7.20	0.78	1.07	0.41	0.039	0.0180	0.0842
After 2nd boil	4.07	0.36	0.89	0.33	0.032	0.0140	0.0728
After 3rd boil	3.65	0.17	0.57	0.26	0.020	0.0104	0.0691

Table 7

Amounts of trace elements present in some species of Holothurians; [mg/kg of the oven dried samples]

Species	Copper		Manganese		Zinc		Lead		Nickel		Cadmium	
	a	b	a	b	a	b	a	b	a	b	a	b
Holothuria scabra [I]	9.2	10.6	3.8	3.8	6.7	8.4	19.2	12.6	35.5	26.0	3.0	1.7
Holothuria atra [I]	2.3	2.6	2.1	3.3	8.6	9.3	7.2	5.1	14.0	12.7	1.4	0.4
Bohadschia marmorata	2.6	–	6.9	–	339.6	–	15.2	–	30.0	–	2.7	–
Holothuria leucospilota	4.3	–	6.5	–	54.2	–	7.6	–	14.3	–	1.1	–

a – amount of trace elements present in unprocessed samples.

b – amount of trace elements present in processed samples.

The elements copper, manganous and zinc are essential and nutritive, whereas lead and cadmium are toxic. Elements such as copper and zinc although essential for life in trace amounts, have an toxit action when ingested in higher amounts. The recommended levels of copper and zinc are 20 and 50 ppm respectively. The amounts of copper and zinc present in the commercial species *H. scabra* and *H. atra* are well below the recommended level. The non commercial species *B. marmorata* and *H. leucospilota* contain zinc in quantities well above the recommended level. On processing the percentage of the nutritive elements [Cu, Mn and Zn] increases slightly but remain well within the recommended level. The percentage of toxic elements [Pb and Cd] decreases [by about 30 – 46%] on processing. The mineral contents of the spicules of five species of holothurians are given in Table 8. The spicules of the commercial species *H. scabra* and *H. atra* have a relatively high calcium content. The spicules of *B. marmorata* has relatively high magnesium content while that of *S. chloronotus* is low in calcium but contain the highest amount of potassium and iron. These findings may be of chemotaxonomic significance. It is relevant to note that shape of spicules among other properties is used[3] in identification of different species of holothurians.

Table 8

Amounts of sodium, calcium, magnesium, potassium and iron present in spicules of different holothurians; [g/100g oven dreid samples]

Species	Na	Ca	Mg	K	Fe
1. *Holothuria scabra*	0.74	32.20	3.21	0.0069	0.0190
2. *Holothuria atra*	0.67	34.93	4.00	0.0012	0.0067
3. *Bohadschia marmorata*	0.82	34.56	19.00	0.0160	0.0270
4. *Sticopus chloronotus*	0.21	14.03	3.84	0.0637	0.1221
5. *Holothuria nobilis*	0.96	226.70	3.20	0.0048	0.0066

The protein contents of fresh and processed *H. scabra* and *H. atra* species are given in Table 9. It is of interest to note that although unprocessed *H. atra* has a very much higher percentage of protein than unprocessed *H. scabra,* the processed species have nearly the same percentage of protein. This may be due to a greater loss of non-protein material from *H. scabra* than from *H. atra* during processing. Also the local *H. scabra* and *H. atra* appear to have higher percentage of protein than the *H. scabra* from South Pacific Islands. [10]

The total free aminoacid and carbohydrate contents of *H. atra* and *H. scabra* have also been estimated by the usual method. The values of the total amount of substances extractable into methanol and the percentages of free aminoacids and carbohydrates present are given inTable 10.

Table 9

Protein contents of fresh and processed *Holothuria scabra* and *Holothuria atra.* (g/100g oven dried samples)

Species	Protein	
	Unprocessed	Processed
Holothuria scabra [I]	37.75	76.44
Holothuria scabra [II]	37.10	75.02
Holothuria scabra [IV]	36.69	73.31
Holothuria atra [I]	64.94	76.63
Holothuria atra [II]	63.85	76.25
Holothuria atra [III]	61.44	73.50
Holothuria scabra[10] [South pacific Islands]	–	59.12

Table 10. Percentage of free amino acids and carbohydrates

Species	Weight of animal/g	Total amount of material in methanol extract (%)	Free amino acids (%)	Carbohydrate (%)
Holothuria scabra (Mandaitivu)	200	3.15	0.33	0.58
Holothuria atra (Mandaitivu)	56	4.70	0.45	1.37

The carbohydrates present in both the species are in the polysaccharide form, as simple sugars were not detected by chromatographic analysis. Comparative two dimensional paper chromatographic analysis has shown that *H. atra* contains seventeen free aminoacids. Fifteen of them have been identified as aspartic acid, glutamic acid, serine, glycine, threonine, alanine, tyrosine, valine, methionine, histidine, lysine, phenylalanine, arginine, leucine and isoleucine. *H. scabra* contains fifteen aminoacids. Fourteen of these have been identified as aspartic acid, glutamic acid, serine, glycine, alanine, tyrosine, threonine, valine, arginine, methinine, proline, phenylalanine, leucine and isoleucine. It is interesting to note that *H. atra* contains nine of the ten essential aminoacids whereas *H. scabra* contains only seven of them.

4. Conclusion

Processed *H. scabra* and *H. atra* from the coastal area of Northern Sri Lanka have a higher protein content [73–76%] than the processed *H. scabra* from the South Pacific Islands [59.12%]. Generally *H. scabra* is richer in alkali, alkaline earth and trace metals than *H. atra* whereas the reverse is true in the case of the elements iron and phosphorus. Both *H. scabra* and *H. atra* have similar Na/Ca ratio. But the K/Ca and Mg/Ca ratios of *H. scabra* are very much higher [> 60%] than those of *H. atra.* Thus it is possible to differentiate *H. scabra* and *H. atra* on the basis of the mineral constituents. Processing increases the protein content and the amounts of copper, manganese and zinc and decreases the alkali, alkaline earth and toxic elements.

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BORON CONTENT OF MARINE ALGAE FROM THE MANDAITIVU AND KIRINDA COASTS AND MINERAL CONTENT OF NINE SPECIES OF ALGAE FROM THE KIRINDA COAST

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Abstract : The boron content of eighteen species of marine algae collected from the Mandaitivu and Kirinda coasts is reported here. Boron is a micronutrient and is essential for plant growth. The feasibility of using algae such as *Gracilaria crassa, Gracilaria edulis, Gracilaria corticata, Centroceros clavulatum* and *Sarcodia ceylanica* which contain more than 200 ppm boron, as fertilizer to meet the boron and other mineral requirement is discussed. The iodine, phosphorus, iron, sodium, potassium, calcium, magnesium, chloride (ionic) and sulphur (total) contents of nine species of marine algae from the Kirinda coast are reported and the values are compared with those of the algae from the northern coast. *Gracilaria fergusoni* has the highest amount of iodine (3990 ppm) reported so far for marine algae from the Sri Lankan coasts.

1. Introduction

As a part of our study of the mineral content of marine algae the boron content of some species of marine algae was estimated. Boron is one of the essential micronutrients for plants. Some plant diseases like top sickness of tobacco, heart rot of beets, brown heart of turnips, internal brown spot of sweet potatoes, split roots in carrots have been reported to be due to boron deficiency.[10] Usually borax [$Na_2B_4O_7.10H_2O$] is used as a source of boron in fertilizers. In this paper the quantity of boron present in eighteen species of marine algae is presented. The feasibility of using these algae as fertilizers is discussed. Results on the amounts of iodine, protein and other minerals present in nine species of marine algae from the Kirinda coast are also reported.

2. Experimental Methods and Materials

The seaweeds were collected from Kirinda and Mandaitivu coasts. About 500 – 750g samples of each of the seaweed species were collected from three to four different places in the same locality, bulked together, washed and air dried for three days. The moisture content was determined by drying in an oven at 105°C to constant weight. The ash content was determined by ashing weighed quantities of samples at 450°C in a muffle furnace until constant weight was obtained. The total nitrogen was determined by the Kjeldhal method[8] and protein [crude] content was calculated by multiplying the total nitrogen content by 6.25.[8] Iodine content was estimated by the alcoholic potash method.[4,5] The amounts of sodium, potassium, calcium, magnesium, trace elements, phosphorous, chloride [ionic] and sulphur [total] were determined by the methods reported previously.[6] The amount of carbonate in ash was determined by a known procedure.[3]

2.1 Determination of the amounts of boron

Seaweed samples of known weight [0.5 – 1.0g] from powdered bulk samples were mixed with $Ca(OH)_2$ [2g], ashed at 450°C and dissolved quantitatively in a known volume of 0.6M HCl. The amount of boron present was determined using curcumin-oxalic acid reagent.[3] The intensity of the colour produced was measured on a LKB–ULTROSPEC UV-Visible spectrophotometer [model 4050] at 540 nm wavelength. This determination was carried out in triplicate [deviation 3 ppm].

3. Results and Discussion

The amounts of boron present in eighteen species of seaweeds are given in Table 1. The results show that some of the algae such as *G. edulis* (202 ppm) *G. crassa* (242 ppm), *G. corticata* (208 ppm), *S. ceylanica* (234 ppm) and *C. clavulatum* (273 ppm) contain over 200 ppm boron. This is more than double the highest amount of boron (100 ppm) found in the leaves of land plants. The high amount of boron in these algae may be due to the relatively large amount of boron present in seawater. The seawater collected from Mandaitivu in June 1984 contains 3.5 ppm boron, whereas the well water samples from Jaffna, Kopay, Thirunelvely and Kondavil contain less than 0.7 ppm boron.

Normally borax ($Na_2B_4O_7 . 10H_2O$) is used as a source of boron in fertilizer as it is water soluble and could be leached down easily. Normal crops require[10] 1–5 kg of boron per hectare. Algae containing boron in excess of 200 ppm could be used as fertilizer so as to provide the required

Table 1. Boron content of Seaweeds in ppm (i.e. mg/kg air dried Seaweed)

Alga	Locality	Date of collection	Boron
(a) Rhodophyta			
1. *Gracilaria edulis* (Gmel) Silva	Mandaitivu	12.02.84	202
2. *Gracilaria crassa* J. Agardh	Mandaitivu	12.02.84	242
3. *Gracilaria fergusoni* J. Ag. I	Kirinda	27.02.83	135
II	Kirinda	15.05.83	110
4. *Gracilaria corticata* J. Ag.	Kirinda	27.02.83	208
5. *Sarcodia ceylanica* Harvey	Kirinda	27.02.83	234
6. *Centroceros clavulatum* J. Ag.	Mandaitivu	12.02.84	273
7. *Laurencia obtusa* (Huds.) Lamouroux	Mandaitivu	12.02.84	126
8. *Spyridia aculeata* J. Ag.	Kirinda	27.02.83	114
9. *Acanthophora delilei* Lamour.	Mandaitivu	12.02.84	57
10. *Polyopas ligulatus* (Harv.) Schmitz	Kirinda	15.05.83	51
11. *Chnoospora fastigiata* J. Ag.	Kirinda	27.02.83	91
12. *Jania natalensis* Harv.	Mandaitivu	12.02.84	43
13. *Amphiroa* sp. Lamour	Mandaitivu	12.02.84	74
14. *Cheilosporum spectabile* Harv.	Kirinda	27.02.83	13
15. *Corynomorpha prismatica* J. Ag.	Kirinda	15.05.83	140
(b) Chlorophyta			
16. *Ulva reticulata* Forsskal	Mandaitivu	12.02.84	58
17. *Ulva lactuca* Linnaeus	Mandaitivu	12.02.84	88
18. *Ulva fasciata* Delile	Kirinda	27.02.83	56

amount of boron. These algae would also provide other mineral nutrients required for plant growth. Of the species having more than 200 ppm boron, *G. crassa*[6], *G. edulis*[6], *G. corticata* and *C. clavulatum*[6] (see Tables 2,3 & 4) have high N, P, K values and are most suitable for use as fertilizers.

Moisture, ash, insoluble ash (insoluble in 0.6 M HCl), carbonate (in ash), nitrogen and protein (crude) contents of nine species of seaweeds from the Kirinda coast are given in Table 2. *Cheilosporum spectabile,* which like *Jania natalensis*[6] is capable of accumulating calcium and depositing it in the form of calcareous skeleton,[9] has the highest amount of ash, insoluble ash, calcium and carbonate. *G. corticata, C. spectabile* and *Ulva fasciata* have a relatively large percentage of insoluble ash, possibly due to accumulation of silica. Some of the algae, for example, *Spyridia aculeata, Corynomorpha prismatica,* and *Polyopas ligulatus* have 12–15% protein and this amount, is somewhat lower than those for some of the species of algae from northern Sri Lanka.[6]

Table 3 shows the amounts of sodium, potassium, calcium, magnesium chloride (ionic) and sulphur (total) found in the nine species of seaweeds from the Kirinda coast. The sodium content of these nine species are generally much higher than that of the species from the northern coast of Sri Lanka.[6] *C. prismatica* has the highest amount (> 10%) of sodium. It is interesting to note that this species also has the highest amount of chloride ions (7.93%) and relatively high total sulphur content (3.47%). Except for the *C. spectabile*, the calcium content of the marine algae from the Kirinda coast is generally lower than that of the algae from the northern coast of Sri Lanka. The *C. spectabile* has calcium content (20.1%) comparable to that of *J. natalensis*[6] (23.85%) and *Amphiroa* sp.[7] (23.29%) from the northern coast of Sri Lanka. This is consistent with the ability of these species to accumulate calcium and deposit it in the form of calcareous skeleton mainly as calcium carbonate. *G. corticata* has potassium in amounts (13.0%) comparable to that found in *G. edulis* (13.49%) from the Mandaitivu coast.[6] This species also has relatively high amounts of ionic chloride (4.36%) and total sulphur (3.86%).

The iron, phosphorus and iodine contents of the nine seaweed species from the Kirinda coast are given in Table 4. *G. corticata, S. aculeata* and *C. spectabile* have a relatively large quantity of iron. The algae species collected from the Kirinda coast generally have a higher phosphorus content than those from the northern coast of Sri Lanka. *G. fergusoni* and *P. ligulatus* have phosphorus in excess of 2000 ppm which is much higher than that of any of the marine algae collected from the northern coast of Sri Lanka. A similar trend is observed for the iodine content. *G. fergusoni* has a higher iodine content than reported for any other marine algae from the Sri Lankan coast. The iodine content of this species is nearly double that of the principal natural source, the caliche deposit of northern Chile.[1]

Table 2 : Moisture, Ash, Insoluble ash, Nitrogen and Protein (crude) contents of Seaweeds from Kirinda Coast. (g/100g air dried Seaweed)

	Alga	Moisture	Ash	Insoluble ash	Carbonate in ash	Nitrogen	Protein
1.	*Gracilaria corticata*	16.4	42.7	8.60	2.53	1.71	10.67
2.	*Gracilaria fergusoni* I	22.4	32.2	3.63	1.31	1.52	9.51
	II	19.4	33.4	4.02	1.52	1.52	9.51
3.	*Sarcodia ceylanica*	28.1	24.8	2.79	0.94	0.97	6.05
4.	*Spyridia aculeata*	17.1	20.3	6.53	2.54	2.07	12.93
5.	*Corynomorpha prismatica*	26.3	36.9	1.57	2.92	2.39	14.93
6.	*Chnoospora fastigiata*	23.9	32.6	1.50	2.47	0.98	6.13
7.	*Cheilosporum spectabile*	2.7	83.3	24.1	33.53	0.39	2.46
8.	*Polyopas ligulatus*	18.0	12.9	0.86	0.93	2.03	12.68
9.	*Ulva fasciata*	19.7	27.1	11.86	2.07	1.21	7.59

NOTE : *G. fergusoni* (II) and *C. prismatica* were collected in May 1983 and all the other samples were collected in February 1983.

Table 3 : Sodium, Potassium, Calcium, Magnesium, Chloride (ionic) and Sulphur (total) contents of Seaweeds from Kirinda coast. (g/100g air dried seaweed)

Alga	Sodium	Potassium	Calcium	Magnesium	Chloride (ionic)	Sulphur (total)
1. *Gracilaria corticata*	2.29	13.00	1.56	0.46	4.36	3.86
2. *Gracilaria fergusoni* I	4.33	6.80	0.81	0.38	6.66	2.13
II	3.40	8.84	0.93	0.52	6.09	2.16
3. *Sarcodia ceylanica*	5.70	1.59	0.50	0.66	4.41	3.82
4. *Spyridia aculeata*	1.30	0.96	0.87	2.91	3.09	1.46
5. *Corynomorpha prismatica*	10.43	1.35	1.62	1.24	7.93	3.47
6. *Chnoospora fastigiata*	6.42	8.01	1.33	0.71	4.70	1.14
7. *Cheilosporum spectabile*	1.38	0.13	20.10	1.80	1.35	0.66
8. *Polyopas ligulatus*	3.06	1.99	0.06	0.46	1.92	1.37
9. *Ulva fasciata*	2.00	0.68	0.42	2.46	1.26	2.36

NOTE : *G. fergusoni* (II) and *C. prismatica* were collected in May 1983 and all the other samples were collected in February 1983.

Table 4 : Iron, Phosphorus and Iodine contents of Seaweeds from Kirinda coast in ppm (i.e. mg/kg air dried seaweed)

Alga		Iron	Phosphorus	Iodine
1. *Gracilaria corticata*		1356	1606	186
2. *Gracilaria fergusoni*	I	468	1861	2109
	II	373	2120	3990
3. *Sarcodia ceylanica*		311	1274	179
4. *Spyridia aculeata*		1074	1030	112
5. *Corynomorpha prismatica*		458	1623	297
6. *Chnoospora fastigiata*		166	1199	182
7. *Cheilosporum spectabile*		1390	268	156
8. *Polyopas ligulatus*		68	2410	435
9. *Ulva fasciata*		187	902	129

NOTE : *G. fergusoni* (II) and *C. prismatica* were collected in May 1983 and all the other samples were collected in February 1983.

Table 5 : The amounts of trace elements present in seaweed from Kirinda coast in ppm (i.e. mg/kg air dried seaweed)

Alga		Cu	Zn	Mn	Ni	Pb	Cd	Co	Cr
1. *Gracilaria corticata*		11	16	38	28	22	2	23	20
2. *Gracilaria fergusoni*	I	5	12	26	6	28	2	9	6
	II	7	17	24	4	29	3	8	5
3. *Sarcodia ceylanica*		9	25	26	5	15	2	10	5
4. *Spyridia aculeata*		11	25	69	23	14	4	13	6
5. *Corynomorpha prismatica*		8	14	46	12	12	1	16	7
6. *Chnoospora fastigiata*		6	13	4	6	11	2	18	10
7. *Cheilosporum spectabile*		2	7	17	8	28	3	27	4
8. *Polyopas ligulatus*		5	14	5	5	10	0.4	27	–
9. *Ulva fasciata*		8	10	13	5	8	no detectable amount	3	7

NOTE : *G. fergusoni* (II) and *C. prismatica* were collected in May 1983 and all the other samples were collected in February 1983.

Table 5 gives the amounts of the trace elements copper, zinc, manganous, nickel, lead, cadmium, cobalt and chromium present in the nine species of marine algae under investigation. The elements copper, zinc, manganese, nickel, cobalt and chromium are essential nutritive (in small amounts) elements but are toxic to human and animals if they are present in large amounts. The amounts of these elements found in the nine species of marine algae are within the recommended limits which are as follows:- copper, 20 ppm; chromium, 100 ppm; nickel, 100 ppm; zinc, 50 ppm.[8] Lead and cadmium are non-nutritive toxic elements. The level of cadmium in these species of seaweeds is low. However the lead content is well above the limit of 2 ppm. The lead content of the seaweeds from the Kirinda coast generally appears to be much higher than that of the seaweeds from the northern coast of Sri Lanka.[6] Compared to the seaweeds from the northern coast of Sri Lanka the seaweeds from the Kirinda coast have relatively high zinc, cobalt and chromium contents and low manganous and nickel contents. The element cobalt which is important in metabolising sulphur containing amino acid, is found in reasonable amounts (> 20 ppm) in *G. corticata, C. spectabile* and *P. ligulatus.* This element and chromium could not be detected[6] in the species of seaweeds collected from the northern coast of Sri Lanka. The mineral contents reported in this paper were determined on algal species collected during one season. Work is being carried out to study the seasonal variation of the mineral contents.

4. Conclusion

Seaweeds such as *G. edulis, G. crassa, C. clavulatum* from the Mandaitivu coast and *G. corticata* and *S. ceylanica* from the Kirinda coast have relatively large amounts of boron. These species are also rich in nitrogen, potassium, phosphorus and other minerals and could be used as fertilizers. *G. fergusoni* is rich in iodine and could be used for the manufacture of iodine. This species could also be used to supplement human diet and animal feed to provide the iodine which is required to control goitre disease. As expected the algae growing in Kirinda coast have a relatively low calcium content than those from the Mandaitivu coast. However they generally have higher sodium and phosphorus content. It is recommended that selected species of algae should be cultivated with the aim of using them as fertilising material.

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PREPARATION AND PROPERTIES OF SOME METAL COMPLEXES OF PLUMBAGIN

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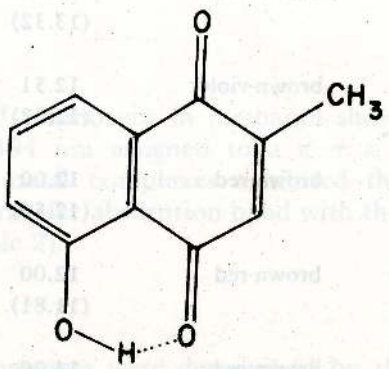
Abstract : The preparation and the characterisation of the complexes formed by plumbagin, a naturally occurring naphthaquinone with the ions Cu(II), Ni(II), Co(II), Mn(II), Zn(II) and Hg(II) is reported. The stability constants of these complexes in solution have been determined using potentiometric titration techniques. The high values observed for the stability constants may have some relevance to support the hypothesis that certain carrier molecules are involved in the uptake of metal ions by plants.

1. Introduction

As a part of an investigation on the naturally occurring ligands we have studied the complex forming ability of plumbagin (I), a naturally occurring naphthaquinone. This paper reports the preparation, characterisation and the solution studies on several of these complexes. These studies may have some relevance to the theory[2] that carrier molecules which form complexes with metal ions are important in metal ion uptake and transport in plants.



2. Experimental

Plumbagin was isolated from the dried root extract of *Aristea ecklonii* as previously published.[4] The product was crystallized as bright orange needles from hexane. The purity of plumbagin was verified by its melting point, ^{1}H NMR, IR and TLC data. The IR spectra were obtained in KBr discs using a Perkin-Elmer 257 spectrophotometer and the UV–VIS spectra using Pye-Unicam model SP 8000 spectrophotometer. The ^{1}H NMR were obtained from a Varian T60 instrument. The pH measurements during the potentiometric titrations were obtained from a Corning model 5 pH meter equipped with combination glass and calomel electrodes. The pH meter was calibrated using standard Corning buffer solutions having pH values 7.00 and 4.00 at 25 ± 1°C. The solvents and chemicals used were of reagent grade. The C–H analysis of these complexes were carried out by Ciba-Geigy Ltd., Geneva, Switzerland.

2.1 Preparation of the complexes

The Cu(II), Ni(II), Co(II), Mn(II), Zn(II), Mg(II) complexes of plumbagin were prepared by mixing the appropriate metal acetate solutions in methanol with hot methanolic solutions of plumbagin. The resultant mixture was heated in a water bath for about 15 min and the precipitates obtained were filtered, washed with hot methanol and dried in vacuo. The yields, in most cases, were 50–60% (based on plumbagin). The analytical data and the colours of the complexes are given in Table 1. The metal analyses were carried out by standard colorimetric methods.

Complex	Colour	Found (Calc.)%		
		Metal	C	H
$Cu(C_{11}H_7O_3)_2.2H_2O$	brown red	13.83 (13.32)	55.10 (55.81)	3.60 (3.80)
$Ni(C_{11}H_7O_3)_2.2H_2O$	brown-violet	12.51 (12.52)	55.00 (56.32)	4.00 (3.84)
$Co(C_{11}H_7O_3)_2.2H_2O$	brown-red	12.00 (12.56)	56.00 (56.31)	3.80 (3.83)
$Mn(C_{11}H_7O_3)_2.2H_2O$	brown-red	12.00 (11.81)	56.30 (56.78)	3.90 (3.87)
$Zn(C_{11}H_7O_3)_2.2H_2O$	brown-red	14.00 (13.75)	55.20 (55.53)	3.80 (3.78)
$Mg(C_{11}H_7O_3)_2.2H_2O$	brown-red	5.50 (5.59)	61.00 (60.78)	3.90 (4.14)

Table 1. Analytical data and the colours of the plumbagin metal complexes.

2.2 Determination of stability constants

Solutions containing plumbagin (5.0×10^{-4} M) and metal acetates (2.5×10^{-4} M) were titrated with carbonate free 0.1 M KOH at μ = 0.1 M (KCl) under an atmosphere of nitrogen and the pH recorded, after the addition of 0.2 ml aliquots of alkali.

3. Results and Discussion

All these complexes possess different shades of brown red colour. The elemental analysis (Table 1) indicate 1:2 (metal:ligand) stoichiometry for all these complexes. The copper complex is slightly soluble in chloroform while all the other complexes are insoluble in chloroform. However, all these complexes are readily soluble in DMSO and pyridine. Their melting points were found to be above 250°C.

3.1 Infrared spectra

Plumbagin has two carbonyl groups, with the hydrogen bonded one appearing at 1640 cm^{-1} and the other at 1660 cm^{-1} (Figure 1). Only the hydrogen bonded carbonyl group should be affected by complex formation and this is indeed what is observed. In the complexes, the carbonyl stretch of free plumbagin at 1640 cm^{-1} appears in the range of 1620–1630 cm^{-1}. Such downward shifts in the carbonyl stretching frequencies of coordinated carbonyl groups have been previously observed[1] in the metal complexes of 1–hydroxyxanthone. This provides definite evidence for the participation of the carbonyl group in the bonding of these complexes. The possible structures for a typical metal complex of plumbagin are shown in Figures II

3.1.1 Electronic spectra

The UV–VIS spectrum of plumbagin in methanol shows a characteristic absorption maximum at 394 nm assigned to a $\pi \rightarrow \pi^*$ transition of the carbonyl group. All the metal complexes exhibited the presence of an additional intense charge transfer absorption band with the maximum in the range of 450–460 nm (Table 2).

3.2 Solution studies

The successive stability constants were determined by the potentiometric techniques and calculated by the method of Irving and Rosotti.[3]

The stability constants calculated in this manner are given in Table 3. These are in agreement with the Mellor-Maley's series[5] for divalent metal

Table 2 Electronic spectral data of the plumbagin metal complexes

Complex	Absorption maximum (nm)	(Epsilon x 10^6)
$C_{11}H_8O_3$(plumbagin)	394	(3.1)
$Cu(C_{11}H_7O_3)_2.2H_2O$	460	(7.1)
$Ni(C_{11}H_7O_3)_2.2H_2O$	452	(6.8)
$Co(C_{11}H_7O_3)_2.2H_2O$	460	(5.9)
$Mn(C_{11}H_7O_3)_2.2H_2O$	465	(7.3)
$Zn(C_{11}H_7O_3)_2.2H_2O$	450	(6.3)
$Mg(C_{11}H_7O_3)_2.2H_2O$	456	(5.7)

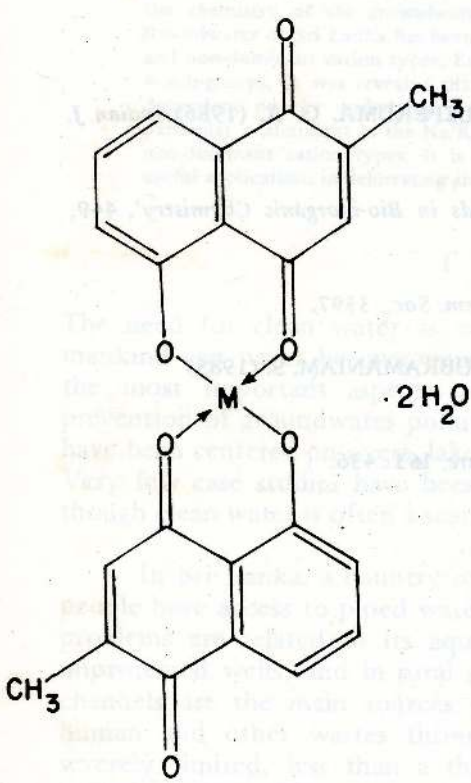
Table 3. Stability constants of plumbagin metal complexes

Metal ion	log K_1	log K_2
Cu(II)	5.31	4.93
Ni(II)	4.90	4.54
Co(II)	4.84	4.66
Mn(II)	4.80	4.28
Zn(II)	4.45	3.74
Mg(II)	4.32	3.73

ions for the corresponding 8–hydroxyquinoline complexes:

Cu(II) > Ni(II) > Zn(II) > Co(II) > Mn(II) > Mg(II)

Studies on complex formation of biologically important metal ions may be important in understanding metal ion transport and storage in plants. The metal ions move against a concentration gradient in the root hairs. The exact mechanism of how the metal ions pass through the cell membrane is not well understood. It has been proposed that certain carrier molecules are involved in this type of transport,[2] analogous to, for example, the role of ferrichromes in the uptake of iron by certain types of bacteria.



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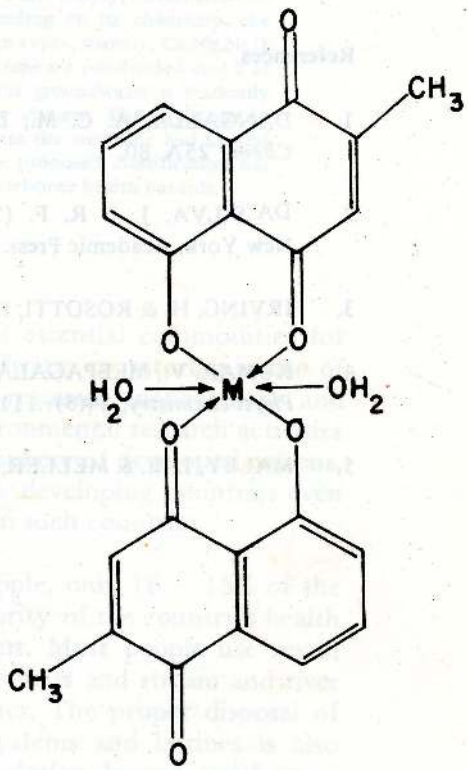

IIb

4. Conclusion

In this context, the results described above on the complex formation by a naturally occurring ligand may provide a model for the uptake, transport and the storage of nutrient metal ions by plants.

Acknowledgement

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A GEOCHEMICAL CLASSIFICATION OF GROUNDWATER OF SRI LANKA

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Abstract : This paper presents a detailed geochemical classification of groundwater of Sri Lanka. In view of the fact that nearly 85% of the population of Sri Lanka use well water and other non-piped water for their drinking water supply, information on the chemistry of the groundwater is essential. Depending on its chemistry, the groundwater of Sri Lanka has been classified into 4 main types, namely, Ca,Mg,Na/K and non-dominant cation types. Each of these major groups are sub-divided into 2 or 4 sub-groups. It was revealed that the chemistry of the groundwater is markedly dependent on the underlying geology as well as the climate. The dry zone in particular is abundant in the Na/K type of water whereas the wet zone had Ca and non-dominant cation types. It is also shown that the proposed classification has useful applications in delineating areas susceptible to waterborne health hazards.

1. Introduction

The need for clean water as one of the most essential commodities for mankind can never be over-emphasized. Groundwater monitoring is one of the most important aspects of groundwater resource management and prevention of groundwater pollution. Most environmental research activities have been centered on rivers, lakes and the atmosphere of developed nations. Very few case studies have been reported from developing countries even though clean water is often a scarce commodity in such countries.

In Sri Lanka, a country of 15 million people, only 10 – 15% of the people have access to piped water, and the majority of the country's health problems are related to its aquatic environment. Most people use small, unprotected wells, and in rural settlements, reservoirs and stream and river channels are the main sources of drinking water. The proper disposal of human and other wastes through sewerage systems and latrines is also severely limited, less than a third of the population having satisfactory latrine facilities. The poor water supply and excreta disposal systems have resulted in 40% of the Sri Lankan population being affected by typhoid, amoebic and bacillary dysentery, infectious hepatitis, gastro-enteritis, colitis and worm infections. The need to carefully monitor the groundwater quality of Sri Lanka, is therefore of high priority and upto now this aspect has been neglected.

Environmental geochemistry essentially deals with the geographical distribution of elements and forms the basis for a variety of interdisciplinary studies involving human and animal health, quality of groundwater, agriculture and nutrition, soil fertility, pollution and mineral exploration. The study of the abundance and distribution of some trace elements and the resulting biological manifestations involves geochemists, public health workers, soil scientists, ecologists and nutritionists.

The chemical quality of groundwater is related to the geology of the area concerned. For example, areas underlain by acid igneous rocks such as granite or arenaceous sedimentary rocks generally contain lower levels of essential trace elements – particularly the first row transition elements – than areas underlain by ultrabasic and igneous rocks or shale. These however, may sometimes contain sufficient concentrations of potentially toxic elements.[15]

It is the aim of this paper to present a detailed chemical classification of the groundwater of Sri Lanka. It is hoped that this chemical classification would help, not only the hydrogeochemist, but also town and country planners and those engaged in the implementation of rural water supply schemes.

2. Materials and Methods

Figure 1 illustrates the general geology and climate of Sri Lanka and Figure 2, the locations of the sampling points for groundwater. All water samples were collected in acid-washed polyethylene bottles and kept cool and dark until tested. All samples were collected during the period July–December 1982. The appendix shows the details of locations. Three samples were taken from each location, for the determination of the following :

Sample 1 : Total dissolved solids, Cl^-, F^-, SO_4^-, HCO_3^-
Sample 2 : NO_3^-, NO_2^-, NH_4^+
Sample 3 : Na, K, Ca, Mg, Fe, Mn, Co, Cr, Cu, V, Zn, SiO_2

2.1 Analytical procedures

The total dissolved solids (TDS), Cl^-, F^-, SO_4^{2-} and HCO_3^- determinations were carried out using 1000 ml of well-mixed unacidified filtered samples (Sample 1). Following the methods of Brown *et. al.*,[1] TDS SO_4^{2-} Cl^- and HCO_3^- measurements were carried out by gravimetry and titrimetry respectively. The fluoride contents of the water were determined by the use of specific ion electrode.[13]

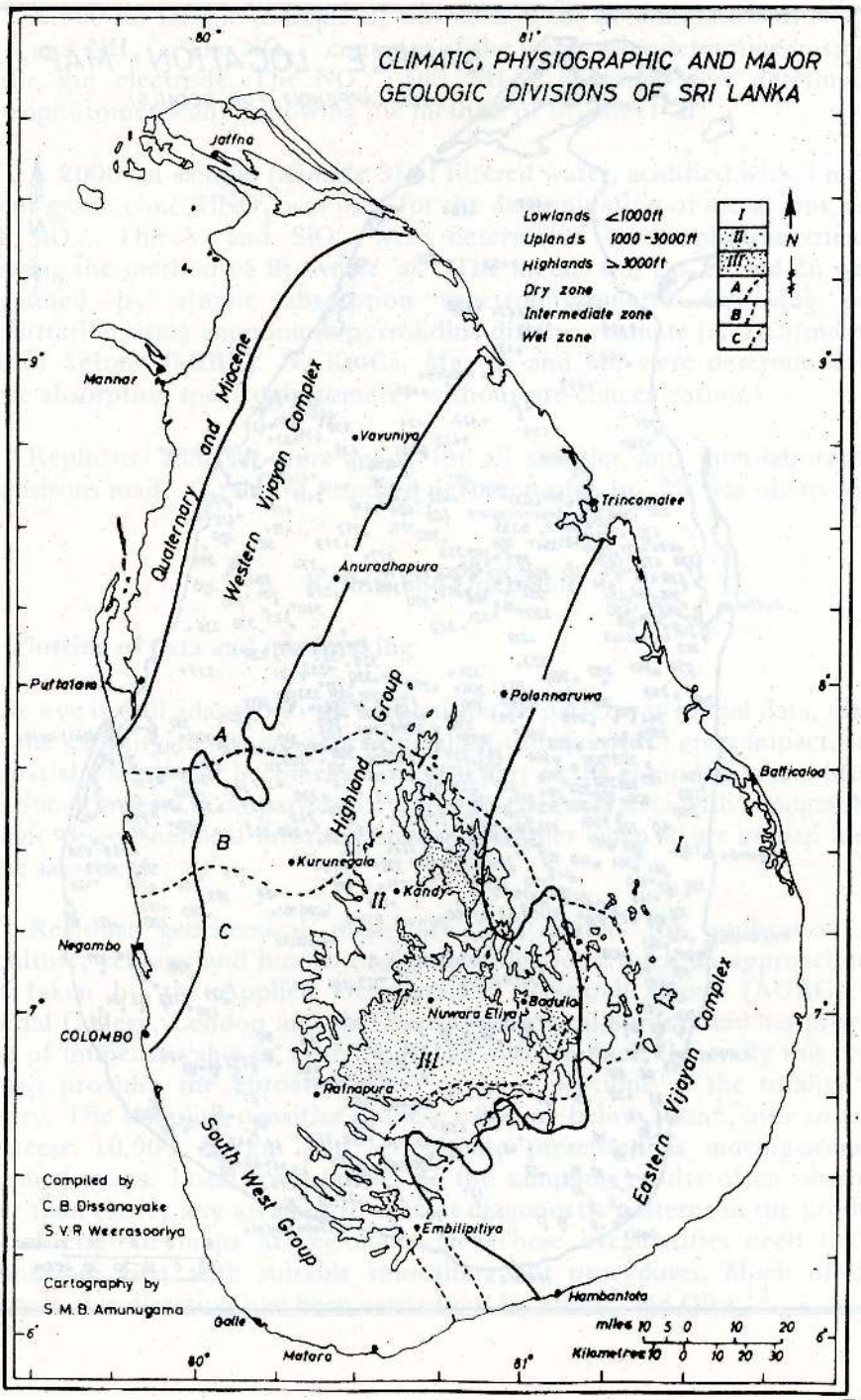


Figure 2. Map showing the locations of sampling points.

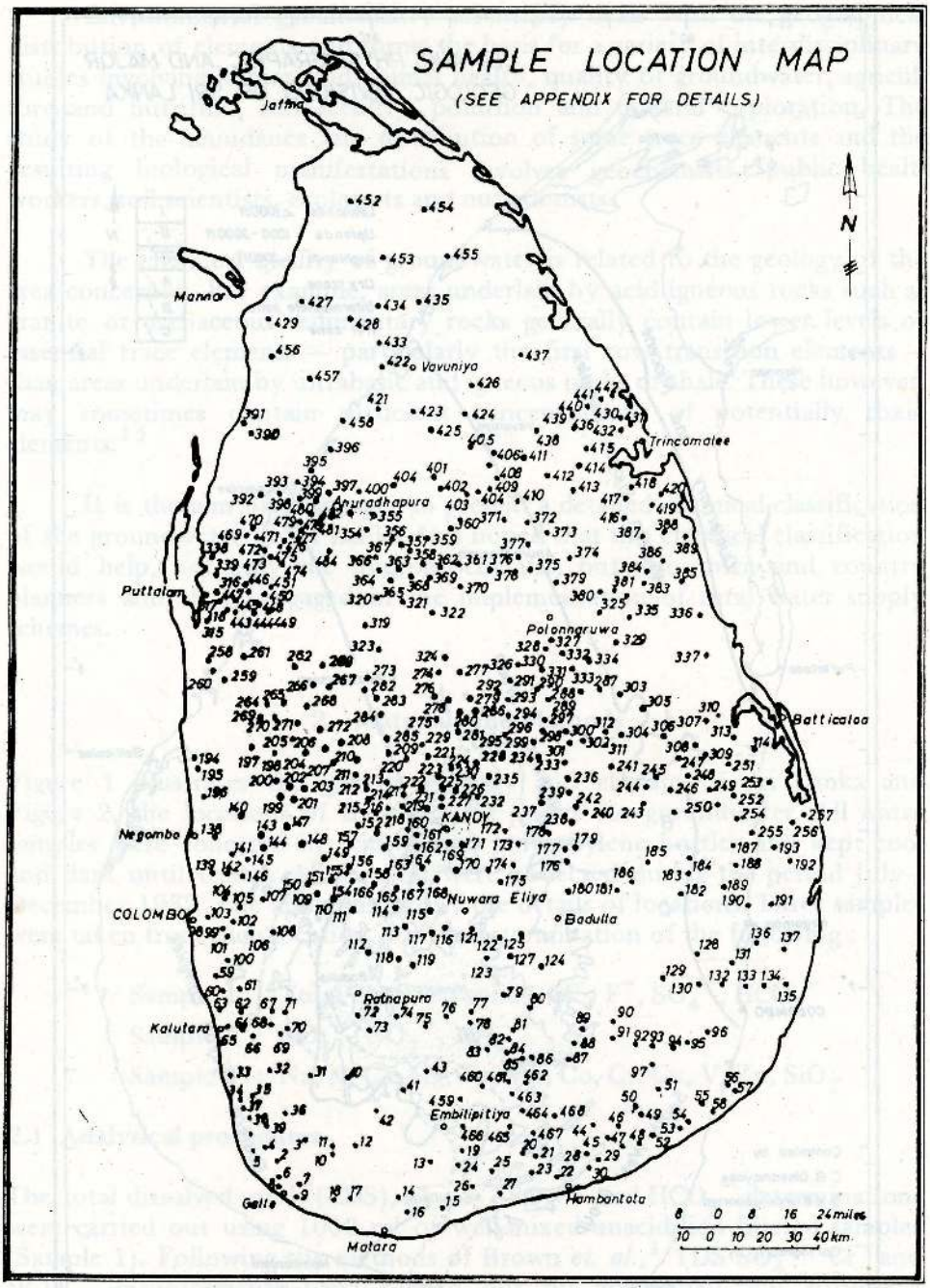


Figure 1. Map showing the climate and geology of Sri Lanka.

A 500 ml sample (Sample 2) was used in the determination of NO_3^-, NO_2^- and NH_4^+. The NO_3^- contents of the water were determined using a specific ion electrode. The NO_2^- and NH_4^+ contents were determined spectrophotometrically following the method of Brown *et al*[1].

A 2000 ml sample (Sample 3) of filtered water, acidified with 3 ml of reagent grade conc. HNO_3 was used for the determination of metal ions, and total SiO_2. The V and SiO_2 were determined spectrophotometrically following the method of Brown *et al.*[1] The metals Cu, Co, Cr and Zn were determined by atomic absorption spectrophotometry following pre-concentration using ammonium pyrrolidine dithiocarbamate (APDC)/methyl isobutyl ketone (MIBK). N, K, Ca, Mg, Fe and Mn were determined by atomic absorption spectrophotometry without pre-concentration.[7]

Replicate analyses were made for all samples and inter-laboratory comparisons made. A relative standard deviation of ± 1 – 5% was observed.

3. Results and Discussion

3.1 Plotting of data and map making

As the eye is well adapted to the recognition of patterns in spatial data, maps have the capacity to present geochemical information with great impact, and the spatial component becomes an integral part of the compilation and interpretational process. Comparison of hydrogeochemical data with topographic geologic or geochemical information is made easier when all are in map form on the same scale.

Regional geochemical maps are best suited for application in agriculture, ecology and human health investigations. Such an approach has been taken by the Applied Geochemistry Research Group (AGRG) of Imperial College, London and the British Geological Survey, and has proved to be of immense value in a large number of disciplines. Generally this type of map provides the broadest view of large portions or the totality of country. The sampling densities of these maps are below 1 km^2, over an area in excess 10,000 sq km and are usually presented as moving-average smoothed maps. Local irregularities of the sampling results often obscure rather than clarify any attempt to extract diagonostic patterns in the production of contour maps at regional scale. These irregularities need to be harmonized, first with suitable smoothing out procedures. Much of the studies in this direction had been carried out by Davis[2] and Olea.[11]

3.2 The chemical basis for the classification of groundwater

The major constituents in aquatic systems include Ca, Mg, Na, K, HCO_3^-, CO_3^{2-}, SO_4^{2-} and Cl^-. The proportions of these eight geochemically significant constituents in natural solution provides the basis for naming the water type. To provide a basis for comparison of water types and to relate them to specific environments, a graphic method of illustrating data and appropriate terminology must be adopted.

The Piper diagram[12] is a multiple trilinear diagram for graphic representation of the major chemical constituents of water, and effectively portrays analytical data. Similar analytical techniques were developed by Hill,[9] Langelier and Ludwig[10] and Romani.[14] The model used in this study is a modification by Hem.[8] Piper diagrams are used in various ways in hydrogeochemistry. The simplest application is merely to display data to represent distinctions among individual water samples. A fairly recent and promising modification of the Piper diagram involves the use of component cation and anion diagrams to classify water. The water type is generally named after the dominant cations and dominant anions – defined as constituting more than 50% of the cation or anion. This has been accomplished graphically by joining the mid-points of each side of each triangular field which divides each triangular diagram into 4 smaller triangles. Thus a water type is easily named, based on the positioning of the points in the cation and anion triangles. Unless there are non-dominant cations or anions, the water type is named after the cations (Ca, Mg, Na/K) followed by a hyphen and a similar term selected for anion possibilities (SO_4, Cl, HCO_3/CO_3). When a water type plots in the Piper diagram in the non-dominant cation or non-dominant anion fields, it indicates that on percentage epm basis, no ion is present in an amount greater than 50%. In such instances, non-dominant cation (NDC) or non-dominant anion (NDA) forms the descriptive name.

3.3 The chemistry of the groundwater of Sri Lanka

The groundwater of Sri Lanka can be classified into the following 4 main water types. The appendix shows all chemical data pertaining to this study.

1. Calcium type
2. Magnesium type
3. Sodium/potassium type
4. Non-dominant cation type

Figure 3 illustrates the distribution of these 4 major water types in Sri Lanka. Each type is further sub-divided into the Cl, SO_4, HCO_3 and NDA types. Table 1 shows the average for the elements and ionic species.

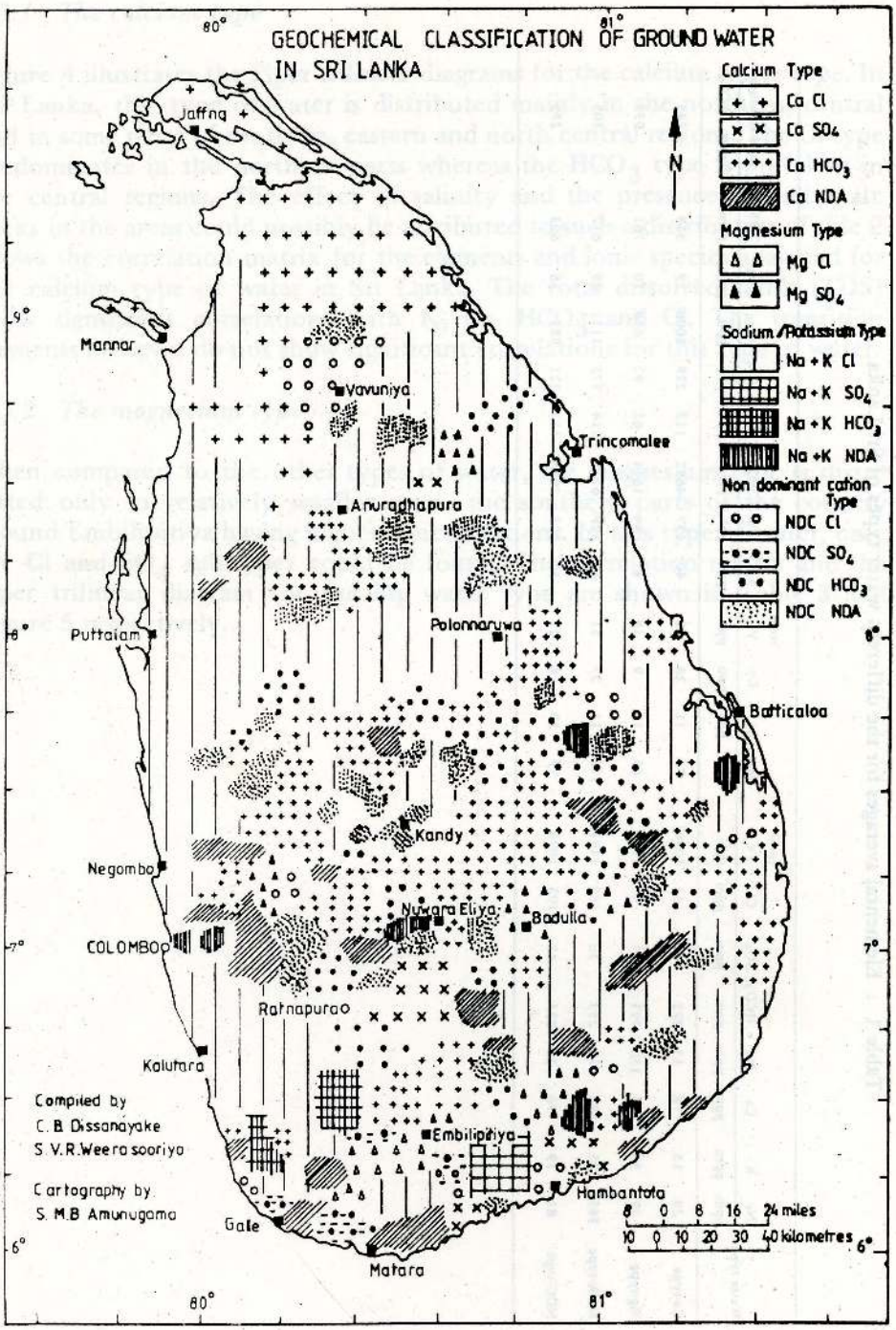


Figure 3. Map showing the distribution of the major groundwater types in Sri Lanka.

Table 1 : Elemental averages for the different water types of Sri Lanka

Water type	Na	K	Ca	Mg	HCO_3	SO_4	Cl	total Fe	Mn	Cr	Co	total V	Cu	Zn	NO_3	NO_2	NH_4	F	SiO_2	TDS	total Hardness
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppm	ppm	ppm, $CaCO_3$
Ca-type	28	15	78	13	222	41	62	1088	76	11	28	58	40	137	4657	113	229	1006	19	358	245
Mg-type	39	38	104	158	393	649	38	1457	65	13	9	38	45	84	1614	62	97	638	10	761	938
Na/K-type	345	35	82	18	253	36	589	1443	112	11	27	51	66	129	6128	114	175	1121	25	617	305
NDC-type	81	19	76	25	253	45	195	1098	79	10	18	22	52	113	3966	113	221	983	18	603	255

3.3.1 The calcium type

Figure 4 illustrates the Piper trilinear diagrams for the calcium water type. In Sri Lanka, this type of water is distributed mainly in the northern, central and in some parts of 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. The effect of salinity and the presence of carbonate rocks in the areas could possibly be attributed to such a distribution. Table 2 shows the correlation matrix for the elements and ionic species analyzed for the calcium type of water in Sri Lanka. The total dissolved solids (TDS) show significant correlations with K, Ca, HCO_3 and Cl. The transition elements however do not show significant correlations for this type of water.

3.3.2 The magnesium type

When compared to the other types of water, the magnesium type is distributed only in relatively smaller areas, the southern parts of the country around Embilipitiya having higher concentrations. In this type of water, only the Cl and SO_4 sub-types could be found. The correlation matrix and the Piper trilinear diagram for the Mg water type are shown in Table 3 and Figure 5 respectively.

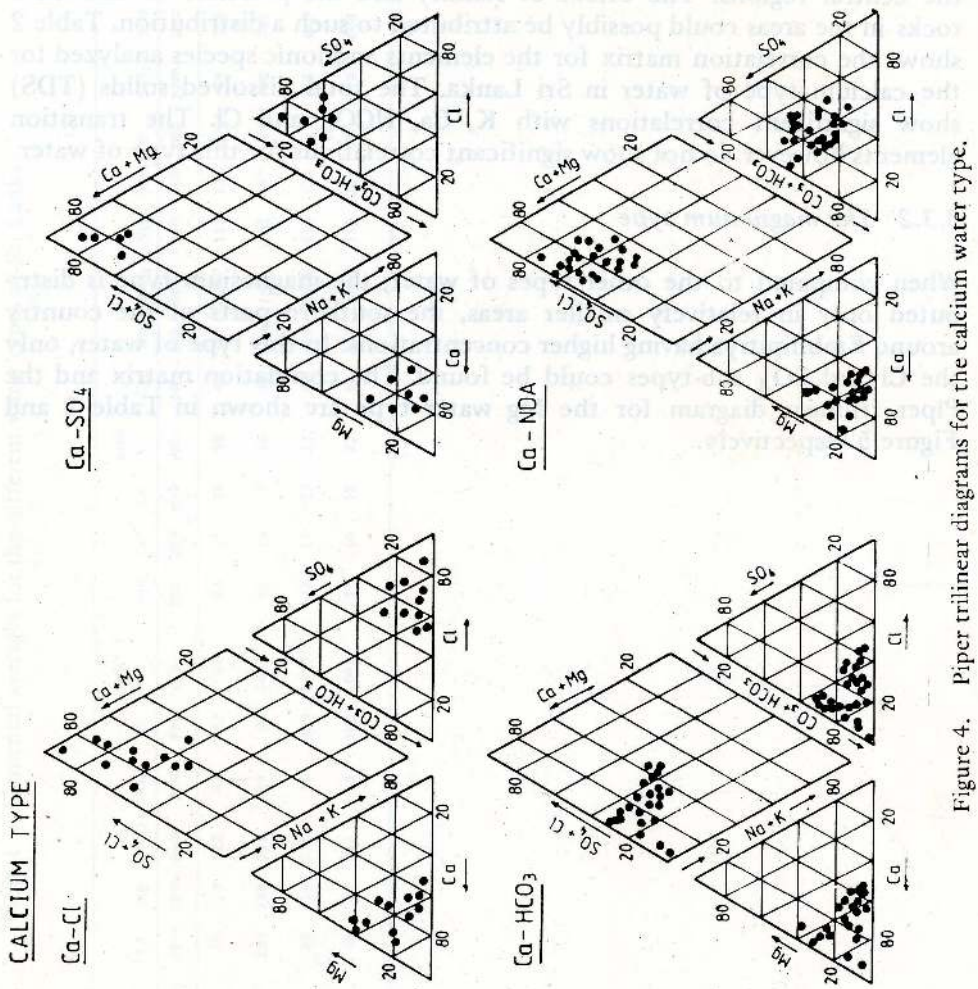


Figure 4. Piper trilinear diagrams for the calcium water type.

Table 2 : Correlation matrix for the calcium type

	Na	K	Ca	Mg	HCO_3	SO_4	Cl	Fe	Mn	Cr	Co	V	Cu	Zn	NO_3	NO_2	NH_4	F	SiO_2	TDS
Na	1.000	0.472*	0.479*	−0.021	0.344	0.028	0.737*	−0.177	0.063	−0.107	0.019	0.072	0.317	−0.006	0.004	−0.093	0.045	0.210	0.187	0.436
K		1.000	0.448	0.021	0.290	0.012	0.728*	−0.117	0.079	−0.148	−0.037	0.040	0.074	−0.081	0.077	−0.012	0.002	0.055	0.205	0.534*
Ca			1.000	0.175	0.851*	0.312	0.593*	−0.181	0.089	−0.113	0.002	0.137	0.249	−0.027	−0.159	−0.146	0.077	0.244	0.149	0.784*
Mg				1.000	0.272	0.331	0.011	−0.026	0.141	−0.043	−0.084	−0.010	0.083	0.023	0.012	−0.149	0.069	−0.050	0.035	0.249
HCO_3					1.000	0.190	0.342	−0.315	0.134	−0.182	0.062	0.185	0.322	0.156	−0.288	−0.031	0.216	0.301	0.033	0.596*
SO_4						1.000	0.003	0.171	0.188	0.134	−0.030	0.109	0.080	−0.014	−0.045	−0.054	0.048	−0.057	0.143	0.108
Cl							1.000	−0.123	0.053	0.103	−0.025	0.012	0.150	−0.087	0.026	−0.112	0.021	0.160	0.248	0.654*
Fe								1.000	−0.094	0.189	0.049	−0.100	−0.297	0.230	0.192	−0.112	−0.155	0.228	0.072	0.201
Mn									1.000	0.117	−0.024	0.164	0.194	0.041	−0.177	0.086	0.119	0.034	0.067	0.058
Cr										1.000	−0.143	0.166	−0.120	0.083	0.074	−0.071	−0.098	0.041	−0.013	−0.074
Co											1.000	−0.007	0.100	−0.098	−0.080	−0.064	0.073	0.145	0.078	0.028
V												1.000	0.028	0.173	−0.198	−0.081	−0.091	0.007	0.116	−0.112
Cu													1.000	0.080	0.197	0.185	0.395	0.294	−0.149	0.204
Zn														1.000	−0.222	0.063	−0.091	0.278	−0.071	0.036
NO_3															1.000	−0.025	−0.216	−0.189	0.048	−0.132
NO_2																1.000	0.165	0.129	−0.152	0.099
NH_4																	1.000	−0.048	0.028	0.107
F																		1.000	−0.006	0.184
SiO_2																			1.000	0.214
TDS																				1.000

* Significant at 95% confidence level

Table 3 : Correlation matrix for the magnesium type

	Na	K	Ca	Mg	HCO_3	SO_4	Cl	Fe	Mn	Cr	Co	V	Cu	Zn	NO_3	NO_2	NH_4	F	SiO_2	TDS
Na	1.000	0.931*	0.954*	0.882*	0.834*	0.947*	−0.379	0.237	0.298	0.068	−0.306	0.003	0.238	−0.063	0.246	−0.163	−0.111	−0.170	−0.202	−0.177
K		1.000	0.957*	0.808*	0.764*	0.919*	−0.166	0.075	0.286	−0.088	−0.099	−0.005	−0.041	−0.091	0.127	−0.137	−0.073	−0.089	−0.064	0.007
Ca			1.000	0.876*	0.828*	0.964*	−0.162	0.129	0.225	0.026	−0.081	0.014	−0.020	−0.142	0.153	−0.199	0.115	0.137	−0.151	−0.067
Mg				1.000	0.874*	0.956*	−0.465	0.283	0.448	0.166	−0.389	0.234	−0.278	−0.197	0.081	−0.207	−0.163	−0.144	−0.362	0.082
HCO_3					1.000	0.813*	−0.251	0.032	0.239	0.048	−0.156	0.105	−0.029	−0.164	0.131	−0.115	−0.069	0.020	−0.313	−0.007
SO_4						1.000	−0.354	0.252	0.369	0.111	−0.284	0.123	−0.212	−0.148	0.126	−0.202	−0.156	−0.173	−0.228	0.009
Cl							1.000	−0.525*	−0.424	−0.305	0.977*	−0.054	0.858*	−0.034	−0.179	0.065	−0.077	0.041	0.292	0.157
Fe								1.000	0.399	0.328	−0.427	0.200	−0.631*	−0.328	0.327	−0.336	−0.597*	0.595*	−0.345	0.067
Mn									1.000	−0.037	−0.403	0.628*	−0.459	−0.241	−0.553*	−0.326	0.327	0.248	−0.270	0.416
Cr										1.000	−0.229	0.330	−0.434	0.265	0.259	−0.010	0.290	−0.540*	−0.138	−0.265
Co											1.000	−0.016	0.844*	−0.128	−0.142	−0.011	0.150	−0.027	0.220	0.190
V												1.000	−0.155	−0.337	−0.430	−0.406	−0.467	0.305	−0.594*	0.487
Cu													1.000	−0.131	−0.144	0.139	−0.066	0.261	0.225	0.306
Zn														1.000	0.159	0.837*	0.077	−0.255	0.723*	−0.307
NO_3															1.000	0.239	−0.178	−0.253	−0.033	−0.370
NO_2																1.000	−0.007	−0.169	0.685*	0.080
NH_4																	1.000	0.892*	0.100	−0.410
F																		1.000	−0.912*	0.125
SiO_2																			1.000	−0.116
TDS																				1.000

* Significant at 95% confidence level

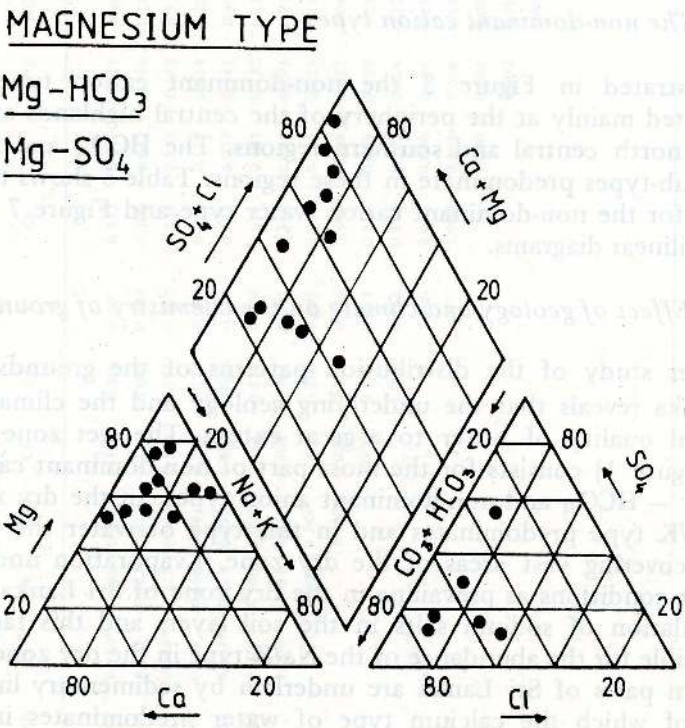


Figure 5. Piper trilinear diagrams for the magnesium water type.

3.3 3 *The sodium potassium type*

This type forms a major group and is distributed widely in Sri Lanka, particularly around the central region. The north western and north central and the south eastern dry zones mainly contain this type of groundwater. From among the sub-types, the Cl type is predominantly found in these regions. Excessive evaporation and probably influence of salinity may have contributed to the prevalence of this water type. Table 4 shows the correlation matrix for the Na/K water type and Figure 6 illustrates the Piper trilinear diagrams.

3.3.4 The non-dominant cation type

As illustrated in Figure 3 the non-dominant cation type of water is distributed mainly at the periphery of the central highlands and some parts of the north central and southern regions. The HCO_3 and non-dominant anion sub-types predominate in these regions. Table 5 shows the correlation matrix for the non-dominant cation water type and Figure 7 illustrates the Piper trilinear diagrams.

3.3.5 Effect of geology and climate on the chemistry of groundwater

A closer study of the distribution patterns of the groundwater types in Sri Lanka reveals that the underlying geology and the climate affects the chemical quality of water to a great extent. The wet zone of Sri Lanka (See Figure 1) consists for the most part of non-dominant cation types and calcium – HCO_3 and non-dominant anion types. In the dry zone however, the Na/K type predominates and in this type of water the Cl sub-type is found covering vast areas of the dry zone. Evaporation under the strong drought conditions as prevailing in the dry zone of Sri Lanka results in the accumulation of sodium salts in the soil layers and this factor is largely responsible for the abundance of the Na/K type in the dry zone. Further, the northern parts of Sri Lanka are underlain by sedimentary limestones, as a result of which the calcium type of water predominates in these parts. Increasing salinity has been observed in areas closer to the shore-lines and in the Jaffna Peninsula in particular, this is commonly seen. The predominating anion in this type of water in the dry zone is Cl.

When one considers the topography, the central highlands have groundwater of the Ca – HCO_3 type and with decreasing elevation, merges into the non-dominant cation type. In the lowlands the Na/K type predominates. Thus a Ca → NDC → Na/K type of sequence is apparent with decreasing elevations from the highlands to lowlands. This sequence could well be due to the different geochemical mobilities of the elements concerned. Further, there are numerous shallow and deep seated fractures and lineaments within the central regions of Sri Lanka and these are mainly responsible for the migration of groundwater within the hardrock terrains.

Table 4 : Correlation matrix for the sodium/potassium type

	Na	K	Ca	Mg	HCO_3	SO_4	Cl	Fe	Mn	Cr	Co	V	Cu	Zn	NO_3	NO_2	NH_4	F	SiO_2	TDS
Na	1.000	0.077	0.634*	0.472*	0.635*	0.093	0.950*	−0.045	0.206	−0.320	0.269	0.007	0.322	0.217	−0.115	−0.248	0.193	0.218	0.123	0.400*
K		1.000	0.076	0.002	0.051	0.145	0.155	−0.123	0.020	−0.161	0.005	0.028	−0.100	−0.042	0.134	−0.165	0.076	0.307	0.039	−0.008
Ca			1.000	0.581*	0.894*	0.176	0.686*	−0.215	0.067	−0.305	0.155	−0.007	0.265	0.156	0.162	−0.318	0.429*	0.219	0.169	0.496*
Mg				1.000	0.677*	0.277	0.519	−0.168	−0.041	0.262	−0.176	−0.099	0.213	0.119	0.214	−0.222	0.156	0.127	0.184	0.297
HCO_3					1.000	0.064	0.661*	−0.213	0.012	−0.307	−0.067	−0.075	0.375	0.077	−0.131	−0.302	0.385	0.202	0.156	0.526*
SO_4						1.000	0.076	−0.206	0.092	0.184	−0.175	0.074	−0.019	0.102	−0.132	−0.154	0.047	0.044	0.194	0.004
Cl							1.000	−0.051	0.237	−0.308	0.301	0.001	0.340	0.268	−0.193	−0.272	0.167	0.247	0.128	0.445*
Fe								1.000	0.244	0.355	0.206	−0.009	−0.061	0.142	0.225	0.144	−0.107	−0.054	−0.147	−0.154
Mn									1.000	0.050	0.273	0.130	0.446*	0.268	0.053	−0.048	0.046	0.300	−0.103	0.002
Cr										1.000	−0.103	0.014	−0.259	0.098	0.102	0.255	−0.148	−0.114	−0.213	−0.123
Co											1.000	0.241	0.181	0.213	−0.024	−0.125	0.083	0.250	−0.050	0.072
V												1.000	0.050	0.050	0.196	−0.119	0.029	0.155	−0.046	−0.109
Cu													1.000	0.305	0.016	0.186	0.076*	0.493	0.084	0.236
Zn														1.000	0.002	−0.020	0.061	0.322	0.050	0.005
NO_3															1.000	0.199	0.030	−0.183	−0.024	−0.140
NO_2																1.000	−0.127	−0.210	−0.133	−0.176
NH_4																	1.000	−0.068	0.131	0.294
F																		1.000	−0.036	0.043
SiO_2																			1.000	0.093
TDS																				1.000

* Significant at 95% confidence level

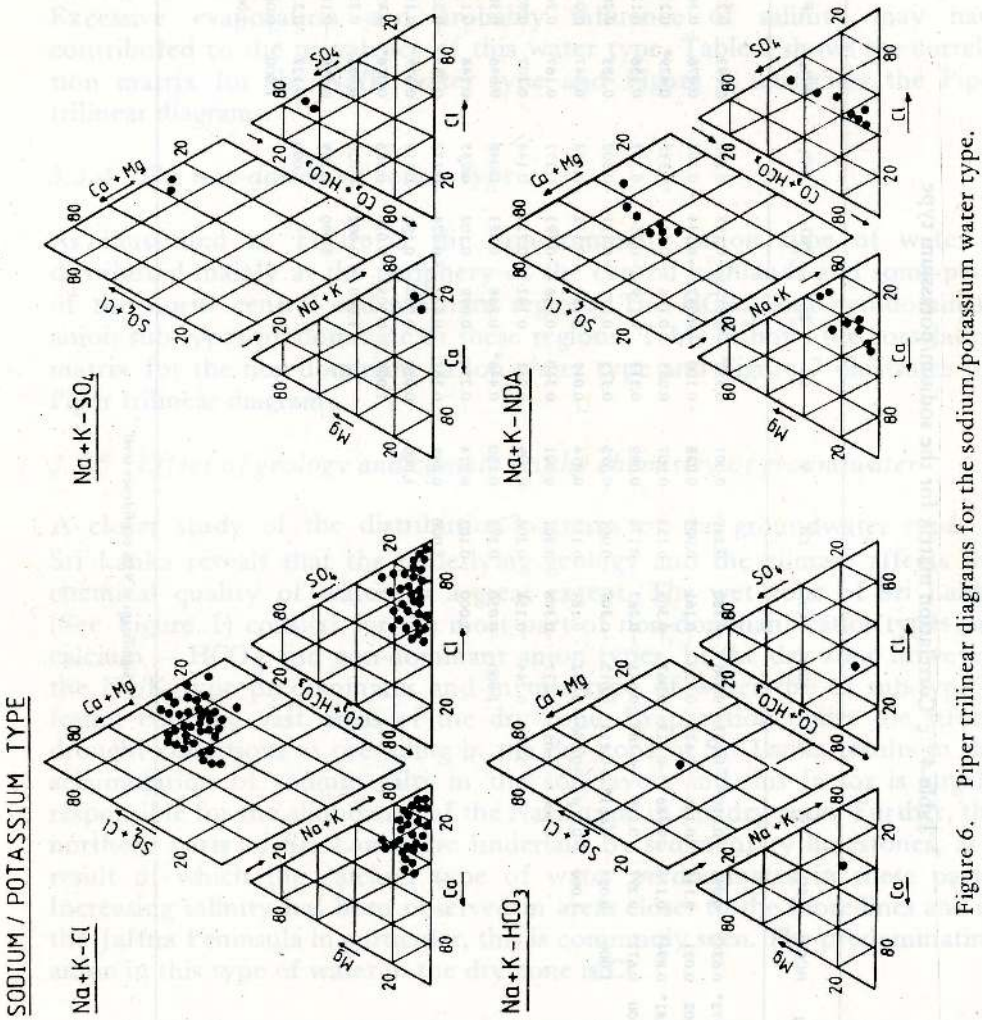
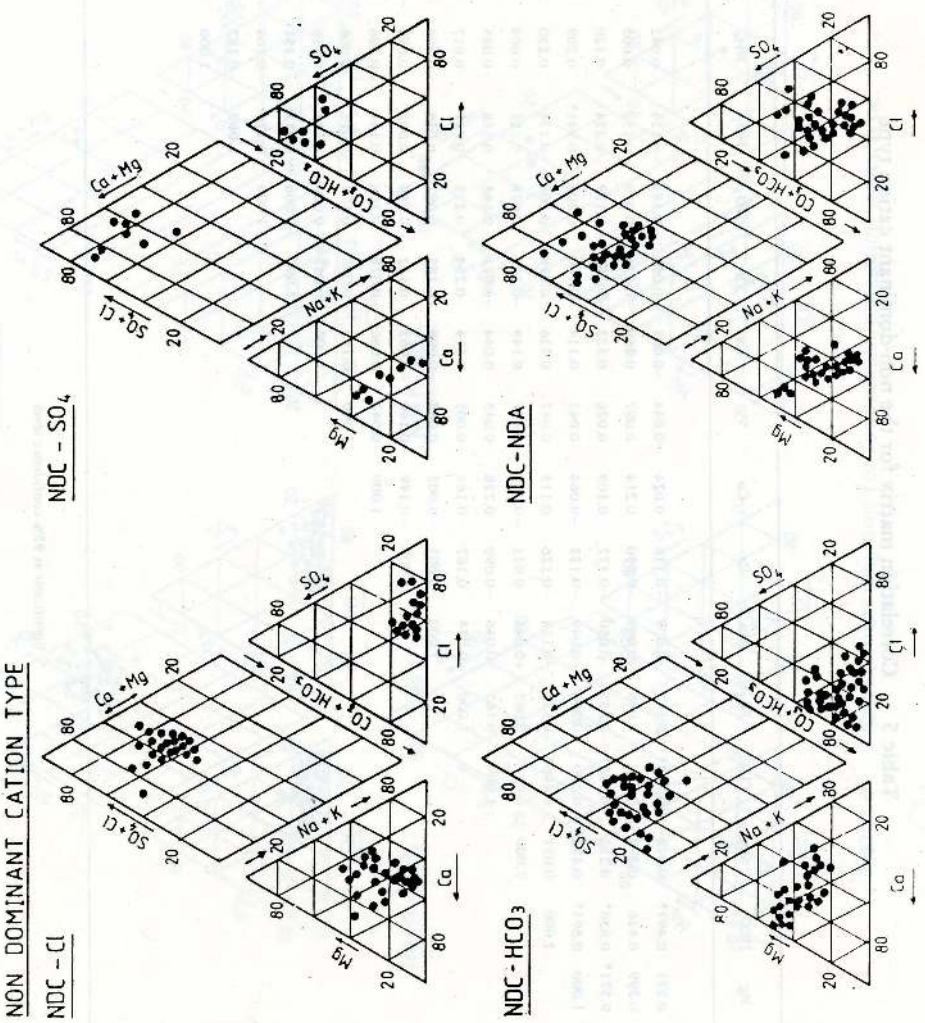


Figure 6. Piper trilinear diagrams for the sodium/potassium water type.

Table 5 : Correlation matrix for the non-dominant cation type

	Na	K	Ca	Mg	HCO_3	SO_4	Cl	Fe	Mn	Cr	Co	V	Cu	Zn	NO_3	NO_2	NH_4	F	SiO_2	TDS
Na	1.000	0.159	0.570*	0.331	0.497*	0.018	0.793*	0.142	0.009	−0.116	0.024	−0.044	−0.001	−0.089	−0.143	0.124	−0.042	0.103	0.140	0.307
K		1.000	0.548*	0.399	0.436	0.279	0.249	−0.096	−0.009	−0.030	0.214	0.097	0.260	0.136	−0.039	−0.152	0.005	0.091	0.206	0.492
Ca			1.000	0.571*	0.856*	0.215	0.586*	−0.255	0.050	−0.172	0.109	0.026	0.323	0.189	−0.199	−0.224	0.120	0.240	0.436	0.760
Mg				1.000	0.691*	0.472*	0.290	−0.200	−0.049	−0.133	−0.064	0.043	0.114	0.100	−0.207	−0.941*	0.209	0.183	0.328	0.509
HCO_3					1.000	0.051	0.486*	−0.333	0.118	−0.126	0.113	0.047	0.436	0.098	−0.204	−0.134	0.250	0.304	0.374	0.780
SO_4						1.000	0.023	0.062	+0.045	0.023	−0.055	−0.032	0.149	−0.117	−0.078	−0.153	0.004	−0.047	0.190	0.072
Cl							1.000	−0.165	−0.046	−0.096	0.228	−0.045	0.044	−0.021	0.168	−0.158	−0.045	0.167	0.168	0.326
Fe								1.000	0.024	0.167	−0.169	−0.005	−0.314	0.254	0.215	−0.029	0.017	0.228	−0.096	−0.233
Mn									1.000	−0.003	0.003	0.082	−0.098	−0.185	0.097	−0.038	0.204	−0.077	−0.105	−0.172
Cr										1.000	0.149	−0.140	−0.065	0.142	0.188	−0.003	0.070	−0.027	−0.166	−0.063
Co											1.000	−0.042	0.066	−0.078	0.168	−0.144	−0.006	0.055	0.170	0.202
V												1.000	0.199	0.001	0.174	−0.015	−0.004	0.091	0.036	−0.030
Cu													1.000	−0.065	0.009	0.105	0.018	0.280	0.097	0.348
Zn														1.000	0.006	−0.033	0.351	0.409	−0.290	−0.211
NO_3															1.000	0.124	−0.104	−0.234	−0.234	−0.207
NO_2																1.000	−0.187	−0.114	−0.120	−0.172
NH_4																	1.000	0.114	0.071	0.017
F																		1.000	+0.052	0.166
SiO_2																			1.000	0.452
TDS																				1.000

* Significant at 95% confidence level



3.3.6 Application in health

The delineation of areas of different water chemistry has applications in studies pertaining to human health and epidemiology. The effect of the chemistry of the groundwater on the health of the human population in Sri Lanka is of paramount importance due to the fact that the vast majority of the people use groundwater directly for their drinking and cooking purposes.

It is apparent from Figure 3 that the effect of Na, K and Cl is more pronounced in the dry zone areas as against Ca and non-dominant cation types in the wet zone. The people living in the dry zone regions are thus subjected to a different water chemistry than those living in other parts of Sri Lanka. The effect of water chemistry on the health of the population in Sri Lanka has been highlighted by Dissanayake *et. al.*[6] and Dissanayake.[4] From these studies it was revealed that there is a correlation between water hardness and the incidence of cardiovascular diseases. Areas underlain by groundwater with high water hardness appeared to have a low incidence of cardiovascular diseases as exemplified by the Jaffna Peninsula. On the other hand, certain regions in the wet zone where water hardness was low, had a higher incidence of cardiovascular diseases. Prior information on the chemical quality of the water of different areas helps in the delineation of disease prone regions. Among the other diseases dependent on the water quality are dental diseases such as dental fluorosis and tooth decay. Earlier studies[3,5] have shown certain areas in Sri Lanka, particularly in the north central and eastern parts to contain anomalous fluoride concentrations in the groundwater. These areas coincided with a high incidence of dental fluorosis, particularly among school children.

4. Conclusions

The groundwater of Sri Lanka has been classified chemically and a map showing the distribution of the different water types prepared. The groundwater has been classified into 4 major types, namely Ca, Mg, Na/K and non-dominant cation types. The Ca–HCO_3 type is found predominantly in the wet zone of the central highlands and appear to be associated with the non-dominant cation types. In the dry zone, the Na/K type is abundant whereas in northern areas particularly in the Jaffna Peninsula, the Ca–Cl type is abundant. It is apparent that the distribution of the different groundwater types is markedly affected by the underlying geology and climatic factors. The map showing the distribution of the groundwater types has application in delineating areas susceptible to health hazards depending on the chemical composition of water.

Acknowledgements

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Chemical Results of the Sampled Well Water: Ca – Cl Subgroup

Location No.	Ca ppm	Mg ppm	Na ppm	K ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	TDS ppm	Total Hardness ppm in $CaCO_3$	Total Fe ppb	Mn ppb	Total Cr ppb	Co ppb	Total V ppb	Cu ppb	Zn ppb	NO_3 ppb	NO_2 ppb	NH_4 ppb	SiO_2 ppm	F ppb	Topographic Sheet
33	60.13	5.55	2.29	20.14	61.0	44.18	70.00	195	164	2700	100	12	2	1	10	3	21,000	28	79	21	140	Alutgama
86	6.00	1.21	2.84	3.51	12.8	3.36	11.00	112	27	110	42	17	7	8	20	217	600	111	11	14	700	Haputale
88	6.61	2.43	1.14	0.39	15.2	0.48	11.69	39	21	110	62	12	1	26	7	218	10	110	7	12	200	"
92	39.87	12.15	13.33	11.73	25.0	4.32	119.81	120	150	110	nd	2	17	4	13	217	3,000	310	12	2	2000	Buttala
100	20.04	0.04	12.85	15.64	43.9	0.43	41.99	101	52	3200	72	22	17	07	10	170	2.000	70	12	2	40	Avissawella
104	20.04	0.14	7.86	7.82	43.9	0.04	32.99	112	56	3200	73	20	1	3	12	120	6,000	122	11	8	430	"
117	20.04	8.48	1.52	0.39	19.5	0.33	41.99	103	85	1110	21	7	2	2	10	17	3,100	127	11	11	300	Hatton
197	88.07	12.10	45.98	31.68	183.0	1.53	170.00	300	270	3110	72	7	1	3	19	9	8,400	112	12	1	70	Dandagamuwa
273	100.20	12.08	45.97	5.86	128.7	5.25	210.00	850	300	70	100	12	10	7	32	22	4,600	10	312	12	40	Nalanda
404	220.00	3.68	68.96	67.26	348.9	4.80	460.00	920	700	1330	20	2	37	31	17	17	2,000	28	17	37	700	Medawachchiya
421	208.00	9.72	10.80	35.97	427.0	4.41	420.00	1700	920	170	27	3	1	7	21	28	2,000	22	627	41	750	Vavuniya
428	208.00	4.86	522.52	278.45	572.9	4.80	1200.00	1500	720	320	17	7	3	11	17	31	110	17	175	73	500	Mantai
442	260.50	11.91	183.90	28.94	616.8	47.07	412.00	1011	700	400	17	11	8	1	125	80	1200	12	137	31	2800	Padaviya
452	260.50	11.91	344.82	283.92	446.6	34.58	1000.00	2200	700	400	82	2	11	20	21	21	10,610	120	175	75	1500	Tunukkai
453	320.60	11.91	413.79	237.38	427.0	5.76	1200.00	2107	850	170	35	7	27	11	19	34	nd	72	175	60	500	Iranamadu
454	200.40	11.91	275.86	228.39	305.0	15.36	1010.00	2100	810	700	30	3	2	12	14	37	nd	90	170	75	1000	"
455	240.40	97.00	551.72	403.98	610.1	15.36	1560.00	4100	1000	170	30	2	7	1	13	32	nd	91	100	60	750	"
456	220.00	60.78	206.89	185.71	305.0	240.13	700.00	1512	800	460	17	2	1	1	20	28	200	30	17	92	500	Murunkan
457	200.40	97.00	758.62	438.40	610.1	96.06	1780.00	1500	900	640	22	2	2	3	10	45	1,000	17	27	37	750	"
458	308.01	72.93	857.58	177.12	610.1	18.25	1920.00	1600	820	820	27	1	3	7	15	27	1,200	27	21	19	1000	"
483	76.75	24.31	27.58	15.64	60.3	63.40	169.00	320	290	800	74	3	1	1	32	28	1,700	120	102	22	321	Kala Oya

Chemical Results of the Sampled Well Water: Ca – SO_4 Subgroup

26	120.08	40.08	45.97	29.33	183.0	344.75	20.00	430	400	3200	122	7	4	20	6	22	110	38	32	31	100	Ambalantota
76	60.12	6.68	28.25	7.63	60.4	144.09	27.00	272	178	870	94	10	7	17	51	100	7,000	27	11	7	400	Ratnapura
120	6.09	0.01	5.6	3.91	0.6	12.96	7.00	114	67	1100	20	7	1	1	61	280	700	900	10	22	190	Hatton
126	20.04	2.41	2.29	2.69	19.5	3.41	12.00	118	60	110	21	3	3	2	10	317	5,000	117	7	18	20	Nuwara Eliya
407	218.83	3.73	25.51	35.97	361.1	46.68	20.00	1500	700	170	24	2	122	117	10	22	210	27	32	22	700	Horowpatana

Chemical Results of the Sampled Well Water: Ca -- HCO_3 Subgroup

Location No.	Ca	Mg	Na	K	HCO_3	SO_4	Cl	TDS	Total Hardness	Total Fe	Mn	Total Cr	Co	Total V	Cu	Zn	NO_3	NO_2	NH_4	SiO_2	F	Topographic Sheet
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm in $CaCO_3$	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppm	ppb	
34	80.16	19.97	2.29	30.73	226.9	101.34	2.00	301	250	2900	112	12	1	28	11	13	11,000	28	62	27	100	Alutgama
35	80.16	21.57	2.29	28.74	263.5	53.31	16.85		254	2710	114	18	1	27	22	12	10,000	18	76	45	110	"
36	100.20	2.70	2.29	15.17	268.4	20.17	29.00		257	2170	78	13	1	17	10	7	12,000	70	7	47	100	"
41	6.80	2.66	0.22	1.42	26.2	4.80	1.77	38	28	2000	38	14	30	3	20	9	3,700	111	2	2	200	Rakwana
43	20.04	5.31	0.22	0.39	67.4	4.80	8.99	292	72	3720	34	13	32	2	15	18	5,000	110	1	8	500	"
45	220.00	120.00	2.29	28.63	738.8	207.49	49.00	1000	850	110	128	3	1	112	12	18	780	28	96	22	770	Kataragama
46	60.12	12.34	2.29	31.59	164.7	48.51	29.00		181	700	111	1	3	122	13	22	910	28	17	37	720	"
53	81.00	12.09	0.01	1.95	189.7	83.18	10.00		254	110	75	2	1	150	10	71	100	100	92	31	720	"
78	9.41	1.32	0.24	0.39	26.2	10.08	2.00	32	17	110	90	12	7	7	7	327	3,000	18	22	8	370	Haputale
102	20.04	7.96	0.22	0.43	71.9	0.96	17.00	142	83	3160	74	30	11	22	4	210	3,000	73	12	3	510	Avissawella
114	20.04	0.02	4.33	3.91	56.7	0.86	7.00	102	51	720	45	11	1	2	60	17	3,700	413	11	11	200	Hatton
121	20.04	10.67	2.29	3.12	61.0	4.46	1.99	119	94	80	19	8	22	1	17	172	22,000	175	9	37	20	Nuwara Eliya
122	22.81	6.07	8.94	3.91	73.2	3.30	7.00	129	83	270	20	7	23	2	22	217	20,000	220	3	32	10	"
124	20.04	1.44	13.79	3.33	55.5	1.58	20.00	114	56	80	22	2	3	7	22	337	10,000	412	3	3	10	"
134	151.00	36.46	68.96	35.43	549.1	4.41	170.00	1800	541	270	81	5	22	22	92	22	110	110	60	40	220	Potuvil
137	156.00	12.15	22.98	0.46	244.0	0.52	119.85	1700	300	300	77	14	17	17	12	41	210	73	90	37	320	"
143	60.12	4.83	1.60	0.59	121.0	3.42	27.00		170	2720	12	9	2	27	2	92	22,000	41	11	2	500	Gampaha
145	60.12	12.10	0.22	0.39	141.5	4.80	17.00	203	200	2120	17	9	1	22	7	90	10,000	53	77	1	280	"
151	40.68	4.10	13.89	2.34	122.0	3.45	10.00	150	112	3000	21	22	1	1	40	27	2,100	80	7	7	700	"
154	60.12	15.68	22.98	14.66	244.0	34.19	33.99	170	215	1220	80	8	17	17	60	12	70	110	1000	17	80	Kandy
155	80.16	3.10	20.04	3.91	250.1	29.77	18.00		213	720	70	7	117	42	70	17	310	57	1750	7	20	"
157	60.12	16.97	7.40	11.73	227.9	44.18	7.00		220	2120	95	2	110	3	60	10	350	111	1200	2	70	"
158	80.16	4.81	6.89	3.71	244.0	19.02	13.99		220	820	92	3	17	2	71	12	1,320	17	780	11	80	"
159	80.16	2.38	6.43	0.08	250.1	4.61	9.99		210	710	70	5	173	7	70	17	7,480	213	172	13	90	"
160	60.12	12.10	7.58	0.35	183.0	47.83	11.99		200	810	70	12	27	1	71	81	10,000	72	370	14	90	"
161	64.00	36.46	2.29	0.50	311.1	52.53	3.99		310	820	100	1	32	27	70	22	10	120	270	3	10	"
162	60.12	7.73	2.29	2.16	183.0	32.61	3.99	190	182	700	90	6	112	48	72	22	7,000	720	470	2	100	"
163	40.08	6.04	9.19	0.74	122.0	25.02	13.99	120	125	2200	80	1	28	22	69	42	3,000	17	440	10	10	"
165	40.08	18.92	16.09	0.66	183.0	34.10	20.00	70	177	1720	60	12	22	27	72	10	310	22	121	2	100	"
166	80.16	4.80	11.49	1.56	244.0	34.97	15.00		220	720	75	9	173	10	73	17	1,320	70	127	3	100	"

168	62.32	2.43	22.98	11.63	298.9	44.18	20.99	110	256	1000	20	11	43	10	44	212	7,500	12	310	10	100	Kandy
169	40.08	7.74	9.19	1.07	122.0	32.18	13.99	180	132	2700	42	7	141	7	45	111	8,000	70	331	1	100	"
170	60.12	12.10	22.98	1.79	183.0	46.58	38.00	—	200	770	70	7	142	3	40	71	2,000	27	127	7	150	"
171	40.08	5.32	6.89	1.34	122.0	23.53	9.99	200	122	7000	90	3	17	2	42	200	1,000	78	140	8	120	"
172	20.04	9.41	1.83	0.71	61.0	39.38	1.99	122	89	2100	210	12	3	4	37	317	2,000	70	60	14	20	Hanguranketa
173	40.08	5.29	0.45	2.00	107.5	44.18	1.99		122	1700	72	12	13	14	20	410	3,000	27	128	40	170	"
175	60.12	4.82	10.12	17.20	183.0	19.06	17.58		170	2120	172	17	3	117	12	317	200	70	420	112	320	"
176	100.00	12.08	45.97	7.23	304.0	96.06	41.98		300	700	43	14	2	312	12	218	1,200	72	440	11	100	"
177	40.08	2.40	22.98	15.01	128.1	34.58	17.00	121	110	110	72	15	4	412	13	320	7,100	74	312	111	990	"
178	60.12	4.82	22.98	3.20	183.0	34.58	27.00	117	170	1100	45	10	42	1	17	327	3,000	12	127	22	120	"
179	42.08	3.61	22.98	4.25	128.1	34.58	27.99	200	120	120	43	10	42	1	20	227	700	120	320	110	320	"
187	86.16	9.10	22.98	32.05	250.7	2.79	69.99	470	238	170	70	2	4	72	173	27	800	320	1000	12	1500	Tirrukovil
188	100.00	5.30	6.62	7.82	305.0	1.59	71.99	500	272	120	112	3	2	7	42	28	920	470	2110	13	1200	"
192	120.24	24.10	22.98	6.41	427.0	4.31	37.00	540	400	130	102	12	7	38	170	72	200	227	2700	17	2300	"
200	60.12	4.80	45.98	2.74	183.0	0.81	80.00	175	170	620	77	67	40	1	12	22	9,200	22	17	1	90	Dandagamuwa
201	60.12	5.50	16.18	3.91	147.6	3.88	59.99	170	172	120	81	4	42	1	13	21	6,000	17	43	2	10	"
202	60.12	5.30	22.99	38.33	183.0	2.79	60.00	200	173	170	82	17	27	3	11	17	6,400	77	41	11	620	"
203	60.12	1.16	22.99	7.43	183.0	2.79	19.99	200	155	110	85	3	31	2	19	22	1,000	27	24	3	730	"
206	40.08	7.22	22.99	9.38	142.1	1.34	50.00	200	120	430	62	2	17	1	22	30	7,000	7	71	3	120	"
207	40.08	6.51	22.99	5.08	122.0	2.09	40.00	250	127	200	75	7	22	1	29	22	8,500	7	13	4	190	"
208	40.08	8.92	10.11	15.64	123.0	2.86	30.00	158	137	560	60	3	17	1	27	31	10,000	3	27	2	300	"
211	40.08	4.81	23.91	0.78	122.0	1.24	39.99	170	120	880	67	12	1	17	20	27	11,00	417	17	3	100	Kurunegala
214	60.12	5.28	9.88	15.64	183.0	1.63	29.99		172	720	64	7	117	20	52	34	7,200	317	127	2	200	"
221	40.08	3.13	2.29	29.21	122.0	12.39	30.00		113	770	58	7	1	22	53	28	4,000	713	31	8	40	"
230	40.08	12.12	2.29	18.77	115.9	53.31	20.00	170	97	770	43	5	7	2	72	74	10,000	22	17	11	10	"
231	40.08	4.83	2.29	29.21	122.0	19.11	30.63	170	97	750	40	5	3	2	71	75	10,000	21	22	12	10	"
232	60.42	34.31	22.98	7.23	286.7	63.40	17.00	150	266	820	41	17	3	412	13	341	300	78	141	21	20	Rangala
233	74.45	12.15	2.29	19.12	244.0	34.10	20.99	120	236	910	42	7	17	312	17	313	270	17	114	2	130	"
234	20.04	1.20	2.29	6.41	61.0	4.32	9.00	170	55	880	70	14	1	217	37	337	10	29	52	3	290	"
236	100.02	2.61	2.29	18.92	263.5	48.03	17.00		261	720	90	3	3	412	21	412	880	28	145	7	90	"
237	140.28	9.87	2.29	6.25	415.4	44.18	11.99		291	720	74	2	1	313	10	320	1,000	74	54	4	170	"
238	68.82	24.31	2.29	39.10	300.1	48.03	17.00		272	710	92	1	1	117	20	317	1,000	120	42	32	270	"
239	100.20	4.55	2.29	26.07	305.0	18.01	27.00		269	620	92	3	1	312	10	217	920	70	43	3	90	"
240	80.86	12.15	22.98	0.04	298.0	35.06	21.99		252	110	90	2	3	412	17	218	620	170	47	31	190	"
244	68.01	36.46	0.22	0.39	311.7	44.18	11.99	1200	320	770	110	8	1	17	74	115	200	920	427	27	130	Maha Oya

																						Topographic Sheet
246	40.08	24.19	0.22		302.6	20.17	21.99	720	300	150	117	13	13	62	21	113	400	470	528	4	20	Maha Oya
248	120.24	4.78	2.29	24.32	329.0	101.34	41.99	730	320	700	120	17	1	27	88	317	100	737	422	3	320	"
250	70.03	243.31	2.29	0.25	272.0	61.43	10.00	700	290	620	120	10	3	17	61	172	9,200	477	412	17	370	"
251	220.20	12.15	45.97	9.19	616.8	84.58	120.00	420	600	440	120	4	11	42	61	72	5,000	112	270	2	620	Kalmunai
257	148.11	24.31	413.79	12.90	385.0	63.40	127.00	700	470	110	70	3	2	41	120	74	5,300	140	270	27	300	"
268	80.16	4.08	22.08	23.62	250.7	61.04	20.00	412	217	630	120	15	13	7	27	10	5,000	512	18	2	570	Wariyapola
270	40.08	4.09	22.98	9.38	122.6	39.63	30.00	317	117	400	122	7	11	1	41	19	1,000	522	12	8	500	"
276	96.05	24.31	2.29	29.17	206.2	85.49	30.00	520	340	130	74	20	42	1	39	17	6,000	21	312	30	130	Nalanda
280	128.11	12.15	2.98	33.63	285.0	113.94	20.00	370	370	810	80	20	7	1	42	72	4,600	26	515	2	170	"
282	40.08	12.13	2.29	3.91	128.7	34.61	12.99	350	150	20	120	22	17	17	32	17	9,200	22	312	17	20	"
284	80.16	2.38	2.29	34.61	194.9	63.46	23.99	370	210	70	120	21	12	2	38	121	9,400	21	532	23	30	"
285	80.16	4.80	2.29	34.10	224.0	44.27	16.00	350	220	80	140	22	27	7	42	18	4,600	22	737	21	70	"
290	100.20	12.00	0.22	0.39	199.1	105.18	20.00	390	300	210	20	10	77	1	92	517	11,700	130	452	3	120	Elahera
291	88.43	24.31	2.29	0.86	305.0	59.61	10.00	420	321	610	76	20	22	1	71	417	6,000	117	132	2	230	"
292	60.12	6.03	2.29	7.27	147.0	63.46	2.00	395	175	310	73	20	27	7	71	217	700	113	437	1	270	"
293	60.12	5.30	22.98	34.33	183.0	101.44	7.00	320	172	710	75	22	12	3	78	312	10,000	122	53	1	70	"
296	96.79	24.31	2.29	25.10	305.0	87.98	27.00	400	342	270	121	22	1	7	62	320	10,000	142	123	6	7000	"
297	84.02	24.31	2.29	24.24	377.8	63.46	13.99	390	360	110	122	14	7	1	82	412	3,100	47	417	7	2320	"
298	97.66	24.31	22.98	10.55	372.7	37.50	41.99	410	341	110	100	10	8	7	61	310	2,700	52	312	1	320	"
301	40.08	24.19	2.29	3.83	226.9	101.34	27.00	342	320	170	110	15	1	1	67	325	10	67	74	12	7000	"
303	116.00	12.15	2.29	30.66	305.0	101.44	20.00	500	340	210	100	2	17	227	92	320	10	9	49	27	270	Rukam
312	140.20	12.03	68.96	13.35	433.8	47.55	119.99		400	600	120	10	22	732	97	31	430	18	27	17	3100	"
325	120.24	2.35	91.95	15.72	372.1	53.31	119.99	427	310	210	120	8	12	22	100	412	210	11	72	10	7000	Polonnaruwa
330	80.16	2.43	68.96	7.39	244.0	9.36	130.00	700	210	70	70	12	32	32	122	418	110	42	18	8	7820	"
332	120.24	2.30	68.96	35.97	366.0	34.58	118.57	600	310	110	34	2	137	30	48	320	110	38	21	1	10000	"
333	120.24	10.81	91.95	31.28	366.0	212.89	169.97	600	345	110	38	18	17	17	71	410	110	40	32	12	9780	"
334	120.24	11.30	68.96	17.98	372.7	15.70	139.98	680	347	100	20	17	20	2	93	317	210	41	31	17	9780	"
337	80.16	7.78	252.87	23.46	189.7	48.03	429.98	293	283	140	240	10	112	411	163	210	10,700	31	127	28	3720	Vakaneri
355	80.16	7.29	2.29	28.94	244.0	44.66	18.00	386	230	1720	27	1	413	212	20	22	12,000	42	127	31	3400	Anuradhapura
356	140.28	0.40	2.29	16.81	427.0	5.28	15.98	653	352	3000	23	3	27	117	18	10	270	17	237	32	3800	"
357	120.34	1.38	68.96	16.42	372.7	34.58	60.54	689	306	120	30	2	117	12	22	10	12,100	51	133	38	3200	"
358	120.24	19.32	45.97	28.94	427.0	24.49	100.00	442	380	110	21	2	27	17	21	12	6,000	22	147	31	3000	"
359	100.20	4.25	91.95	5.47	311.7	15.36	143.99	460	268	610	22	3	28	22	23	120	12,000	27	132	37	2920	"
361	140.24	23.23	68.96	14.07	488.1	13.36	139.98	657	447	70	25	17	22	28	18	720	820	17	162	17	400	"
362	100.20	13.28	68.96	9.38	366.0	34.58	39.98	608	305	1000	21	11	27	13	21	340	720	92	337	11	600	"

																								Topographic Sheet
363	60.12			14.07	183.0	34.56	39.98	474	189	2000	22	10	22	12	29	170	4,000	95	920	30	700	Anuradhapura
364	84.06	9.36	22.98	19.53	311.7	15.36	39.98	373	260	370	27	2	27	17	27	122	9,200	93	172	31	720	"
366	80.16	6.68	45.97	9.77	244.0	26.41	80.00	354	228	270	24	7	111	27	17	180	110	37	415	21	410	"
368	160.32	1.36	68.96	28.94	494.8	15.36	124.99	659	406	110	320	20	117	14	42	170	400	43	413	17	5000	"
369	160.32	2.33	45.97		494.8	15.36	66.11	753	410	420	72	21	27	17	31	720	720	47	213	21	4070	"

Chemical Results of the Sampled Well Water Ca – NDA Subgroup

Location No.	Ca	Mg	Na	K	HCO_3	SO_4	Cl	TDS	Total Hardness	Total Fe	Mn	Total Cr	Co	Total V	Cu	Zn	NO_3	NO_2	NH_4	SiO_2	F	
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm in $CaCO_3$	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppm	ppb	Toppgraphic Sheet
7	80.16	7.23	25.50	4.34	122.0	136.50	70.00	384	280	2730	12	21	17	7	11	18	7,000	18	81	47	40	Ambalangoda
8	63.64	12.16	21.20	4.34	122.0	29.60	22.10	298	209	3700	120	20	22	13	12	22	4,000	12	80	32	60	"
9	100.20	9.17	22.90	0.43	116.0	99.20	70.00	302	288	3000	110	23	21	2	17	23	7,000	22	78	11	80	"
10	108.07	24.31	22.90	3.56	183.0	196.10	50.00	340	370	2710	60	20	12	50	61	7	7,100	12	82	28	100	Morawaka
11	100.20	3.07	21.20	4.30	189.8	108.21	70.00	327	313	3000	63	22	12	40	36	3	7,000	21	87	27	60	"
15	88.02	36.47	22.90	0.39	128.8	187.30	90.00	410	370	7260	73	12	22	40	2	27	11,000	51	37	62	70	Matara
16	100.23	38.79	22.90	0.39	193.9	196.90	70.00	411	410	6000	70	27	17	28	17	13	70	72	17	67	20	"
37	40.08	4.76	2.30	31.36	91.5	27.41	38.00	170	112	2700	122	12	1	18	11	14	11,200	71	17	21	90	Alutgama
38	62.12	7.95	22.90	4.82	140.3	53.31	43.00	278	175	2190	160	17	1	100	11	11	11,000	27	101	77	20	"
39	62.12	8.75	2.30	3.29	104.9	34.61	44.12	180	172	3000	27	22	1	1	10	10	10,000	22	200	31	120	"
48	60.12	3.94	45.90	20.41	132.4	63.40	79.01	172	160	110	112	9	4	127	10	72	110	120	12	44	670	Kataragama
58	80.16	6.00	22.90	24.63	183.03	82.61	50.01	440	225	400	122	7	7	320	70	45	1,000	170	3	32	520	Yala
79	5.60	1.21	2.80	1.48	12.8	5.31	7.01	28	29	110	27	12	22	1	10	217	3,000	71	17	7	210	Haputale
82	8.80	1.21	5.70	1.56	12.8	10.11	13.11	40	27	110	41	2	2	17	10	218	900	21	11	1	400	"
89	8.80	0.12	1.60	0.39	12.8	0.52	11.12	47	27	80	43	20	17	21	9	417	1,000	110	10	13	560	"
108	40.08	0.65	9.10	3.91	61.0	6.11	27.02	152	127	3000	78	19	2	127	17	420	1,110	28	12	2	380	Awissawella
113	11.60	0.48	1.80	0.78	31.7	2.42	2.01	98	49	720	32	8	2	1	82	71	3,200	270	10	3	170	Hatton
128	40.08	5.31	13.70	0.42	61.0	4.43	40.01	172	122	720	72	10	42	1	27	22	820	12	11	27	220	Passara
129	40.08	3.13	22.90	0.36	104.9	4.74	27.02	153	113	110	70	20	4	1	21	13	110	70	2	37	10000	"
140	60.12	2.39	22.90	34.19	129.3	4.47	72.11	122	100	5000	42	13	3	117	10	92	10,000	122	9	2	270	Gampaha
142	40.08	4.83	2.30	1.56	61.1	4.43	22.01	117	120	1220	18	10	3	110	7	94	7,000	320	11	3	490	"
144	60.12	12.10	9.90	3.91	117.1	6.82	41.02	211	200	3110	13	12	1	17	3	95	3,200	110	78	3	210	"
146	42.28	3.48	11.71	3.91	61.0	5.81	28.11	204	120	1700	21	14	7	1	8	71	11,000	320	12	7	390	"
147	40.08	2.64	19.61	3.91	61.0	5.82	32.01	179	111	4000	71	13	8	1	10	70	17,000	73	10	1	420	"
184	60.12	11.90	22.91	5.87	122.0	4.31	72.00	170	200	70	70	3	7	2	73	77	1,000	17	922	98	1700	Nilgala
243	140.28	12.05	68.90	16.81	263.6	192.10	100.00	470	400	620	112	10	2	122	69	142	600	337	327	2	30	Maha Oya
275	100.00	36.46	0.21	0.39	196.5	101.30	100.00	500	400	410	76	18	37	2	43	120	2,600	22	718	12	230	Nalanda
288	100.00	36.46	22.91	12.90	254.4	150.11	72.00	540	400	110	111	13	22	27	87	317	4,600	117	137	14	40	Elahera
473	66.73	36.47	2.29	nd	190.3	115.75	31.97	422	317	610	142	10	118	1	19	27	3,100	7	62	11	1100	Kala Oya
477	79.36	12.16	183.90	8.21	208.6	63.40	300.00	400	248	170	72	01	13	11	31	18	3,200	11	33	31	400	"
478	91.26	12.16	45.97	27.38	253.2	34.58	119.99	353	278	270	71	12	2	17	30	27	2,100	12	37	38	100	"

Chemical Results of the Sampled Well Water Mg – SO_4 Subgroup

Location No.	Ca ppm	Mg ppm	Na ppm	K ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	TDS ppm	Total Hardness ppm in $CaCO_3$	Total Fe ppb	Mn ppb	Total Cr ppb	Co ppb	Total V ppb	Cu ppb	Zn ppb	NO_3 ppb	NO_2 ppb	NH_4 ppb	SiO_2 ppm	F ppb	Topographic Sheet
12	60.12	45.63	2.52	0.39	61.0	187.50	70.00	370	320	2210	58	18	22	38	41	2	820	27	48	11	420	Morawaka
459	200.40	308.77	91.95	41.06	915.0	1200.00	1.98		1770	2000	72	12	1	30	25	50	2000	60	14	3	430	Tibulketiya
460	601.20	611.71	206.89	233.08	1220.2	3746.39	10.00		4170	1600	77	14	3	35	24	75	3000	48	92	8	460	"
462	26.37	36.46	22.98	17.43	122.0	144.09	27.00	490	216	1450	83	12	4	48	22	88	110	45	11	13	490	"
463	39.87	72.93	22.98	12.63	183.0	192.12	81.99	450	400	1250	77	12	17	75	23	80	820	45	12	2	490	"
465	36.07	253.58	22.98	13.19	732.1	480.30	7.00	1005	1044	1450	79	19	2	75	23	77	1700	60	22	3	530	"
466	85.37	243.13	22.98	14.86	274.5	960.61	10.00	1695	1214	1600	72	17	1	80	24	60	700	65	2	1	505	"
467	75.15	121.56	45.97	69.61	305.0	516.33	10.06	1712	688	2050	105	8	3	48	20	48	600	65	16	10	510	"
468	89.37	243.13	22.98	29.78	305.0	982.70	27.00	1462	1224	2000	90	7	2	30	20	30	600	65	1	14	800	"

Chemical Results of the Sampled Well Water Mg – Cl Subgroup

148	6.75	24.31	22.98	2.02	121.4	4.41	17.00	200	117	2320	17	14	3	3	12	77	7000	70	12	7	420	Gampaha
180	7.95	24.31	16.17	7.82	128.1	19.11	32.00	110	120	720	44	16	3	1	12	410	2100	127	221	30	130	Hanguranketa
186	19.92	60.50	9.19	12.51	305.0	3.57	28.00	152	300	170	42	7	3	7	70	27	270	47	792	7	3780	Nilgala
411	100.20	8.74	0.22	39.10	434.4	3.45	170.00	1510	610	120	28	7	47	27	270	70	1270	82	17	17	1000	Horowpatana

Chemical Results of the Sampled Well Water Na + K/Cl Subgroup

Location No.	Ca	Mg	Na	K	HCO_3	SO_4	Cl	TDS	Total Hardness	Total Fe	Mn	Total Cr	Co	Total V	Cu	Zn	NO_3	NO_2	NH_4	SiO_2	F	
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm in $CaCO_3$	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppm	ppb	Topographic Sheet
3	64.02	21.32	160.90	4.34	153.8	20.20	320.00	372	250	3710	78	17	27	17	11	21	720	72	12	32	80	Ambalangoda
4	88.07	12.16	163.50	4.97	122.0	63.40	330.00	340	270	2800	93	10	10	12	12	12	2700	18	92	37	90	"
5	69.22	24.31	296.80	39.10	61.0	381.80	370.00	371	273	2100	122	20	11	27	13	17	1820	70	17	30	70	"
23	66.03	27.90	273.60	16.03	61.0	188.00	450.00	317	365	1710	140	3	1	10	2	18	310	110	20	40	1720	Ambalantota
28	216.00	60.12	919.00	15.64	555.8	53.31	1560.00		692	110	100	1	17	2	10	50	720	70	27	14	1700	Hambantota
29	126.00	120.00	1333.00	35.19	616.8	101.34	2150.00		617	210	112	7	12	2	11	72	710	72	21	31	1800	"
31	8.39	10.4	68.96	4.47	67.7	5.28	100.00	82	46	3100	72	7	7	11	32	7	40,000	9	100	17	20	Alutgama
32	20.04	8.79	22.93	29.72	44.5	19.69	73.00	89	72	3200	63	10	3	7	12	2	41,000	17	111	22	130	"
47	60.12	10.34	114.00	23.69	61.0	96.06	217.00	137	176	200	111	8	2	17	10	71	210	72	41	27	730	Rakvana
50	60.12	5.55	712.00	18.38	128.7	5.28	1153.00	170	164	400	52	17	3	145	21	173	320	92	11	43	600	"
51	60.12	11.94	2252.00	38.32	183.0	27.37	2514.00	192	180	1200	58	1	2	142	20	232	6,000	17	7	41	610	"
52	87.99	100.00	1241.00	32.45	250.7	101.34	2091.00	478	470	300	74	3	1	140	9	60	10	111	2	31	700	"
55	83.96	60.12	183.00	17.09	311.7	101.34	298.00	375	360	170	67	1	17	127	32	71	110	20	11	42	600	"
56	20.04	40.04	114.00	5.47	61.0	53.31	178.00	501	100	700	120	2	1	200	70	25	920	100	7	71	720	Yala
59	9.88	4.86	45.98	19.98	25.6	5.30	100.00	248	42	3200	78	21	1	11	10	70	12,000	170	12	13	120	Panadura
60	40.08	4.82	68.97	15.25	85.4	48.00	120.00	399	92	3210	120	30	3	2	11	70	13,000	780	13	13	100	"
61	8.00	3.65	68.97	28.94	37.8	34.50	110.00	242	35	4000	122	35	8	7	22	20	12,000	520	7	12	10	"
62	20.04	1.93	68.97	37.04	61.0	34.50	120.00	370	58	2700	123	27	2	7	9	32	10,000	419	7	24	90	"
63	11.20	4.86	22.99	38.33	51.8	5.30	70.00	252	48	3200	123	28	12	8	7	31	12,000	229	2	1	70	"
64	10.80	1.21	56.51	4.69	1.2	4.80	97.00	257	47	2700	128	21	12	8	2	32	12,000	140	2	2	170	"
65	4.78	2.43	56.51	16.87	1.8	9.60	100.00	292	32	3700	125	21	17	7	2	17	12,000	232	7	14	200	"
66	8.39	4.86	56.51	26.63	6.1	9.60	120.00	382	22	2700	124	22	3	7	3	94	12,110	370	11	3	110	"
67	19.83	2.06	2.82	2.34	54.9	1.92	10.00	471	41	7000	77	19	2	10	22	92	21,000	170	17	42	130	"
69	10.40	3.64	28.25	9.60	1.2	3.36	70.00	274	52	3780	91	20	7	11	13	93	10,000	920	12	13	70	"
70	10.62	4.37	28.25	22.05	4.2	0.96	82.00		41	3780	92	20	8	10	14	91	20,000	720	21	31	170	"
80	2.00	1.19	5.65	1.90	26.1	0.48	12.00		19	720	22	13	1	1	10	410	110	71	10	13	700	Haputale
90	20.04	0.60	91.95	4.94	43.9	0.52	170.00		75	80	70	1	2	17	17	418	2,000	1000	2	31	270	Buttala
91	12.00	0.48	92.71	39.10	22.5	0.09	200.00		50	120	71	7	3	7	12	315	780	720	7	3	1000	"
98	2.79	0.36	68.96	25.53	61.0	2.92	88.00		22	120	100	32	21	721	7	122	20,000	40	72	2	100	Colombo
101	20.04	1.66	45.97	3.16	56.7	4.80	71.00	190	94	3200	72	36	3	17	7	140	2,000	172	17	15	520	Avissawella
106	12.00	0.24	22.98	6.22	43.3	0.52	40.00	142	35	2370	77	27	8	7	15	210	1,000	43	11	7	410	"

																				Topographic Sheet
130	20.04	1.44	68.96	38.57	61.0	3.45	120.00	143	56	330	70	13	47	2	22	27	720	131	11	48	2780	Passara
132	51.22	12.15	137.00	4.70	155.5	4.41	200.00	240	178	130	70	8	13	22	100	13	110	120	42	12	200	Puttuvil
136	27.98	12.15	91.95	36.68	83.6	5.85	170.00	270	120	440	72	10	112	18	21	42	170	71	80	42	210	"
150	40.08	4.10	5.97	20.02	18.9	9.60	90.00	290	112	2120	27	20	1	8	7	13	3,100	41	11	2	270	Gampaha
152	64.44	12.15	91.95	25.27	183.0	5.81	165.00	170	211	1800	95	10	22	12	60	42	350	530	120	3	100	Kandy
174	40.08	2.89	68.96	2.85	73.8	47.05	110.00	122	89	2100	210	12	3	4	37	317	2,000	70	60	14	20	Hanguranketa
194	60.12	12.00	250.00	387.56	176.9	3.88	720.00		200	1120	112	7	47	7	11	22	3,100	21	920	3	20	Chilaw
195	40.08	4.80	183.00	23.46	77.4	2.79	320.00		120	2000	110	2	37	21	17	27	3,000	17	1010	12	110	"
196	60.12	4.80	91.00	32.06	183.0	1.63	170.00		170	3210	112	7	37	31	22	17	3,000	12	1277	7	100	"
199	40.08	12.10	91.00	37.86	115.9	3.57	180.00		150	6820	78	7	32	2	11	10	5,000	70	22	12	170	Dandagamuwa
210	20.04	9.65	114.00	3.13	61.0	3.09	180.00		90	870	62	7	3	12	27	87	4,600	322	12	17	20	Kurunegala
213	40.08	2.88	116.00	19.95	122.0	0.78	200.00		112	120	66	17	1	22	73	37	3,200	127	118	4	170	"
216	60.12	12.82	91.00	28.70	183.0	34.58	180.00		108	190	70	8	2	27	82		4,400	422	32	11	100	"
223	40.08	4.83	160.00	2.34	122.0	19.11	250.00		120	710	70	3	17	32	51	27	14,200	320	21	12	110	"
224	20.04	6.54	45.00	10.55	61.0	25.88	80.00	127	77	120	50	16	21	37	52	26	5,800	218	27	21	200	"
225	20.04	6.54	114.00	17.98	67.7	25.93	190.00	nd	77	120	41	8	22	41	60	73	6,600	17	17	52	110	"
252	156.00	36.54	643.00	14.07	1043.9	34.58	719.00	nd	540	440	100	10	02	31	143	22	10,100	217	720	27	720	Kalmunai
256	12.81	12.15	137.00	72.39	268.0	5.30	310.00	700	370	210	80	2	3	48	170	73	10,100	157	270	22	230	"
258	40.08	5.81	137.00	32.65	26.3	101.34	240.00	640	124	720	112	18	21	7	62	10	6,000	17	420	110	500	Attulu Oya
259	40.08	6.54	137.00	19.08	122.0	25.81	230.00	700	127	610	120	5	21	2	61	20	2,700	9	572	127	700	"
260	40.08	12.12	91.00	31.20	122.0	47.64	170.00	470	150	110	111	3	21	2	73	17	3,100	7	720	21	1000	"
261	60.12	0.93	206.00	19.47	189.7	34.58	310.00	571	154	20	112	10	17	2	47	12	4,200	47	12	110	320	Wariyapola
262	20.04	2.17	252.00	11.37	67.7	44.18	370.00	1082	59	40	120	13	32	3	79	13	6,400	122	17	2	410	"
264	86.45	24.31	275.00	38.32	195.8	67.72	520.00	540	316	710	140	12	3	2	42	17	800	270	17	12	430	"
307	88.00	48.62	321.00	18.77	427.0	58.17	414.00	300	420	560	110	2	11	22	121	141	20,000	3	90	27	3200	Rukam
308	100.00	34.46	229.00	6.67	304.4	63.46	420.00	420	400	110	117	2	13	227	172	141	110	72	12	17	3100	"
309	176.00	12.15	252.00	31.67	536.3	58.17	410.00	400	490	720	122	7	17	113	170	132	10,700	20	18	21	3120	"
310	156.00	12.15	229.00	19.16	427.0	34.58	410.00	440	440	470	20	1	22	117	170	131	21,000	17	27	22	980	"
313	120.00	4.78	758.00	0.78	311.7	48.99	120.00	470	320	110	120	3	27	117	180	32	22,000	120	1142	47	670	Batticaloa
314	100.00	12.15	482.00	13.68	300.1	101.34	720.00	500	300	120	200	2	117	217	146	142	21,000	77	1224	22	700	"
316	287.00	48.62	919.00	20.72	630.8	106.14	1642.00	3137	918	360	160	10	2	3	47	71	2,000	90	1400	14	450	Puttalam
317	410.00	91.05	1149.00	18.38	1226.9	63.40	2004.00	3812	1376	320	240	11	3	2	43	82	2,000	20	1700	13	700	"
322	80.00	6.56	183.00	11.34	244.0	44.66	280.00	708	227	360	220	17	1	3	27	17	4,800	97	32	8	300	Dambulla
323	80.00	5.10	298.00	5.47	250.7	44.18	444.00	720	221	1100	170	2	7	2	24	73	7,800	92	14	2	130	"
324	100.00	5.95	252.00	37.57	305.0	15.36	430.00	700	975	760	74	3	3	27	27	72	11,000	27	17	3	400	"
326	100.00	4.74	137.00	15.55	196.4	44.18	310.00	300	320	720	20	22	117	28	72	310	110	27	22	7	8210	Polonnaruwa

																						Topographic Sheet
327	120.00	10.08	206.00	22.68	257.4	24.97	410.00	340	342	30	72	17	17	39	132	422	210	17	28	2	5020	Polonnaruwa
335	80.16	7.78	252.00	23.46	189.7	48.03	430.00		232	340	120	7	13	312	142	172	210	71	332	12	10000	Vakaneri
338	208.00	48.62	367.00	25.81	629.6	20.17	720.00	1500	720	170	71	9	7	1	19	27	1,000	27	470	27	100	Kalpitiya
339	220.00	36.46	758.00	26.59	666.2	44.18	1270.00	1400	100	370	70	12	3	1	18	32	2,100	17	137	21	500	"
354	80.00	7.78	137.00	19.16	250.7	44.66	216.00	653	332	110	18	2	42	417	19	10	22,000	32	47	13	760	Anuradhapura
365	120.00	5.03	275.00		866.0	5.28	436.00	1052	321	3110	22	5	127	22	22	170	7,000	54	317	34	400	"
370	82.00	48.62	206.00	29.87	427.0	34.58	360.00	542	406	170	77	18	22	22	32	42	610	37	415	27	5070	"
371	67.00	36.46	252.00	1.95	311.7	34.58	410.00		318	70	10	7	18	13	69	127	1,000	17	277	21	1500	Kaudulla
376	120.00	5.27	206.00	32.45	311.7	34.58	369.90		322	110	22	15	17	1	78	317	190	52	112	21	3000	"
377	80.00	24.31	183.90	10.95	304.6	39.38	300.00	348	370	110	100	16	18	1		218	2,000	54	22		1300	"
378	68.00	36.46	183.90	21.95	268.0	5.28	369.90	392	320	140	22	18	1	2	111	340	210	50	47	22	3000	"
381	83.00	14.04	459.00	11.73	263.5	39.38	719.60	400	258	2700	440	3	2	3	120		1,100	17	92	27	7000	Kathiraveli
383	96.00	48.62	206.00	39.03	372.7	39.38	419.90	987	440	1700	720	3	13	17	170	172	2,700	37	74		3270	"
385	100.00	12.15	735.00	35.19	226.9	63.40	1201.10	712	300	1700	720	1	41	1	200	440	11,200	12	60	21	3200	"
386	80.00	5.30	666.00	3.51	244.0	63.40	1000.00	700	222	2300	320	2	10	1	170	210	10,200	7	60	27	4000	"
387	88.00	24.31	597.00	23.85	250.7	34.58	1000.00	600	322	3720	320	7	20	2	320	210	700	10	70	27	4120	"
388	80.00	51.44	758.00	21.50	433.8	39.38	1201.20	622	412	1320	370	3	10	10	420	440	7,000	20	60	22	4000	"
389	66.00	36.46	712.00	28.94	250.7	5.28	1200.00	700	317	920	420	7	20	10	400	320	200	30	70	27	3200	"
390	62.00	36.46	827.00	30.50	244.6	10.08	1370.00		305	1700	20	1	3	21	22	140	170	22	1937	19	400	Marichchukkaddi
391	40.00	3.62	459.00	1.56	56.1	53.31	719.90		115	710	21	2	13	7	21	20	270	23	1127	48	500	"
392	90.00	36.42	1103.00	17.20	263.5	149.37	1720.00		376	640	40	2	22	17	31	10	110	21	1320	3	350	"
393	60.00	9.43	1195.00	30.50	108.3	34.58	1919.90		189	710	70	2	21	17	44	14	210	17	1311	7	400	"
394	84.00	12.15	1172.00	7.82	250.7	34.58			260	170	42	3	17	11	43	12		12	1402	70	700	"
395	82.00	27.96	1264.00	28.54	330.0	15.36	2000.00		321	720	17	2	22	2	18	70	10	17	1321	42	780	"
396	80.00	2.38	91.00	30.34	195.8	5.82	200.00		210	810	22	3	28	7	32	22	810	22	377	30	80	"
400	200.00	53.36	1011.00	32.06	677.8	34.58	1700.00	820	720	300	7	5	18	13	27	7	700	27	112	21	300	Madawachchiya
401	140.00	6.06	666.00	10.55	305.0	7.80	1270.00	717	600	120	2	2	117	17	22	2	2,100	32	227	31	570	"
402	100.00	7.02	1000.00	39.10	262.9	14.40	1700.00	617	540	1000	7	2	32	27	24	7	2,100	13	73	41	600	"
405	200.00	3.63	482.00	106.37	427.0	5.33	1000.00	717	620	710	8	2		27	22	120	1,700	32	100	37	600	"
408	110.00	6.07	337.00	38.71	348.9	2.01	720.00	700	540	170	20	2	273	37	72	41	110	37	17	21	800	Horowpotana
412	16.00	1.21	741.00	28.15	353.2	0.52	1200.00	7000	340	230	22	11	27	22	220	77	2,000	82	113	13	1500	"
416	168.00	2.43	321.00	35.97	305.0	4.37	720.00	620	520	3700	320	13	173	712	122	120	11,000	60	92	27	2000	Trincomalee
417	148.00	6.07	643.00	39.10	427.0	4.80	1200.00	618	820	3700	420	12	117	112	100	700	9,200	92	148	13	3750	"
418	116.00	3.64	1360.00	43.80	353.8	5.81	2200.00	512	440	3700	320	11	217	117	100	420	7,200	97	90	17	3270	"
419	102.00	4.48	1333.00	43.41	311.7	4.41	2200.00	517	440	10000	420	14	217	117	200	600	1,700	97	90	1	3700	"

																				Topographic Sheet
420	140.00	1.21	1195.00	49.92	305.0	3.45	2000.00	617	400	820	340	12	200	100	200	520	9,200	90	90	12	3100	Trincomalee
425	220	8.50	580.00	145.48	616.8	14.40	1200.00	2100	900	480	31	2	1	1	22	70	720	17	427	47	1000	Vavuniya
426	226.00	3.71	955.00	35.97	483.2	4.80	1700.00	2100	720	400	48	7	78	11	17	43	1,300	11	322	37	750	,,
427	222.00	6.07	82.00	39.10	471.6	4.80	420.00	1210	800	400	27	3	2	1	27	22	610	30		181	200	Mantai
429	208.00	8.50	966.00	82.51	610.1	14.45	1720.00	1700	870	320	22	2	7	2	17	24	220	22		27	1000	,,
430	148.00	8.50	992.00	43.41	556.4	4.89	1720.00	1700	720	460	22	13	42	1	110	300	12,000	28	278	92	1800	Nilaveli
431	200.00	97.01	511.00	67.26	427.6	53.31	1200.00	1300	900	640	21	14	17	3	110	1700	11,000	27	231	90	1000	,,
432	300.00	60.53	1678.00	23.85	1043.9	14.88	2700.00	1250	1000	820	20	17	22	2	220	420	9,000	11	431	11	800	,,
436	216.03	97.25	1057.00	34.41	1037.2	34.58	1700.00	1500	940	3800	24	12	27	12	220	21	3,200	12	122	71	1500	Padawiya
437	204.00	109.00	678.16	19.55	738.0	35.00	1270.00	1700	960	3800	72	2	1	1	17	20	100	17	327	43	1400	,,
438	220.00	85.00	781.60	1.95	921.0	44.00	1270.00	2000	900	400	23	3	11	1	270	27	2,100	22	131	27	2000	,,
443	160.00	3.79	643.67	8.21	488.0	15.00	1000.00	953	416		220	20	10	12	nd	24	19,000	37	17	21	100	Galgamuwa
445	87.00	24.31	206.89	10.16	372.0	20.00	320.00	1300	320	400	190	14	12	11	60	21	5,600	47	23	22	1000	,,
446	94.42	36.46	114.94	28.15	439.0	24.00	203.00	1919	386			19	2	2	61	22	9,200	87	41	2	500	,,
448	40.08	11.67	160.91	23.85	128.0	15.36	290.00	1480	398	720	270	21	8	17	63	71	7,200	92	117	3	1000	,,
449	40.08	3.89	206.89	35.19	183.0	44.18	294.90	452	202	560		17	11			17	9,000	42	118	27	700	,,
450	12.82	36.46	183.90	28.00	243.0	5.28		1012	423	2000	430	20	2	1		13	7,000	97	122	21	600	,,
469	67.94	36.47	321.83	150.00	427.0	15.36	620.00	420	320	420	120	7	2	27	17	17	1,700	8	82	27	1500	Kala Oya
470	110.00	12.16	321.83	179.00	122.0	206.00	700.00	444	327	320	170	3	1	211	21	22	2,700	11	32	31	1200	,,
471	88.00	12.16	344.82	195.00	427.0	48.00	622.00	443	372	110	120	2	3	2	20	18	3,000	17	37	30	1100	,,
472	51.30	12.16	206.89	191.00	61.0	154.00	470.00	342	178	610	142	9	18	273	18	70	2,100	2	87	40	1000	,,
475	72.00	19.94	275.86	82.00	220.0	63.00	490.00	453	332	810	75	7	27	24	32	10	1,900	9	43	21	1100	,,
479	92.06	12.16	505.74	243.00	274.0	53.00	1000.00		280	110	72	2	7	12	42	22	2,100	17	32	32	400	,,
481	75.23	24.31	344.82	150.00	195.0	53.00	20.00		288	1000	78	12	11	2	36	72	3,100	10	14	14	330	,,
482	96.87	12.16	160.92	117.00	258.0	34.00	410.00		292	1410	75	14	2	1	41	17	2,700	12	111	18	310	,,

Chemical Results of the Sampled Well Water Na + K/SO_4 Subgroup

Location No.	Ca ppm	Mg ppm	Na ppm	K ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	TDS ppm	Total Hardness ppm in $CaCO_3$	Total Fe ppb	Mn ppb	Total Cr ppb	Co ppb	Total V ppb	Cu ppb	Zn ppb	NO_3 ppb	NO_2 ppb	NH_4 ppb	SiO_2 ppm	F ppb	Topographic Sheet
25	0.21	0.01	25.5	0.04	6.7	35.1	10	432	401	2000	77	7	4	12	3	21	810	71	47	28	500	Ambalantota

Chemical Results of the Samples Well Water Na + K/HCO_3 Subgroup

40	6.80	4.00	2.29	18.48	43.9	5.28	10	42	27	720	43	20	27	7	30	7	1,300	80	12	3	100	Rakwana
68	20.4	0.22	68.96	17.83	60.4	4.80	120	384	53	250	82	21	1	10	12	34	9.700	182	10	11	170	Panadura

Chemical Results of the Sampled Well Water Na + K/NDA Subgroup

44	80.00	11.02	91.95	38.32	183.0	96.06	161.00	340	328	1100	57	2	12	72	24	143	7,100	17	40	27	720	Katharagama
49	40.00	11.16	68.96	20.98	80.5	82.61	108.00	132	128	110	78	10	1	142	132	27	2,000	90	10	25	610	"
99	7.20	0.24	13.44	7.82	40.8	0.52	20.00	72	280	6220	112	30	17	222	2	712	11,000	45	70	1	500	Colombo
105	8.80	0.48	45.97	1.51	56.1	0.52	42.00	112	61	4490	70	22	7	2	12	270	1,000	17	12	10	330	Avissawella
115	20.04	0.22	22.98	4.81	57.3	4.41	10.00	112	51	910	30	2	1	1	80	80	10,000	137	11	7	30	Hatton
156	0.20	0.48	4.36	0.18	6.1	3.36	3.00	200	210	3100	90	7	111	17	67	18	3,520	210	1000	12	100	Kandy
253	156.00	12.15	206.89	29.33	475.2	82.61	320.00	420	440	440	100	7	1	30	141	21	10,300	317	770	122	400	Kalmune
281	100.00	2.36	114.94	24.24	305.0	63.46	158.00	340	360	110	82	21	7	1	47	210	6,000	17	617	27	70	Nalanda
304	87.00	48.62	183.90	17.20	433.8	101.44	270.00	420	420	210	120	3	22	17	111	42	100	17	87	2	1370	Rukam

Chemical Results of the Sampled Well Water NDC – Cl Subgroup

Location No.	Ca ppm	Mg ppm	Na ppm	K ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	TDS ppm	Total Hardness ppm in $CaCO_3$	Total Fe ppb	Mn ppb	Total Cr ppb	Co ppb	Total V ppb	Cu ppb	Zn ppb	NO_3 ppb	NO_2 ppb	NH_4 ppb	SiO_2 ppm	F ppb	Topographic Sheet
2	42.00	10.97	39.60	39.90	61.9	1.30	170.00	320	4200	2790	100	22	22	72	11	13	9,200	18	90	37	100	Ambalangoda
19	60.10	6.52	48.50	42.60	128.8	54.30	130.00	1000	1770	73	73	12	2	20	2	22	110	62	89	3	780	Ambalantota
21	80.00	36.40	48.50	0.39	61.7	37.50	280.00	470	300	2700	140	2	17	40	7	27	20	69	75	17	2000	"
22	46.40	36.47	71.50	47.32	105.0	62.70	256.00	320	216	1180	122	4	22	11	7	12	10	120	27	43	1230	"
54	60.60	60.12	91.90	30.05	199.0	3.40	266.00	320	304	210	75	7	1	157	20	73	100	11	11	32	600	Kataragama
57	60.10	12.03	68.90	20.10	122.0	5.76	190.00	502	75	500	124	3	12	217	72	35	1,000	120	7	27	520	Yala
77	2.60	1.33	2.82	2.73	0.6	0.96	10.00	43	12	920	92	10	1	2	17	217	2,000	27	20	3	200	Haputale
87	4.30	2.43	7.58	0.18	7.0	3.36	20.00	92	20	700	48	17	1	17	6	372	120	111	11	15	700	"
93	28.00	1.21	7.38	3.91	10.3	0.52	90.00	340	120	700	60	12	11	7	10	412	6,000	400	10	17	2370	Buttala
97	40.00	0.24	45.97	1.85	59.7	3.45	92.00	1200	110	120	72	12	3	7	21	318	6,000	127	7	12	980	"
103	8.80	0.48	7.22	11.73	43.3	0.04	26.00	114	42	2210	70	30	2	17	1	230	4,000	12	82	2	230	Avissawella
135	10.00	36.46	121.00	39.10	348.9	4.41	270.00	1900	400	310	85	12	110	21	117	13	100	120	74	41	230	Potuvil
139	60.10	4.83	45.00	85.32	122.0	4.80	117.00	200	170	6220	100	11	17	2	9	17	10,000	27	11	12	110	Negombo
149	40.00	4.83	45.00	0.18	56.1	6.34	92.00	211	120	3000	12	24	2	2	7	27	2,000	72	13	3	500	Gampaha
219	20.00	10.64	2.29	19.59	60.4	3.39	50.00		94	720	72	10	3	11	52	27	4,000	127	33	11	200	Kurunegala
227	20.00	5.57	2.29	18.38	7.3	5.76	40.00	170	73	710	43	7	1	31	60	73	10,000	22	14	2	110	"
255	147.00	36.46	229.00	26.20	450.2	101.34	410.00	420	520	110	120	7	8	31	120	17	10,000	132	300	17	310	Kalmune
278	80.00	16.95	68.00	36.60	195.8	63.40	170.00	270	270	110	75	12	7	8	40	170	6,000	24	612	17	170	Nalanda
305	95.00	12.15	114.00	2.73	263.5	53.36	200.00	440	300	170	112	7	17	111	122	121	820	2	27	13	2000	Rukam
318	98.30	12.15	114.00	18.38	263.5	53.31	211.00	294	296	560	220	12	1	17	31	24	1,700	21	327	2	400	Puttalam
319	100.00	4.80	91.00	38.71	196.4	19.21	340.00	616	270	480	430	7	17	2	23	10	7,200	70	47	11	720	Dambulla
321	87.00	24.31	137.00	22.68	250.7	44.18	280.00	800	318	320	270	8	27	17	37	27	6,200	62	37	4	320	"
328	120.00	10.61	137.00	33.63	366.0	5.28	270.00	700	344	110	38	12	30	42	72	500	100	42	12	7	13 130	Polonnaruwa
379	80.00	55.31	206.00	19.94	313.1	10.08	270.00	388	428	210	20	12	3	3	64	415	110	27	92	10	3000	Kaudulla
380	84.00	53.00	137.00	0.89	330.0	34.58	300.00	470	429	110	21	10	2	7	120	317	110	12	98	11	3200	"
409	107.60	6.10	165.00	27.76	355.0	5.81	400.00	1700	520	270	22	2	113	13	75	40	420	97	27	31	1000	Horowpatana
410	120.00	8.74	0.22	39.10	434.4	3.45	170.00	1500	600	170	2	3	42	71	120	22	600	92	32	37	970	"
413	204.00	2.43	183.00	67.26	433.8	5.31	500.00	2150	610	410	22	22	32	37	198	22	2,700	86	113	17	1000	"
414	220.00	12.15	114.00	105.00	682.7	5.81	500.00	2100	1200	230	24	17	42	37	240	27	7,000	82	17	32	1200	"
415	188.00	6.07	91.00	28.15	470.4	3.45	400.00	2150	720	130	27	10	32	43	220	13	9,000	82	32	37	1000	"
422	260.00	8.50	224.00	38.71	610.1	4.75	700.00	2010	1000	400	22	1	8	3	17	27	2,000	17	322	47	800	Vavuniya
433	312.00	48.62	275.00	14.47	629.6	63.40	720.00	2000	980	800	45	1	7	17	15	41	800	17	170	47	500	Puliyankulam
484	71.00	24.31	68.00	27.76	189.7	67.72	179.00		295	1120	75	7	1	1	27	27	2,000	17	117	27	3101	Kala Oya

Chemical Results of the Sampled Well Water NDC – SO_4 Subgroup

Location No.	Ca ppm	Mg ppm	Na ppm	K ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	TDS ppm	Total Hardness ppm in $CaCO_3$	Total Fe ppb	Mn ppb	Total Cr ppb	Co ppb	Total V ppb	Cu ppb	Zn ppb	NO_3 ppb	NO_2 ppb	NH_4 ppb	SiO_2 ppm	F ppb	Other Remarks
6	80.16	18.00	68.90	39.10	105.0	289.40	120.00	372	278	3100	110	22	12	23	11	21	100	120	81	17	100	Ambalangoda
17	80.16	53.87	48.50	4.30	128.8	297.40	97.00	453	422	2700	68	10	3	36	13	23	5000	10	82	68	210	Morawaka
18	86.81	48.63	30.40	8.21	128.8	339.00	25.00	437	417	3700	41	24	2	10	11	24	5210	21	80	63	10	Morawaka
24	84.81	48.63	25.50	0.39	122.0	272.20	60.00	428	412	2000	72	10	3	10	7	27	210	70	17	2	1920	Ambalantota
42	6.01	1.98	2.29	5.02	6.7	15.36	7.00	43	20	1960	42	19	11	7	10	2	2300	120	1	2	400	Rakwana
118	20.04	6.44	17.93	3.91	26.2	92.69		114	77	1010	30	3	22	1	59	80	1700	420	21	12	70	Hatton
464	55.91	97.25	26.66	156.43	305.0	470.22	40.76	200	540			12	3				900		17	1	nd	Timbolketiya
474	86.57	24.31	91.95	36.74	245.2	293.51	37.00	448	312	720	122	17	22	22	21	17	2700	3	67	24	1100	Kala Oya

Chemical Results of the Sampled Well Water NDC – HCO_3 Subgroup

Location No.	Ca ppm	Mg ppm	Na ppm	K ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	TDS ppm	Total Hardness ppm in $CaCO_3$	Total Fe ppb	Mn ppb	Total Cr ppb	Co ppb	Total V ppb	Cu ppb	Zn ppb	NO_3 ppb	NO_2 ppb	NH_4 ppb	SiO_2 ppm	F ppb	Topographic Sheet
72	20.04	14.95	11.58	3.91	104.3	34.58	17.00	200	112	2920	120	2	2	7	49	22	2,100	62	20	3	380	Ratnapura
73	32.00	12.52	28.25	0.86	117.1	68.20	12.00	260	132	1980	143	3	7	1	49	17	110	51	7	2	320	"
74	26.00	12.52	22.10	3.91	122.0	34.50	18.00	270	117	2000	92	7	3	1	47	70	8,000	53	7	7	410	"
75	30.00	12.15	23.92	3.91	117.1	48.00	20.00	220	127	720	93	11	2	3	52	72	7,920	17	7	1	390	"
83	6.79	3.64	1.97	0.68	22.5	14.40	2.00	42	27	270	42	12	4	3	10	412	1,700	21	7	3	520	Haputale
107	8.00	0.36	9.45	3.91	44.5	0.81	10.99	79	35	6860	72	24	3	27	11	121	11,000	27	17	3	420	Avissawella
127	9.19	6.07	1.37	4.28	43.3	0.38	11.99	120	48	720	22	17	22	7	21	213	10,000	217	2	11	100	Nuwara Eliya
133	68.00	36.00	68.90	3.48	305.0	5.81	116.01	1750	320	110	82	7		17	12	14	210	143	50	71	270	Potuvil
164	60.00	6.76	19.99	0.39	176.9	48.00	19.00	170	178	2310	82	2	17	21	43	17	8,310	28	327	12	150	Kandy
167	60.00	5.30	13.79	3.01	190.0	20.60	20.00	120	172	1220	22	13	41	11	41	21	7,000	77	312	7	10	"
181	68.00	36.00	45.90	9.64	324.5	63.40	69.99	210	320	120	41	10	13	13	13	27	2,100	140	773	2	20	Nilgala
185	67.90	36.30	22.90	4.93	312.3	7.45	2.79	145	320	110	41	3	1	1	73	72	110	28	773	17	2900	"
190	76.00	36.30	22.90	14.08	366.0	3.18	47.00	527	340	430	114	7	2	1	150	53	1,000	412	1400	27	2300	Tirrukkovil
191	96.40	48.40	11.40	19.55	483.2	3.84	31.99	500	441	520	117	13	3	32	160	77	10	317	1700	22	2100	"
193	88.00	48.40	45.90	13.69	450.8	7.76	48.00	470	420	110	100	11	8	39	140	12	100	317	4000	18	2300	"
217	20.00	11.40	0.22	1.01	61.0	5.76	30.00	213	97	900	72	12	1	32	73	172	21,400	311	37	11	320	Kurunegala
241	120.00	72.00	91.90	4.10	609.5	130.60	120.00	500	600	780	100	10	14	120	70	110	880	227	722	21	20	Maha Oya
245	88.00	48.00	22.90	26.20	233.8	44.10	71.99	170	420	120	110	7	1	42	73	211	280	622	622	1	70	"
263	67.10	48.00	45.90	2.73	427.0	10.00	80.00	777	368	730	122	18	11	13	31	12	12,800	278	22	27	410	Wariyapola
265	61.60	36.00	22.90	9.15	309.3	53.30	40.00	400	304	720	100	18	2	7	28	22	7,200	420	18	42	410	"
267	44.80	24.00	2.29	7.12	244.0	11.30	10.00	417	212	110	110	15	21	2	31	10	3,000	417	18	1	400	"
277	68.00	36.00	2.29	17.75	366.0	18.70	20.00	400	320	120	73	18	10	7	33	210	3,200	22	718	22	170	Nalanda
279	72.00	24.00	22.90	24.63	244.0	101.40	40.00	300	280	310	77	13	2	1	41	170	6,000	25	514	3	270	"
286	43.60	12.15	22.00	5.47	193.4	34.60	16.00	540	159	810	100	18	22	12	42	170	4,600	100	332	1	270	Elahera
294	48.00	12.51	22.00	23.86	189.7	68.20	17.00	370	170	610	77	18	17	2	65	317	10,000	114	471	5	230	"
299	60.10	46.30	22.00	18.65	354.6	101.40	12.98	341	341	110	140	12	3	8	61	320	4,300	50	112	2	100	"
300	63.70	36.40	2.29	5.86	330.6	63.40	10.99	342	342	430	122	12	2	1	80	420	5,000	62	73	18	7000	"
302	97.60	48.60	2.29	30.93	477.1	63.40	21.99	4444	444	120	75	17	1	1	69	321	6,000	17	172	11	320	"
435	300.00	60.00	1678.00	23.85	1043.9	14.80	2700.00	2100	970	320	40	4	2	2	20	31	720	28	100	31	1000	Puliyankulam

																					Topographic Sheet
439	220.00	109.00	91.00	25.42	982.9	44.10	270	4000	1000	380	22	12	17	2	117	31	1,000	12	327	28	2400	Padaviya
440	208.00	97.00	160.00	22.29	1060.4	5.20	300	3000	920	700	21	12	2	7	117	32	1,100	62	427	27	3000	"
441	204.00	109.00	229.00	35.19	1036.7	44.10	420	3200	960	700	22	11	7	1	117	70	1,210	17	426	37	2600	"
447	140.00	11.54	206.00	30.50	122.0	33.00	530	630	386	360	275	21	7	7	61	25	7,500	27	42	3	1200	Galgamuwa
306	68.00	24.31	68.00	0.39	206.8	48.07	141	270	270	270	110	3	22	13	112	72	110	1	92	61	3270	Rukam
360	100.00	7.90	91.00	19.55	311.0	20.17	163	592	283	1000	17	7	117	27	17	10	720	38	751	24	780	Horowupatana
367	100.00	6.24	114.00	5.86	305.0	34.58	176	516	276	110	340	2	113	13	18	120	120	32	313	22	270	Anuradhapura
372	91.00	12.15	91.00	15.01	263.5	39.38	170	322	278	270	21	3	42	2	70	227	220	7	277	27	1200	Kaudulla
373	76.00	24.31	45.00	12.94	244.0	37.46	119	319	292	110	27	2	117	1	72	222	110	12	327	17	3000	"
374	70.00	36.46	45.00	33.47	287.9	34.58	139	342	327	430	21	13	32	2	2	413	210	17	217	14	2700	"
375	124.00	24.31	183.00	21.54	433.8	58.11	300	429	412	130	22	13	117	1	63	317	410	27	312	17	3200	"
403	140.00	8.97	27.00	28.15	427.0	8.26		890	720	2000	17	2	17	22	27	2	1000	14	17	42	1000	Medawachchiya
423	208.00	133.00	44.00	77.00	776.0	34.00		2000	1070	700	28	1	22	1	27	27	1000	20	113	41	900	Vavuniya
424	202.00	156.00	22.98	106.00	410.0	596.00		2100	1150	780	31	1	27	1	22	73	2,700	24	431	27	950	"

Chemical Results of the Sampled Well Water NDC – NDA Subgroup

Location No.	Ca	Mg	Na	K	HCO_3	SO_4	Cl	TDS	Total Hardness	Total Fe	Mn	Total Cr	Co	Total V	Cu	Zn	NO_3	NO_2	NH_4	SiO_2	F	Topographic Sheet
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm in $CaCO_3$	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppb	ppm	ppb	
27	84.00	80.16	2.29	27.45	319.2	101.00	60.00	442	412	1700	143	2	7	9	7	22	410	37	38	38	300	Ambalantota
30	216.00	120.24	1333.33	35.19	616.8	101.00	2150.00	712	617	210	112	7	12	2	11	72	710	72	21	21	1800	Hambantota
84	2.00	2.90	2.82	3.36	12.2	4.80	8.00	43	32	20	43	7	8	2	17	317	700	27	2	1	810	Haputale
85	6.79	2.43	2.90	2.73	19.5	5.28	10.00	47	17	120	42	8	3	4		318	6,000	100	7	10	270	"
94	28.00	1.21	9.13	3.91	43.3	4.80	41.00	500	120	110	61		3	3	7	315	110	120	1	27	3200	Buttala
95	68.00	2.43	22.94	31.51	183.0	9.60	78.00	470	270	120	70	13	2	1	9	611	210	131	2	2	1390	"
109	20.00	8.38	13.10	7.82	56.7	44.00	21.00	142	85	2700	40	1	1	82	41	112	2,000	82	21	7	270	Avissawella
110	8.01	0.38	3.91	3.91	25.0	0.48	17.00	99	36	6000	42	9	1	87	40	117	1,000	87	17	2	170	"
111	20.00	0.07	22.98	2.29	61.0	4.41	7.00	78	53	4200	42	2	3	2	71	70	1,700	120	11	13	70	Hatton
116	20.00	4.35	8.96	11.73	57.4	16.01	11.99	112	68	820	22	3	3	7	62	172	2,700	170	11	2	10	"
119	20.00	6.29	22.98	13.31	61.0	3.50	40.00	103	76	2100	27	2	1	1	60	22	7,000	890	12	11	170	"
123	8.79	4.86	18.39	3.85	37.8	2.92	18.00	114	42	10	12	12	17	1	10	320	2,100	327	4	12	10	Nuwara Eliya
125	20.00	2.65	16.09	3.51	50.0	3.41	17.00	119	61	10	20	2	2	3	13	337	10,000	118	1	27	70	"
131	100.00	16.94	68.96	29.01	305.0	1.63	170.00	2000	320	120	74	9	142	12	17	21	100	17	75	70	20	Pottuvil
138	40.00	4.83	22.98	32.98	61.0	5.81	71.00	175	120	6120	112	10	22	3	10	22	7,000	70	12	11	20	Negombo
141	60.00	6.27	68.96	5.31	183.0	8.26	71.00	275	170	3300	20	12	170	3	9	90	12,000	110	9	7	170	Gampaha
182	60.00	12.10	45.97	144	183.0	47.83	71.00	211	200	130	100	7	12	2	128	37	1,100	17	774	30	980	Nilgala
183	60.00	6.53	45.97	10.16	128.1	25.79	79.00	210	127	120	78	8	2	13	27	27	1,200	52	427	32	1320	"
198	40.00	24.20	68.97	39.09	189.7	8.57	140.00	170	200	70	70	2	117	7	14	17	7,000	112	19	1	230	Dandagamuwa
204	40.00	10.85	45.98	21.12	122.0	3.88	90.00	210	145	720	63	11	2	1	43	46	9,400	16	27	8	920	"
205	20.00	12.07	12.55	11.73	61.0	3.87	30.00	210	100	320	64	12	13	1	41	22	2,400	6	22	7	990	"
209	20.00	8.92	10.11	15.64	122.0	2.86	30.00	200	100	720	52	11	4	17	49	71	5,400	777	17	2	90	Kurunegala
212	40.00	2.63	30.57	1.96	128.1	0.46	80.00	178	111	880	64	7	2	27	49	38	6,200	312	28	8	120	"
218	20.00	10.18	2.29	5.70	56.1	15.36	30.00	112	92	1720	71	10	17	17	80	11	3,600	210	42	12	110	"
220	20.04	9.70	2.29	29.17	61.0	38.00	30.00	170		720	67	11	2	18	52	27	3,600	342	34	7	270	"
222	20.04	10.67	2.29	15.07	61.0	39.00	20.00	143	94	110	40	7		21	74	32	4,800	217	27	2	320	"
226	20.04	4.84	2.29	18.38	7.3	5.76	40.00	122	70	110	42	7	11	40	59	31	10,000	13	42	11	130	"

																				Topographic Sheet	
229	40.08	4.83	22.98	30.97	122.0	22.00	61.00			170	42	7	2	7	77		9,000	27	22	17	200	Kurunegala
242	148.00	36.46	91.95	10.55	446.6	248.00	77.00	1200	520		120	12	3	77	72	14	300	1230	940	3	120	Rangala
266	44.02	24.31	45.97	6.84	194.6	58.00	70.00	427	210		124		18	1	32	21	2,600	22		31	390	Wariyapola
269	40.00	6.52	22.98	27.61	122.0	13.00	70.00	300	127	430	120		22	1	43	18	8,400	511		2	560	"
271	40.00	5.32	45.97		123.2	63.00	39.00	312	122		140		11	1	47	22	2,000	227		1	520	"
272	62.00	6.15	45.97	22.68	151.9	63.00	70.00	1317	131		122		27	3	77	21	3,000	317		1		
283	20.00	12.13	2.29	7.89	43.3	48.00	20.00	400	100	10	170	12	22	17	37	17	6,000	27	772	3	10	Nalanda
287	96.00	24.31	68.96	24.24	311.7	154.00	72.00	500	340	170		12	77	24	84	413		120	432	12	320	Elahera
289	87.97	24.31	45.97	26.20	217.8	101.00	119.00	400	320	310	120	17	11	7	84	217		122	337	18	20	"
295	40.00	9.69	22.98	21.96	122.0	86.00	27.00	470	140	730	78	19	2	3	64	310		130	712	3	100	"

Chemical Results of the Samped Well Water (Un Classified data)

Location Number	TDS ppm	Total Hardness ppm in $CaCO_3$	Total Cr ppb	Cl ppm	Fe ppb	Mn ppb	Zn ppb	Co ppb	NO_3 ppb	NO_2 ppb	NH_4 ppb	SiO_2 ppm	Cu ppb	Total V ppb	F ppb	Topographic Sheet
13	330	317	21	135	2320	42	17	27	7,100	62	27	17	42	28	60	Morawaka
14	320	312	17	350	3000	72	18	2	10,000	28	30	62	12	20	100	"
20	1100	4170	3	465	1780	71	27	7	110	57	92	27	5	30	1000	Ambalantota
71		113	1	10	2000	98	18	11	8,000	27	62	9	43	2	170	Ratnapura
81	30	10	3	14	10	45	312	3	820	22	11	2	10	3	820	Haputale
96	1200	270	14	89	720	62	217	1	820		11	12	17	8	2070	Buttala
112	82	40	10	3	1110	40	77	7	3,700	127	62	17	51	3		Hatton
189	540	370	7	37	730	122	71	11	710	317	1270	47	160	72	2700	Tirrukkovil
215	117	211	6	80	1720	66	120	3	5,400	411	27	1	53	21	130	Kurunegala
228	173	97	2	20	110	44	120	1	8,000	17	27	8		3	100	"
235	200	44	17	10	720	42	318	2	4,000	27	522	12	14	117	130	Rangala
247	272	440	10	17	170	122	112	12	10	627	627	7	87	67	110	Maha Oya
249	270	240	17	17	600	120	170	2	11,700	322	322	5	67	320	920	"
254	700	540	1	327	620	80	132	7	10,200	127	270	2	140	32	410	Kalmunai
274	720	340	21	190	110	72	12	117	5,600	17	712	11	34	27	140	Nalanda
311	420	422	2		500	120	313	11	32		22	3	91	338	3200	Rukam
315	1512	712		188	400	160	17	1	1,100	12	4200		41	7	400	Puttalam
320	700	217	7	680	640	300	77	22	2,400	75	28	3	21	7	130	Dambulla
329	720	356	20	320	10	38	34	11		31	17	3	72	17	720	Polonnaruwa
331	670	342	12	117	120	82	522	13	610	37	27	7	70	47	10020	Polonnaruwa
336	811	268	8	1400	3400	270	210	127	200	32	114	112	162	113	2000	Vakaneri
384		361	8	100	4300	440	422	21	nd	17	73	21	198	2	3300	Kathiraweli
397															4000	Anuradhapura
398															3100	Kala Oya
399															4500	"
406	1000	620	2	72	20	nd	12	21	2,110	91	27	27	27	43	500	Horowpatana
434	2130	700	3	1720	560	40	42	1	820	22	100	27	10	3	750	Puliyankulam

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VITAMIN A AND β – CAROTENE CONTENT OF SOME COMMON FOODS

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Abstract : The content of vitamin A and its precursor, β-carotene was determined in some commonly available foods in Sri Lanka. The edible portion of the uncooked food samples were used for analysis. The concentrations of vitamin A and β-carotene were determined by fluorescence and absorbance spectrophotometry by established methods. Fish and ox liver were the richest sources of vitamin A. The vitamin A content in other animal foods except eggs and milk, was not sufficient to make a significant contribution to the daily vitamin A intake in a Sri Lankan diet. The β-carotene content of dark green leafy vegetables ranged from 61.0 – 99.5 μg/g and was two to three times higher than that of other vegetables and fruits. A major proportion of the daily dietary requirement of vitamin A could be obtained as β-carotene from green leafy vegetables.

1. Introduction

Vitamin A is required for growth, reproduction, vision and maintenance of the integrity of epithelial tissues. Its deficiency in the early stages leads to night blindness and xerophthalmia, which may ultimately progress to blindness, if untreated.[2,6] Deficiency of vitamin A is mainly due to inadequate dietary intake of the vitamin or its precursor, β-carotene. Therefore, it is of utmost importance to identify good sources of vitamin A and β-carotene among the foods commonly available in Sri Lanka. In fact, the identification of dietary sources of vitamin A, is listed as a research priority in the latest report published by the WHO expert committee on vitamin A deficiency.[7] The only data available at present is based on analyses carried out in India[3] and on preliminary studies by Atukorala *et al.*[1] in Sri Lanka.

In this study, analyses for vitamin A and β-carotene have been carried out on some commonly available foods in Sri Lanka.

2. Methods

2.1 Sampling: The food samples were purchased from three different areas of Colombo to obtain a mean value for the foods commonly sold in

Colombo. A weighed amount (0.2 – 0.5 g) of the edible portion of the raw, uncooked food was used for analysis. When analyses were carried out on plant foods, specimens (for replicate estimations) were taken from different leaves selected at random. Three different randomly selected samples of each food item were analysed and the mean ± SEM taken.

2.2 The concentration of Vitamin A was determined by a modification of the fluorometric method of Thompson and co-workers.[5] Alcoholic KOH (30%) was used for saponification instead of (60%) aqueous KOH and the saponification time was increased to 30 minutes. Vitamin A was selectively extracted into hexane and the fluorescence was measured against a blank using a Perkin–Elmer LS3 fluorescence spectrophotometer. Each sample of food was analysed in triplicate.

Retinyl acetate (Sigma, U.S.A.) was used to prepare a standard solution. Vitamin A derivatives being labile compounds, the absorbance of the diluted standard was checked prior to use. The standard solutions were processed in the same manner as the food samples. The mean percentage recovery was 98.71 ± 1.30.

2.3 The concentration of β -carotene was determined by a spectrophotometric method.[3,4]

A standard solution was prepared by dissolving all trans β -carotene (Sigma, U.S.A.) in absolute ethanol (Reiden de Haen, Germany). This stock solution (1 mg/ml) was prepared every two weeks and stored in the dark at 4°C.

Carotenoids were extracted into petroleum ether after saponification of food samples. The petroleum ether extract was washed twice with 92% methanol to remove xanthophylls.[4] Its optical density was measured at 450 nm using a SP 6 – 450 UV visible spectrophotometer. Each estimation was carried out in duplicate.

The mean percentage recovery was 97.5 ± 2.10.

2.4 Statistical significance was assessed using the Student's t test.

3. Results and Discussion

The vitamin A content of flesh foods is given in Table I. Both fish and ox liver had more vitamin A than meat or fish. Fish liver had the highest amount of vitamin A (95.03 ± 17.79 μg/g) with slightly lower amounts in ox liver, but the difference was not significant. The amount of vitamin A in chicken was significantly higher ($p < 0.001$) than that of other meats.

Table 1 Vitamin A content of flesh foods

Food	Vitamin A (μg/g) Mean	SEM
Meat		
Beef, muscle	0.29	0.08
Chicken, muscle	2.020	0.20
Mutton, muscle	0.75	0.30
Pork, muscle (lean)	0.349	0.13
Fish		
Seer *(Scomber sp.)**	0.404	0.011
Para *(Carangids)**	0.338	0.089
Kelawalla *(Euthynnus sp.)**	tracc	–
Thalapath *(Istiophorus gladius)**	0.115	0.018
Hurulla *(Sardinella sirus)**	1.413	0.204
Salaya *(Sardinella jussieu)*	1.395	0.355
Prawns	1.196	0.495
Liver		
Ox liver	76.84	5.84
Fish liver (Para)	95.03	17.79

Each value is the mean of 3 samples.

* The edible portion of large fish without skin was used for analysis.

Table 2. β–Carotene and vitamin A content of Eggs and Milk

Food	β–Carotene		Vitamin A	
	Mean	SEM	Mean	SEM
Egg, Hen (μg/100 g)	364	72	195	23
Cow's milk (μg/100 ml)				
Pasteurised, bottled	71.0	12.5	52.2	18.5
Pasteurised, packeted	115	17.0	60	14.9
Sterilised, bottled	trace	–	40.5	7.2
Fresh, unboiled	120	8.6	87.6	19.6

Each value is the mean of 3 samples.

Table 3. β–Carotene content of cereals, starchy roots and pulses.

Food	β–Carotene (μg/g)	
	Mean	SEM
Cereals		
Rice, parboiled	–	–
Rice, Raw, milled	–	–
Wheat flour	trace	–
Starchy roots*		
Potato *(Solanum tuberosum)*	2.78	0.40
Sweet potato *(Ipomea batatas)*	2.31	0.47
Innala *(Coleus rotundifolius)*	0.232	0.081
Kiriala (Habarala) *(Colacasia esculenta)*	0.199	0.035
Pulses		
Mysoor Dhal *(Cajanus cajan)*	12.90	3.4
Cow pea *(Vigna unguiculata)*	2.50	0.31
Mung (Green gram) *Phaseolus aureus*	7.22	0.52

Each value is the mean of 3 samples.

* Starchy roots without peel were used for analysis.

Of the different varieties of fish studied, small fish (Hurulla and Salaya) had a significantly higher ($P < 0.01$) amount of vitamin A than large fish (Table 1).

The β -carotene and vitamin A content of eggs and milk is given in Table 2. Eggs provide a rich source of both β -carotene (364 ± 72 μg/100g) and vitamin A (195 ± 23 μg/100g). Fresh, unboiled cow's milk had the highest amount of β -carotene with slightly lower amounts in packeted pasteurised milk and significantly ($p < 0.05$) lower amounts in bottled pasteurised and sterilised milk. Vitamin A content of milk also showed a similar variation, but the difference was not significant.

Rice showed no detectable amounts of β -carotene, while wheat flour contained only traces (Table 3). Of the starchy roots studied, potato and sweet potato had a higher content ($p < 0.01$) of β -carotene than other starchy roots. The β -carotene content in pulses was higher than that in cereals or starchy roots, with Mysoor dhal and green gram having significantly ($p < 0.05$) higher amounts than cowpea.

The β -carotene content of vegetables analysed is given in Table 4. Dark green leafy vegetables had a significantly higher ($p < 0.02$) amounts of β -carotene compared to other vegetables except carrots. Moderate amounts of β -carotene were observed in spring onions, leeks and legumes with levels decreasing in that order. Of the vegetable fruits studied, pumpkin had the most β -carotene (Table 5).

Coconut contained only traces of β -carotene. Among fruits, significantly higher ($p < 0.001$) amounts of β -carotene were found in mango and papaw, with mango of the Karthakolumban variety having the highest amount (Table 6).

4. Conclusions

The results obtained in the study are comparable to a similar study carried out on Indian foods.[3] The food samples were analysed in the fresh state as purchased and the effect of cooking or processing on the vitamin A and β -carotene content was not studied.

Both fish and ox liver were rich sources of preformed vitamin A. Meat and fish, with a low content of vitamin A (0.2 – 2 μg/g) do not make a significant contribution to the vitamin A supply in an average Sri Lankan diet. Eggs and milk form a richer source of preformed vitamin A and β -carotene.

Table 4. β—Carotene content of vegetables.

Food	β—Carotene (μg/g) Mean	SEM
Dark-Green leafy vegetables		
Mukunuwenna *(Alternanthera sessilis)*	99.5	16.7
Kankun *(Ipomea aquatica)*	81.4	12.0
Gotukola *(Centella asiatica)*	87.1	19.5
Kathurumurunga *(Sesbania grandiflora)*	75.8	28.2
Spinach *(Basella alba)*	61.9	10.7
Sarana *(Sesuvium portulacastrum)*	76.5	12.2
Other vegetables		
Leeks *(Allium porrum)*	21.29	6.01
Cabbages *(Brassica oleracea)*	2.75	0.65
Carrots* *(Daucus carota)*	40.39	1.17
Spring onions *(Allium cepa)*	30.36	0.73
Legumes		
Beans *(Phaseolus vulgaris)*	18.60	0.99
Winged Beans *(Phaseolus lunatus)*	17.69	1.05
String Beans *(Vigna cylindrica)*	7.59	0.03

Each value is the mean of 3 samples.

*Food without peel was used for analysis.

Table 5. β–Carotene content of vegetable fruits

Food	β–Carotene (μg/g) Mean	SEM
Vegetable fruits		
Brinjals *(Solanum melongena)*	2.13	0.65
Pumpkin* *(Cucurbita mixima)*	12.77	0.89
Snake gourd *(Trichosanthes anguina)*	5.14	3.88
Bitter gourd *(Mormordia charantia)*	2.34	0.56
Ladies fingers *(Hibiscus esculenteus)*	3.25	0.98
Ribbed *gourd (Luffa acutangula)*	1.82	1.06

Each value is the mean of 3 samples.

The edible part of each food was used for analysis.

*Food without peel was used for analysis.

Table 6. β–Carotene content of fruits

Food	β–Carotene (μg/g) Mean	SEM
Coconut *(Cocos nucifera)*	trace	–
Fruits*		
Orange *(Citrus sinensis)*	2.06	0.76
Plantains (Ambul variety) – *Musa sapientum*	2.81	0.42
Plantains (Kolikuttu variety) – *Musa sapientum*	2.58	0.30
Pineapple *(Ananas comosus)*	5.15	0.62
Papaw *(Carica papaya)*	22.4	0.49
Mango *(Mangifera Indica)*	20.96	0.58
Mango *(Karthakolumban variety)- Mangifera Indica*	31.51	1.10
Guavas+ *(Psidium guajava)*	8.97	0.86
Ripe Jak fruit *(Artocarpus heterophyllus)*	2.71	0.60

Each value is the mean of 3 samples.

* The edible portion of each fruit without skin or seeds was used for analysis.

+ The fruit was used with skin.

Most of the commonly available plant foods showed significant amounts of β -carotene. The dark green leafy vegetables analysed (e.g. Mukunuwenna, Gotukola) had a two to three times higher content of β -carotene compared with other vegetables, and therefore constitute a very important dietary source, although the biological activity of β -carotene per unit weight is lower than that of vitamin A (1 International unit of vitamin A = 0.3 μg vitamin A or 0.6 μg β -carotene[2]). Other vegetables (carrots, leeks, spring onions and legumes) were moderate sources of β -carotene. Fruits, especially papaw and some varieties of mango, also make an important contribution to the supply of β -carotene as they can be consumed in the raw state without prior processing. These studies suggest that a major part of the daily dietary requirement of vitamin A in a Sri Lankan diet could be had in the form of β -carotene from commonly available plant foods.

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STUDIES ON THE AGAROPHYTE, *GRACILARIA EDULIS* – EXPERIMENTAL FIELD CULTIVATION AND METHODS OF IMPROVING YIELD AND QUALITY OF AGAR.

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Abstract : Preliminary investigations on the extraction of phycocolloids from five common red algae of Sri Lanka revealed that *Gracilaria edulis* forms a suitable source for the production of agar. This coupled with the relative abundance of this species prompted the investigations on the cultivation of this alga and on the methods of extraction of agar from this species. Vegetative fragments from the apex of the plant were used as "seed" material for planting. Planting of alga was carried out from October 1982 to June 1983 and each month an experiment was set up using algae collected in that month. The algae grew to its maximum size in about 2½ to 3 months attaining a length of 30 – 35 cm and fresh and dry weights of 20 – 30 g and 1.5 to 2.5 g respectively. The agar content and gel strength of agar obtained from cultured *G. edulis* were determined. The amount of agar increased with increase in growth of alga but there were no significant differences in the gel strength of agar. These data compare well with those obtained for naturally occurring *G. edulis*. The effects of different pre-treatments of naturally occurring *G. edulis* on the yield and gel strength, have been studied. While prior wet grinding increased both yield and gel strength of agar, prior soaking did not have any improvement on the agar. Extraction under pressure resulted in a product with increased yield and gel strength. Prior alkali treatment of the sea weed was found to increase the gel strength and pretreatment with KCl upto a concentration of 4% increased the gel strength markedly.

1. Introduction

Marine macroscopic algae which are popularly known as seaweeds are gaining importance as food and also as source of commercially important polysaccharides such as agar, carrageenan and alginic acid. Seaweeds have also been used as a source of biomass and in a number of pharmaceutical products[6,7]. A large number of seaweeds that could be utilised for these purposes are found along the coasts of Sri Lanka[3,4]. Of these seaweeds, species of *Sargassum* and *Gracilaria* have been reported to be present in appreciable quantities. The former could be utilised for the extraction of alginic acid and the latter for agar. Thus there is considerable scope for the utilization of these seaweeds in Sri Lanka.

Several species of red algae occurring in Sri Lanka have been found to be potential sources of agar[1,2] and two species of *Gracilaria* namely *Gracilaria edulis* and *Gracilaria verrucosa* are found in appreciable quantities. However, the estimated quantity of available *Gracilaria*[3] is far below the requirements of an industry for the production of agar. Therefore exploitation of these algae at industrial level cannot be based on the raw materials that could be collected from natural beds alone. In addition indiscriminate harvesting of *Gracilaria* for export as raw sun dried seaweeds by private small scale exporters makes this small resource even smaller. These factors therefore limit the proper utilization of these red seaweeds for commercial purposes in Sri Lanka.

Under these circumstances the only alternative is to increase the amount of raw material by artificial cultivation. Cultivation of seaweeds have been successfully practised for a long time in countries like Japan, Philippines, Indonesia and India. A preliminary investigation on the cultivation of *Gracilaria lichenoids (= G. edulis)* has been carried out at Puttalam lagoon in Sri Lanka too.[10] Further, Sivapalan and Theivendirarajah[11] have shown that this species could also be cultivated in other parts of the country. The main reason for undertaking the cultivation of seaweeds such as *Gracilaria* is the increase in demand for this valuable raw material for economic exploitation. The present work on the cultivation of *G. edulis* was carried out at Mandaitivu, Jaffna.

Extraction of agar from Sri Lankan seaweeds have been investigated previously.[1,2] In many instances it has been observed that many red algae yield little agar and the gel strength of the agar is also low. It is possible to increase the yield and gel strength of agar by various pretreatments. A systematic study on improving the yield and gel strength of agar obtained from *G. edulis* has also been undertaken during the present investigation.

2. Materials and methods

G. edulis was cultivated at Mandaitivu which is an island situated on the west of Jaffna peninsula. This area was selected for cultivation as it supported good natural growth of *G. edulis* and the seawater environment is also ideal for the growth of this species. Further, this alga grows well in shallow water and the area selected formed the required habitat.

Seaweeds are cultivated by means of spore production and by vegetative fragmentation and the latter has been found to be much easier and quicker for *G. edulis*.[9] Several methods for propagating *Gracilaria*, including vegetative fragmentation on coir ropes[9] coir net frames[15] and on coral stones[13] have been carried out. In this investigation all these methods were tried out, where vegetative fragments of about 2 cm long, usually taken from

the apical portions of the *Gracilaria* plant were employed. This "seed" material was inserted into the twists of coir ropes or coir net frames at regular intervals. The long line coir ropes or coir net frames with the algae planted were attached to wooden poles and suspended under water. In the case of coral stones, weeded coral stones were tied with coir ropes containing the planting material by nailing the ropes. These were then submerged under water. The level of water above the planting material was maintained throughout the investigation. However, during low tides the planting materials were exposed, but this was only for a short period.

The project was carried out from October 1982 to June 1983 and each month a fresh set of planting was made using fragments from a number of plants collected that month in order to ascertain the best period for the cultivation and harvesting of *G. edulis*. Observations were made every week after planting on the increase in linear growth, wet weight and dry weight of the algae. The mean length was determined by measuring the length of 20 plants selected at random. The wet and dry weights were determined by removing all the algae from one meter length of coir ropes or one square meter area of coir net frames and the results were related to the weights per plant or per metre length area or square metre area of coir ropes. The plants that attained maturity were clipped at the bottom leaving a fragment on coir rope. Regeneration studies on these fragments were also made using the same parameters. During the period of investigation physical parameters of the sea water such as salinity, oxygen concentration and temperature were also recorded.

The cultured *G. edulis* was analysed for its agar content and gel strength of agar. The gel strength was determined by a penetrameter and expressed as g cm^{-2}. These values were compared with the values obtained for *G. edulis* grown naturally.

Detailed studies on improving the yield and quality of agar were made on naturally grown *G. edulis*. For the purpose of extracting the phycocolloid unless stated otherwise, the following method was employed. In each experiment 10g of powdered *G. edulis* was soaked in distilled water overnight and the excess water was drained off. Fresh distilled water was added to the seaweed in the ratio of 1:20 (w/v) and the pH of the mixture was adjusted to 5. The mixture was boiled for 30 min and after boiling the seaweed was filtered through double layers of muslin cloth. The filtrate was frozen overnight at −10°C in the deep freeze. The frozen sample was subsequently thawed at room temperature and the excess water was drained off. The agar extracted was spread into thin films over a polythene sheet and dried at 50–55°C in a drier. The dried agar was ground in a micromill and used to determine the yield, and its gel strength and the results are expressed as % agar and g cm^{-2} respectively.

3. Experiments and Results

Analysis were carried out initially on the agar obtained from five red algae namely *G. edulis, G. crassa, Hypnea musciformus, Gelidiella acerosa* and *Laurencia obtusa.* It was found that *G. edulis* produced the highest yield of agar. Agar solution of different concentrations (1%, 1.5% & 2%) were prepared using agar obtained from the five algae under investigation and the gel strength, melting temperature and setting temperature were determined. These values were compared with those obtained for a sample of Difco agar (Table 1).

It is apparent from the result that *G. edulis* shows superior quality with respect to qualities of agar and because of this fact and the relative abundance of this species it was decided to carry out an extensive investigation on field cultivation of *G. edulis* and to improve the qualities of agar obtained from it.

The cultivation programme was initiated on 09.10.1982. Fragments of the alga obtained from a few plants were planted and weekly observations were made on the growth of the alga from the 2 cm fragments in terms of increase in linear growth, increase in wet and dry weights (Table 2).

The results show that growth of *G. edulis* from 2 cm fragments is remarkable as the plant attained about 12 cm in eight weeks with a growth rate of about 0.6 cm per day. Similar observations were made on fresh planting that were carried during subsequent months. It is revealed (Table 3) that cultivation programme can be started during every month of the year. This is in accordance with the observations that *G. edulis* can be collected from its natural habitat at Mandaitivu throughout the year. However, algae planted during October 1982 and January 1983 grew faster and luxuriantly. The conditions during the months of October and January seem to favour faster growth and these months could be selected for any extensive cultivation of the algae.

Further observations indicate that *G. edulis* attains its maturity in about 2½ – 3 months reaching a length of 20 – 30 cm and fresh and dry weights of 20 – 30g and 1.5 – 2.5g respectively (Table 4).

Analysis of agar obtained from cultivated *G. edulis* during its different stages of growth indicates that with increase in age of the plant the agar content also increased but the gel strength remained unchanged (Table 5). Comparison of the qualities of agar obtained from cultured and naturally obtained *G. edulis* revealed no difference in the agar content or gel strength of agar. However, processing of alga for agar extraction was much easier with cultivated alga as it was relatively free from calcium deposits and other extraneous materials.

Table 1 : Properties of phycocolloid obtained from some red algae

Alga	% moisture	% agar	strength of agar solution (% w/v)	Setting temp./°C	Melting temp./°C	Gel strength g/cm^{-2}
Gracilaria edulis	86.2	40.0	1.0*	38*	56*	80.2*
			1.5	39	60	140.8
			2.0	40	63	199.3
Gracilaria crassa	84.8	38.4	1.0	41	68	66.5
			1.5	43	70	138.0
			2.0	42	72	168.5
Hypnea musciformis	89.2	34.5	1.0	39	58	95.8
			1.5	42	61	130.3
			2.0	43	60	149.0
Gracilaria acerosa	68.0	20.0	1.0	38	53	65.3
			1.5	37	56	80.3
			2.0	35	58	118.5
Laurencia obtusa	85.8	29.5	1.0	36	56	72.8
			1.5	38	53	88.6
			2.0	34	58	102.3
Difco agar	—	—	1.0	35	58	280.0
			1.5	40	65	392.0
			2.0	43	72	495.0

* The three values in columns 4, 5, 6 and 7 under each algal species refer to the setting temperature, melting temperature and gel strength of 1.0%, 1.5% and 2.0% of agar solutions prepared from the extracted agar of the alga).

Table 2. Growth of *Gracilaria edulis* after different periods

Age of Plant (weeks)	Length (cm)	Fresh weight (g)	Dry weight (g)
1	3.8	1.01	0.11
2	4.2	1.83	0.21
3	5.4	2.42	0.26
4	6.9	2.88	0.31
5	7.4	3.10	0.35
6	9.3	9.80	0.48
7	11.5	13.50	0.99
8	12.3	14.20	1.30

Table 3. Growth of alga (increase in dry weight) planted at different periods of the year

Algae planted on	Dry weight (g) at the end of week							
	1	2	3	4	5	6	7	8
1st Oct. 1982	0.41	0.54	0.75	1.18	1.38	1.67	1.48	1.82
29th Oct. 1982	0.11	0.21	0.26	0.31	0.35	0.48	0.99	1.30
3rd Dec. 1982	0.20	0.32	0.48	0.71	0.95	1.02	1.18	1.26
12th Jan. 1983	0.24	0.31	0.33	0.46	0.54	1.31	1.81	2.27
18th Feb. 1983	0.11	0.20	0.41	0.54	0.72	0.92	1.01	1.21
13th Mar. 1983	0.10	0.27	0.22	0.51	0.63	0.83	1.02	1.31
12th Apr. 1983	0.12	0.34	0.44	0.56	0.62	0.86	1.01	1.02
8th May 1983	0.30	0.39	0.49	0.67	0.97	1.09	1.21	1.48

Table 4. Growth of *Glacilaria edulis* at the time of harvest

Date of planting	Date of harvest	Length (cm)	Fresh weight (g)	Dry weight (g)
1st Oct. 1982	12th Jan. 1983	34.5	20.6	1.40
3rd Dec. 1982	13th Mar. 1983	31.7	24.2	2.30
18th Feb. 1983	8th May 1983	29.3	29.7	1.82

Table 5. Yield and gel strength of agar obtained from *Gracilaria edulis* after different periods of growth.

Age of plant (weeks)	% yield	Gel strength (1.5% solution)
4	20.0	125.8
5	20.5	131.2
6	24.8	120.4
7	29.0	134.3
8	31.0	118.8
9	37.8	102.6
10	41.1	114.2
11	40.2	122.6
12	43.2	112.8

Observations so far have indicated that *G. edulis* could be grown successfully on artificial substrata by vegetative propagation and that the quality of agar obtained from the cultured agar is comparable to that of the agar found in natural beds. Thus artificial cultivation together with the natural raw material cast ashore due to wave action will provide adequate seaweeds or commercial extraction of agar.

With the information available it was decided to study the properties of agar on the different methods of extraction. In the initial studies analysis of agar obtained from *G. edulis* was carried out on air dried algal thallus without powdering before extraction. It was noticed that there was considerable increase in the yield of agar by powdering the seaweeds prior to extraction, however the gel strength did not improve by this pretreatment (Table 6).

When the effect of soaking the seaweeds prior to extraction was investigated it was found that prior soaking did not enhance either the yield of agar or the gel strength of powdered seaweed (Table 7).

An experiment was undertaken to determine the time of extraction that gives the best yield. It was observed that with increase in the time of extraction both the yield and gel strength of agar increased (Figure 1).

Extraction of agar using different methods were tried out. Seaweeds were either boiled for 25 mins or autoclaved at 15 lbs pressure for 25 mins. This experiment involved powdered/unpowdered and soaked/unsoaked treatments.

The results (Table 8) indicate that extraction of agar by autoclaving increased both the yield and gel strength irrespective of whether the seaweed was powdered or soaked.

The requirements of a suitable pH for extraction of agar was subsequently examined and it was found that pH near 5 – 6 gave higher gel strength but the amount of agar produced was greater in the more acidic conditions (Figure 2).

Finally the effect of concentration of initial seaweed water mixture prior to extraction was investigated. It was observed that with increase in the quantity of water the yield of agar also increased but the gel strength was better with a relatively concentrated solution (Table 9).

Several reports have indicated that pre-chemical treatments of either the seaweed or agar improved the quality of agar. These aspects were explored in the following experiment.

Table 6. Effect of powdering *Gracilaria edulis* on the yield and quality of agar.

Treatment	% agar	Gel strength (1% solution)
Powdered	32.8	81.2
Unpowdered	20.3	85.6

Table 7. Effect of prior soaking of powdered seaweed on the yield and quality of agar.

Treatment	% agar	Gel strength (1% solution)
Soaked	25.7	79.3
Unsoaked	23.5	82.5

Table 8. Effects of different methods of extraction on the yield and quality of agar.

Treatment	Extraction by	% agar	Gel strength (1.5% solution)
Soaked powdered	boiling	14.4	146.0
	autoclaving	27.2	168.5
Soaked unpowdered	boiling	19.0	150.4
	autoclaving	32.0	178.3
Unsoaked powdered	boiling	12.2	166.0
	autoclaving	20.4	180.0
Unsoaked unpowdered	boiling	14.6	160.0
	autoclaving	24.2	174.0

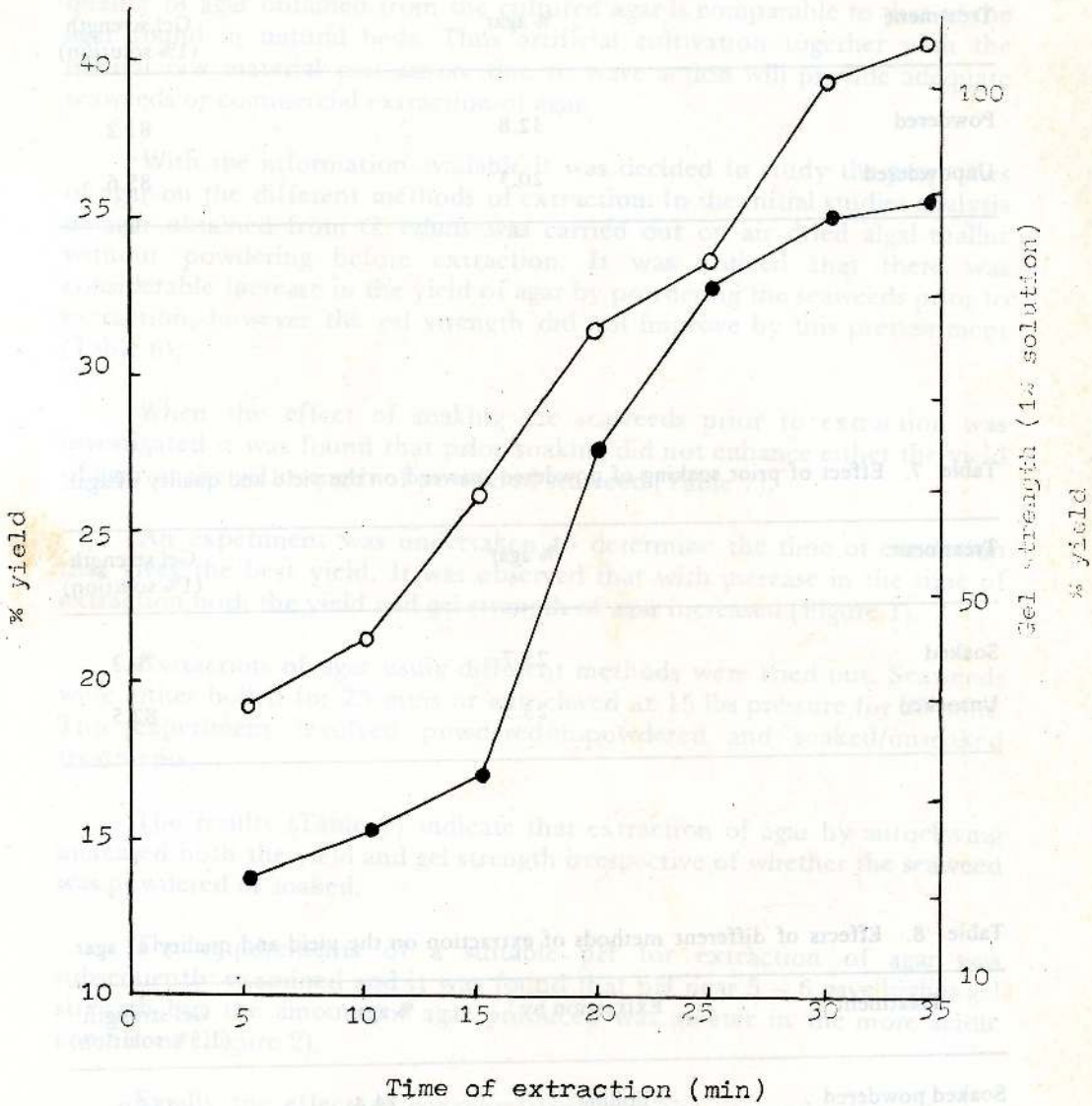

Figure 1. Effect of different periods of extraction on the yield and quality of agar.

○—○ — % yield

●—● — Gel strength g cm^{-2}

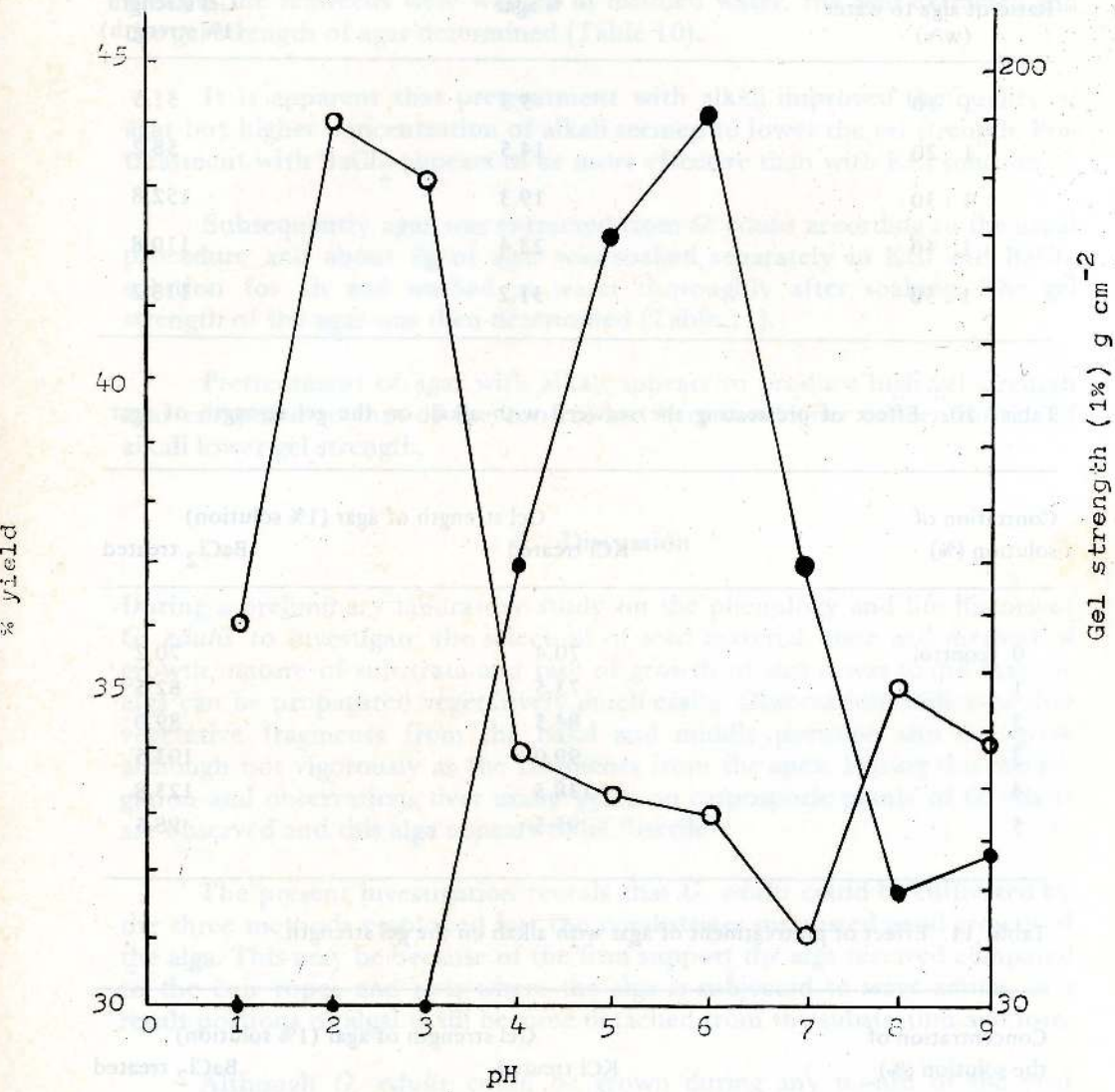

Figure 2. Effect of pH on the yield and quality of agar

○——○ — % yield

●——● — Gel strength g cm^{-2}

Table 9. Effect of seaweed: water ratio on the yield and quality of agar.

Ratio of alga to water (w/v)	% agar	Gel strength (1% strength)
1 : 10	5.3	31.5
1 : 20	14.5	58.2
1 : 30	19.3	152.8
1 : 40	23.4	110.8
1 : 50	31.2	113.2

Table 10. Effect of pretreating the seaweed with alkali on the gel strength of agar.

Contration of solution (%)	Gel strength of agar (1% solution) KCl treated	$BaCl_2$ treated
0 (control	70.4	70.2
1	73.5	82.5
2	84.5	89.0
3	99.0	103.5
4	138.5	123.8
5	95.5	98.5

Table 11. Effect of pretreatment of agar with alkali on the gel strength.

Concentration of the solution (%)	Gel strength of agar (1% solution) KCl treated	$BaCl_2$ treated
0 (control)	96.2	96.2
1	136.9	128.0
2	121.4	110.2
3	102.4	102.3
4	98.4	93.8
5	90.5	88.8

Powdered samples of seaweed were soaked for 1h separately in 50 ml KCl and $BaCl_2$, solutions of concentration 1%, 2%, 3%, 4% and 5%. After soaking the seaweeds were washed in distilled water, the agar extracted and the gel strength of agar determined (Table 10).

It is apparent that pretreatment with alkali improved the quality of agar but higher concentration of alkali seemed to lower the gel strength. Pretreatment with $BaCl_2$ appears to be more effective than with KCl solution.

Subsequently agar was extracted from *G. edulis* according to the usual procedure and about 2g of agar was soaked separately in KCl and $BaCl_2$ solution for 1h and washed in water thoroughly after soaking. The gel strength of the agar was then determined (Table 11).

Pretreatment of agar with alkali appears to produce high gel strength agar compared to that of the control but here too higher concentrations of alkali lower gel strength.

5. Discussion

During a preliminary laboratory study on the phenology and life history of *G. edulis* to investigate the selection of seed material, time and method of growth, nature of substrata and rate of growth of alga it was found that the alga can be propagated vegetatively much easily. Observations indicated that vegetative fragments from the basal and middle portions also can grow although not vigorously as the fragments from the apex. During this investigation and observations over many years no carposporic plants of *G. edulis* are observed and this alga appears to be "sterile".

The present investigation reveals that *G. edulis* could be cultivated by the three methods employed but the coral stones supported good growth of the alga. This may be because of the firm support the alga received compared to the coir ropes and nets where the alga is subjected to wave action, as a result portions of algal thalli become detached from the substratum and lost.

Although *G. edulis* could be grown during any month of the year frequent growth of other algae occurred on the coir ropes which prevented the growth of this alga. This was noted with the over growth of *Chaetomorpha sp.* during November 1982, *Struvea sp.* during January 1983 and *Jania sp.* during April 1983. During these periods frequent weeding out of these seaweeds was essential for the better growth of *G. edulis*. During weeding portions of thalli of *G. edulis* were also sometimes removed from coir ropes and lost. The major algae that grew among *G. edulis* on coral stones were species of *Acanthophora* and *Caulerpa.*

One other problem facing cultivation of *G. edulis* is that of grazing by fish particularly species of Siganids. This was evident from the observation that damaged or browsed seaweeds had truncated apical tips as opposed to the tapered apical tips of intact thalli. Stephen *et al* (1981) showed similar browsing of *G. edulis* by herbivore fishes. The present investigation reveals that *G. edulis* could be grown on artificial substrata from vegetative fragments to harvestable size in about three months. Regeneration studies from the harvested algae indicate that plants are able to grow at the same rate as the fresh planting material thus indicating its remarkable regeneration capacity. This makes three harvests possible in an year. Further it is possible to harvest about 1 kg wet *G. edulis* from one metre length of coir ropes.

Of the five species of red algae studied *G. edulis* was found to be superior in terms of yield of agar and the ease with which the agar could be extracted. This alga has been found to be the most abundant of the algae studied. Thus with the indigenous supply of *G. edulis* together with cultivation on artificial substrate it appears that this alga could be made useful for the commercial production of agar in this country. Similar claim has been made elsewhere.[7] *Gelidiella acerosa,* the principal agarophyte in several countries including India has been claimed to yield good quality agar. Similar observation has not been observed with the *G. acerosa* studied and this observation substantiates the observations recorded by Dantanarayana *et al.*[2]

Several reports claim that there is seasonal variation in agar content and gel strength of agar obtained for different months.[8] Similar variations have also been observed in this investigation and the agar obtained during April were of better quality. Raju and Thomas[9] reported that the quality of agar was better in algae obtained in the second and third harvest compared to the first. However, such an improvement was not observed during the present investigation.

Effects of pretreatment of *G. edulis* on the yield and quality of agar have been investigated.[12] During the extraction of agar grinding seaweeds prior to extraction has certainly increased the yield and quality of agar from *G. edulis.* However prior soaking did not improve the quality of agar significantly as indicated by Kappanna and Visweswara Rao.[5] It can be concluded that wet extraction of the ground seaweed at a pH of 5.6 for relatively longer period give better yields of agar with good gel strength. Experiments have also shown that the gel strength of agar could be improved by prior alkali treatments.

While *G. edulis* appears to be the most promising of the red algae studied, other algal species too have been found to yield agar suitable for commercial use in the food industry.

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GEOLOGICAL SETTING AROUND THE HEADS OF THE TRINCOMALEE CANYON, SRI LANKA

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Abstract : Detailed geological mapping was undertaken in the land around the heads of the Trincomalee Canyon, in an attempt to determine its probable origin. This Canyon is in alignment with the Mahaweli shear zone. It has the trend similar to the general strike of the country rocks and has three principal heads, one at the Trincomalee inner harbour and two at the Koddiyar Bay. The head at the inner harbour and the one south east of the bay probably follow a fracture zone. The River Mahaweli has played a major role in forming the two main heads and the sub-heads at the Koddiyar Bay. The survey reveals that the shape of the Canyon heads are controlled by the geology of the area.

1. Introduction

In 1908, Somerville first noted several deep and narrow notches in the submarine plateau off the east coast of Sri Lanka.[1] The Trincomalee harbour is in one of these and during the two World Wars this harbour was of immense interest as it was found to be an extraordinarily deep canyon. Several workers studied it at different times[2,5,6,7] and confirmed it to be a large submarine canyon.

The canyon has three main heads and these heads have cut into the land. The Trincomalee inner harbour is in one and Koddiyar Bay is in the other two heads (Figures 2,5 and 6). Thus, since the land surrounds all these heads, this situation was found to be ideal to study the geology around the canyon heads. A detailed geological mapping programme was carried out in the area around the heads of the Trincomalee Canyon and an attempt was made to find whether the development of the canyon heads are geologically controlled.

Geological mapping was undertaken using air photographs including mosaics from the Survey Department of Sri Lanka. Air photos (scale 1:20,000 – 1984 air surveys) mosaics (scale '2 inches = 1 mile' – 1956) were available for the entire area. All geological data were transferred to the mosaics for the preparation of the final geological map of the area.

This work was carried out as a part of the Trincomalee Canyon study programme conducted by the National Aquatic Resources Agency.

2. Physiography

The Trincomalee Canyon has a length of 40 + km with an average slope of about 1/18 or 3° . The volume of the canyon was computed as the material missing from the continental margin and is approximately 1000 km^3. The general trend of the canyon axis is north east – south west.

Three principal heads were identified, two at the Koddiyar Bay and one at the inner harbour (Figure 2). The narrow outer shelf trough formed by the headward bifurcation of the main canyon axis forms the head at the Trincomalee inner harbour. The other bifurcations form two heads at the Koddiyar Bay.

The axis of the main head at the Koddiyar Bay trends north-east for about 6 km with a slope of 1/7 or 8° and at a depth of 600 m. it bends 90° to north-west for a distance of about 3 km with a gentle slope of 1/30 and again turns 90° back to north-east at a depth of 700 m (Figure 2). The axis again runs north-east for about six km at a slope of about 4° or 1/15 and then turns north-north-east at a depth of 1500 m. As it goes further on the continental slope the canyon turns gradually to north-east, and thereafter broadens and debounches on the continental rise at a depth of about 3400m. The two other heads of the canyon project landwards and trend in a north west-south east direction and are only 50 m deep.

3. General Geology

More than 90% of the island of Sri Lanka is underlain by Precambrian metasedimentary rocks which are grouped into two major lithological zones – the Highland Series and the Vijayan Series (Figure 1). Within the Highland Series a subdivision of the south-west group has been identified.[3] The Vijayan Series is geographically divided into the Eastern and Western Vijayan.

The Highland Series is composed, predominantly of granulite facies rocks, the main rock types being charnockites and their variants, quartzites, marbles and varieties of metasedimentary gneisses. The Vijayan Series consists of hornblende biotite gneisses, migmatites, granites and granitic gneisses of the amphibolite facies. The south-west group is characterized by calc-gneisses, calc-granulites, wollastonite-bearing calciphyres and cordierite-bearing gneisses with sillimanite.

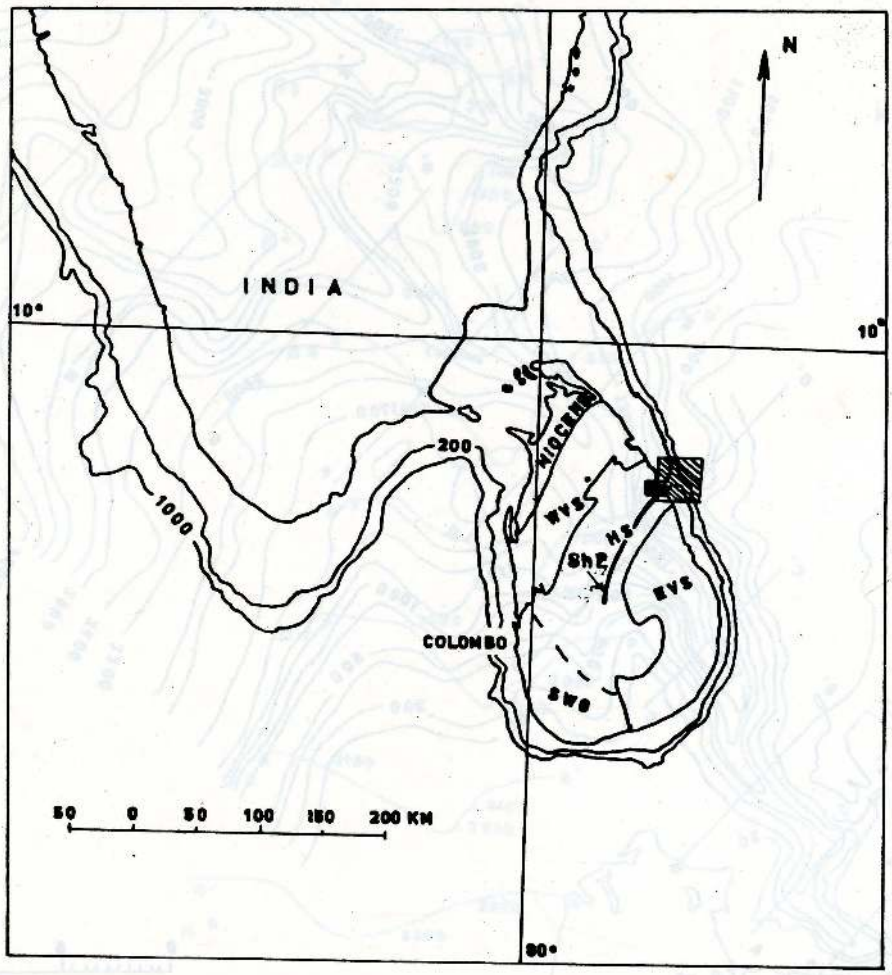

Figure 1. Outline geological map of Sri Lanka showing the study areas (shaded and cross–hatched)

H.S. – Highland Series
W.V.S. – Western Vijayan Series
E.V.S. – Eastern Vijayan Series
S.W.G. – South West Group

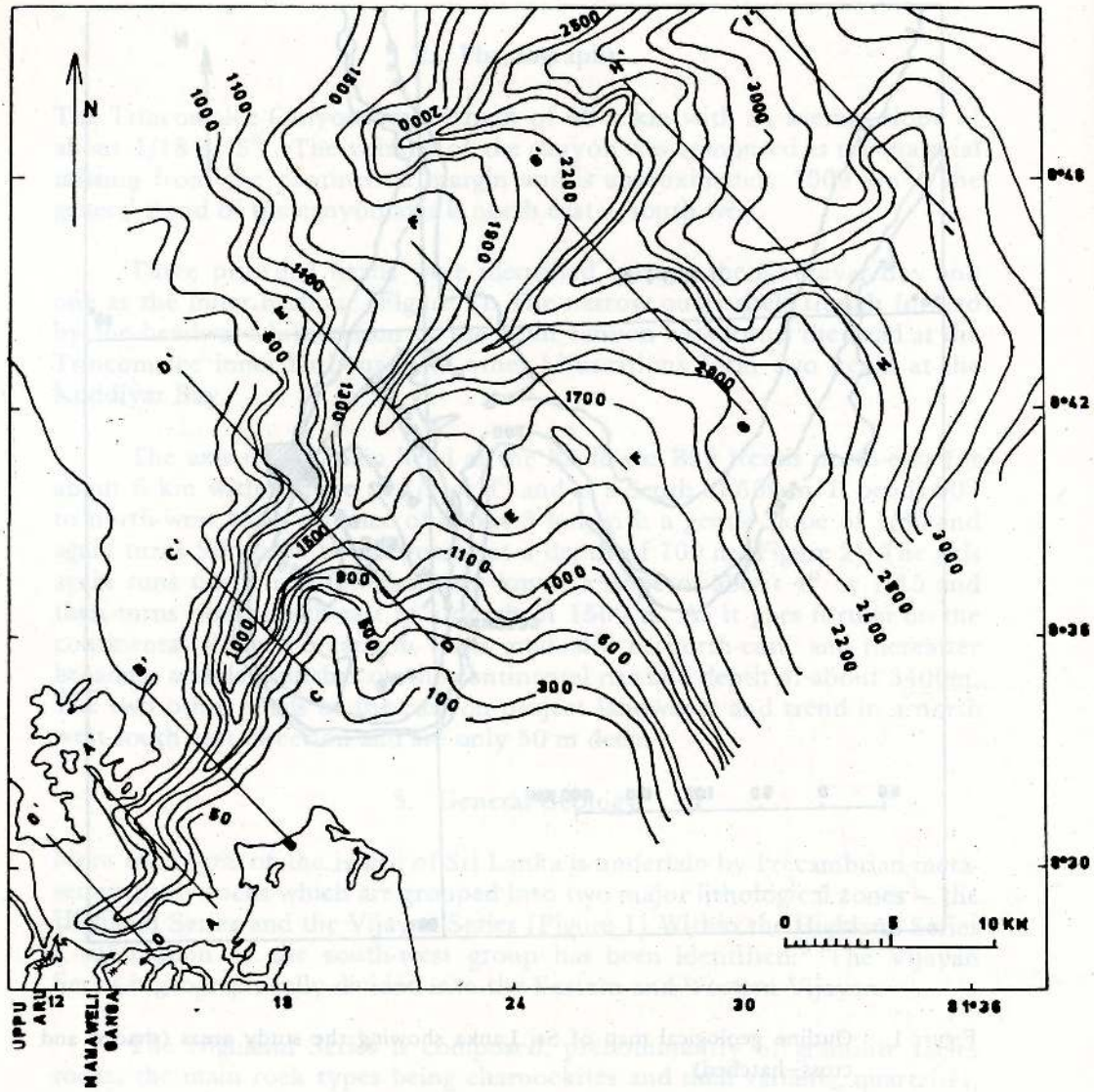

Figure 2. Bathymetric chart (in metres) of the Trincomalee Canyon. Shaded area of Figure 1 (Stewart et al. 1964b).

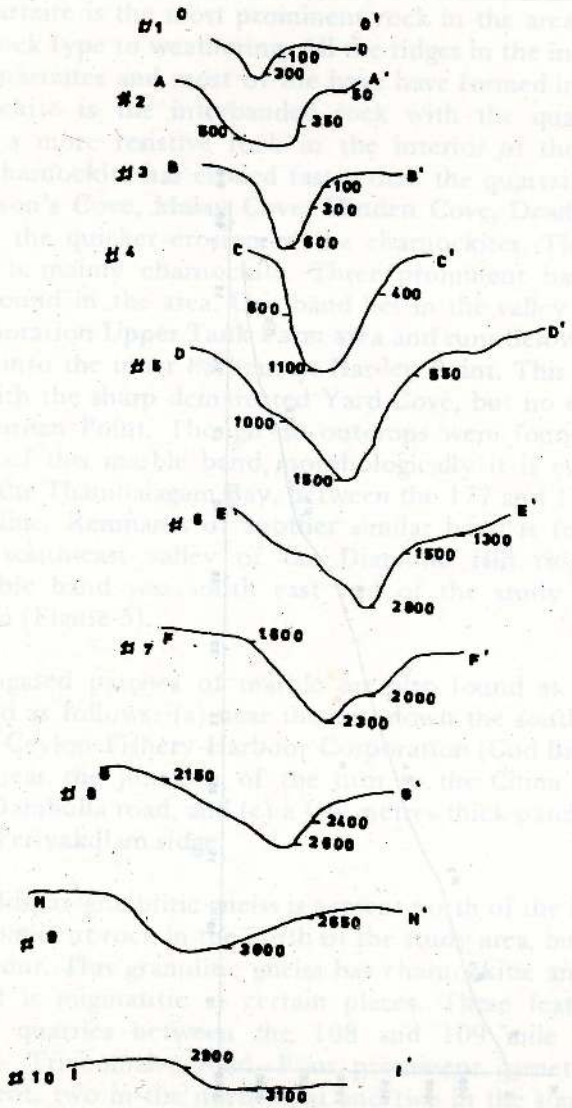

Figure 3. Transverse profiles of the Trincomalee Canyon. Profiles oriented to face down Canyon. For location see Figure 2. Vertical exageration x 5.8. Depth in metres.

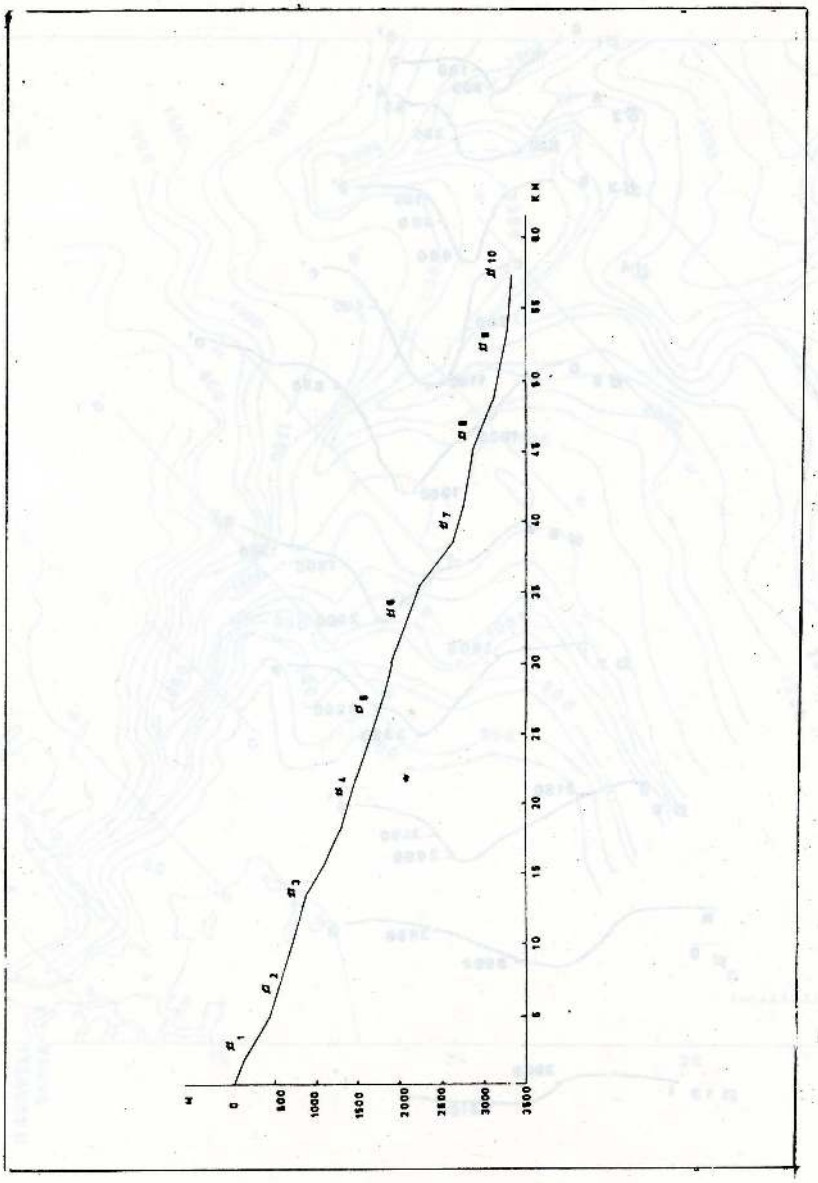

Figure 4. Longitudinal profile down axis of Trincomalee Canyon. Numbers on the profile refer to Figure 3.

The area studied falls under the Highland Series group of rocks (Figure 1) and is covered by the one inch to one mile Trincomalee topographic sheet. Quartzite is the most prominent rock in the area and is also the most resistive rock type to weathering. All the ridges in the inner harbour are composed of quartzites and most of the bays have formed in between these bands. Charnockite is the interbanded rock with the quartzite. Though charnockite is a more resistive rock in the interior of the island, at the harbour area, charnockite has eroded faster than the quartzite. Most of the bays as Nicholson's Cove, Malay Cove, Minden Cove, Deadman's Cove are formed due to the quicker erosion of the charnockites. The southeast of Koddiyar Bay is mainly charnockite. Three prominent bands of impure marbles were found in the area. One band lies in the valley bottom of the Petroleum Corporation Upper Tank Farm area and runs below the China Bay railway station into the inner harbour at Harden Point. This marble band is in alignment with the sharp demarcated Yard Cove, but no exposures were seen beyond Harden Point. Though no outcrops were found in the south west extension of this marble band, morphologically it is evident that the band runs into the Thambalagam Bay, between the 177 and 177½ mile posts of the railway line. Remnants of another similar band is found at Marble Beach in the south-east valley of the Diamond Hill ridge. The other prominent marble band was south east end of the study area near the Ullackalie lagoon (Figure 5).

Thin elongated patches of marble are also found at several places. They are located as follows: (a) near the sea, down the south-east slope of the ridge at the Ceylon Fishery Harbour Corporation (Cod Bay) new circuit bungalow, (b) near the junction of the turn to the China Bay from the Trincomalee – Dambulla road, and (c) a few metres thick patch at the south-west bay of the Periyakulam ridge.

A pink feldspar granulitic gneiss is present north of the inner harbour. This is a very prominent rock in the north of the study area, but is not found around the harbour. This granulitic gneiss has charnockitic and basic layers interbanded and is migmatitic at certain places. These features are well exposed at the quarries between the 108 and 109 mile posts of the Anuradhapura – Trincomalee road. Four prominent garnet-biotite-gneiss bands were present, two in the north west and two in the south east of the study area. The shape of the land north of Sampur (Figure 5) and the garnet-biotite-gneiss and charnockite lithology clearly shows that the differential weathering and erosion has contributed to the form of it. The garnet-biotite-gneiss band near Ullakulam (Figure 5) is not traceable due to the lack of fresh outcrops and at some leached outcrops it is difficult to distinguish garnet-biotite-gneiss and charnockite. A coarse grained scapolite-diopside rock is found at the old quarry near the Ceylon Fishery Harbour Corporation, Cod Bay circuit bungalow. Several fine grained porphyritic basalt dykes were observed near this coarse grained rock and they are closer to the

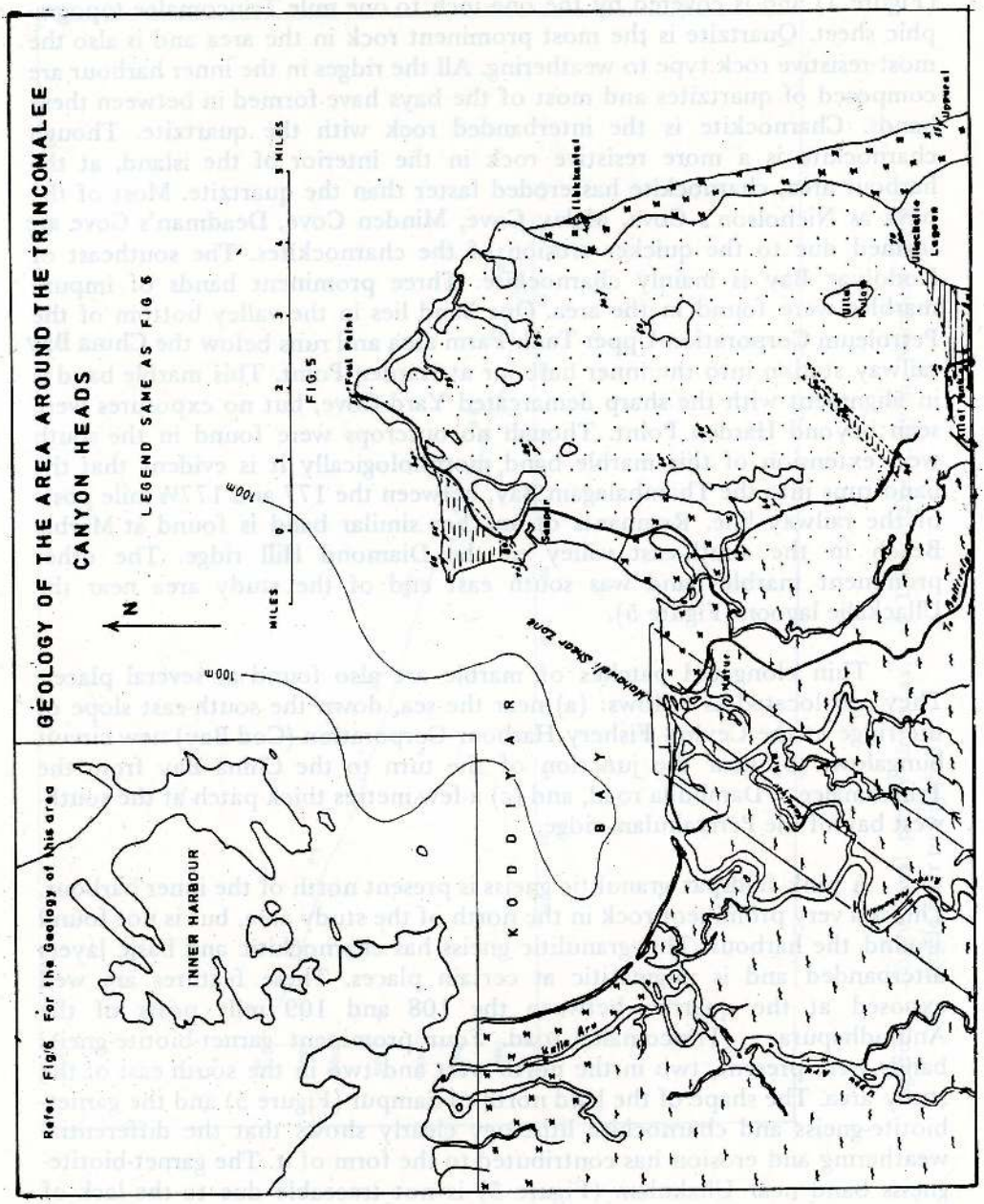

Figure 5. Geology of the area around the Trincomalee Canyon heads.

Sri Lanka Port Authority jetty. Similar dykes of few metres thick have also been observed in the north coast of the Great Sober Island. A traceable anorthosite band is present at the south end of the study area near Ullackalie Lagoon (Figure 5). The area covering from Mutur to Tambalagam Bay is the Mahaweli flood plain and is the land next to the two canyon heads at Koddiyar Bay. This area is covered with recent alluvial deposits (Figure 5).

4. Structure

The aerial photographs of the area covering the coastal belt from Seruwila up to Nilaweli on the scale of 1:20,000 and 1:40,000 were studied for the preliminary structural investigations. The mega-scale structures observed in the air photo interpretation were confirmed in the field mapping, and a few more medium to small scale structures were identified. The area is characterized by south-westerly plunging antiforms, a synform and steeply dipping basin (*"arena"*).

The two ridges at the Navy premises on either side of the Nicholson's Cove are limbs of the southernmost antiform with the axis running right across the Dutch Point. This is an assymetrical antiform. The axis of the adjoining synform falls across the Great Sober Island and the Trincomalee town. The nose of it is closer to the Fort Fredrick. The axis of the other antiform is through China Bay. A steeply dipping basin (*"arena"*) is found north west of the area. The pink feldspar granulitic gneiss, the core rock of this "arena" dips almost vertically. The above structural features do not show much influence on the formation of the canyon. Two major faults are located across the two small bays at the Cod Bay. One runs across Palaiyuttu and displaces the quartzite ridge north of it. The other fault is through Tekiluttu and displaces the same ridge at another location. These faults have directly influenced the opening up of Cod Bay (Figure 6).

The south east part of the area is of uniform dip at an average 50° north west. Minor flexures were seen in abundance at most of the large outcrops (Figure 5).

5. Discussion

With the limited data available it is rather difficult to draw definite conclusions on the genesis of the Trincomalee Canyon. It is, however, evident that several factors have contributed to its formation. If the 100 m contour line is considered as the sea level during the ice age (17,000 years ago), the landward end of the Trincomalee Canyon would have been very simple at that time, with only one principal head.

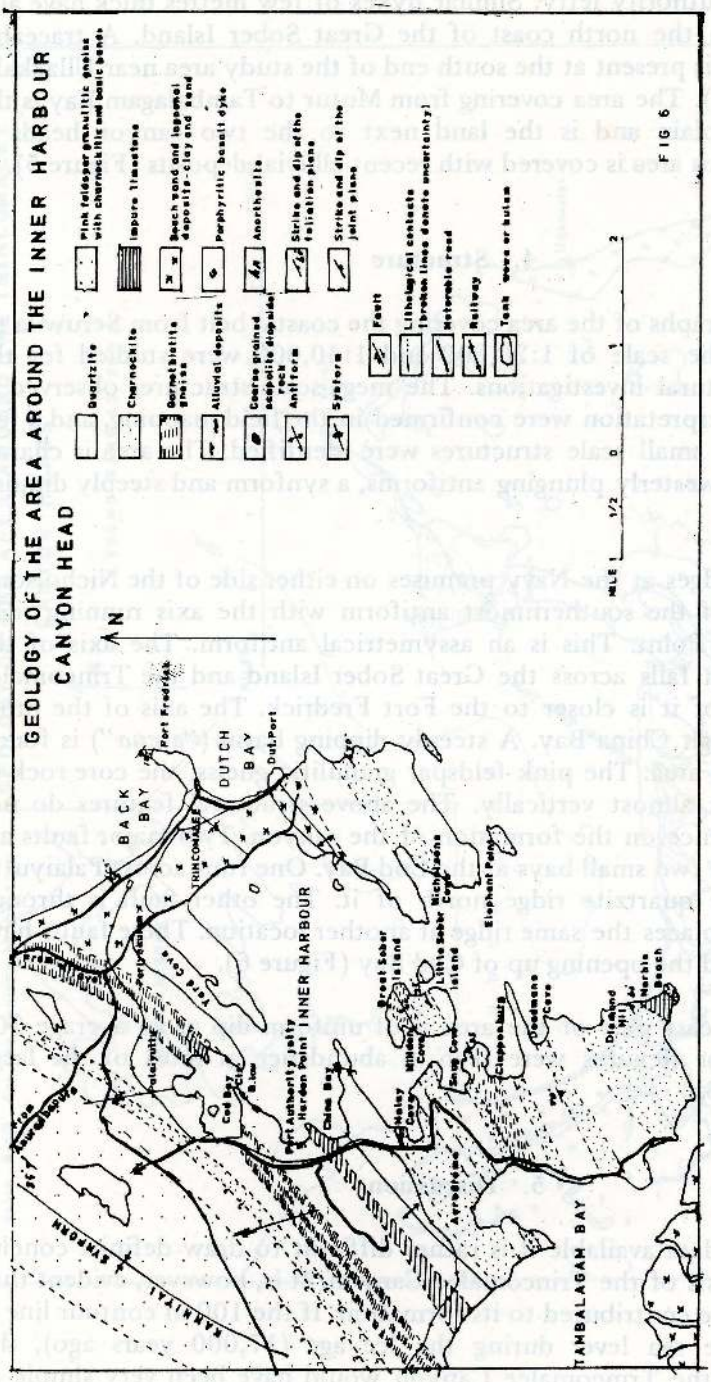

Figure 6. Geology of the area around the inner harbour canyon head.

Several small canyons are also found in the continental shelf of Sri Lanka. Some of these are located off the main river valleys but only at Trincomalee do the canyon heads come within 600 ft of the shore.[6] Uppu Aru which is in the flood plane of the Mahaweli River has its mouth where the head of the canyon begins (Figure 2). It is reasonable to assume that during the ice age the Mahaweli waters moved into the canyon through Uppu Aru and it is interesting to note that even at present these two rivers are connected.[4]

Vithanage[8] has reported that the geological mapping of the eastern section of the Polonnaruwa sheet (near Gallella) shows that the Mahaweli lineament follows a N–S shear zone along a calc-gneiss band and probably continues N–E to Trincomalee where a series of deep submarine canyons have been located. Vithanage[9] observed that the River Mahaweli and the Trincomalee Canyon are in the Mahaweli Shear zone. The Mahaweli shear zone could therefore be a contributing factor to the formation of the Trincomalee canyon. Except for the principal axial head of the canyon, all the other heads lie above the 100 m contour line. The formation of the inner harbour head and the second head at the Koddiyar Bay have undoubtedly developed after the ice age.

Bush and Bush[2] suggest the sharp bend of the canyon in Koddiyar Bay could be due to a fault zone. Such a fault zone could also have given rise to the inner harbour head and the second head in Koddiyar Bay. During the ice age the inner harbour area may have had the normal ridge valley topography as we find in the present day land. With the rise in the sea level the inner harbour area has got submerged gradually and the present bays have opened up rapidly due to wave and current actions. All the ridges around the inner harbour are made up of quartzites and the valleys are charnockites, marble and gneisses. The present day bays have formed in valleys of the ice age and are due mainly to differential erosion. The probable fault suggested by Bush and Bush[2] falls across the Cod Bay. Two other faults have also been identified which cut across Cod Bay and northwest openings of the Cod Bay are due to these faults.

The inner harbour opens up in two directions and the carving parallel to the general trend of the area is due to differential erosion and that oblique to the trend line is along fracture planes. These forms have developed due to the structure and lithology of the area around the inner harbour.

It has been observed that another canyon head is developing at the mouth of the Mahaweli River (Figure 2). Taking into consideration that the Mahaweli was connected to Uppu Aru[4] during the Ice Age and recently changed its position, it is evident that the river has played a major role in the formation of the small canyon head at its present mouth. This shows that the Mahaweli River also has influenced the form and the development of the canyon.

6. Conclusions

The recent geological mapping done in the land around the Trincomalee Canyon shows that the form of the inner harbour head is structurally and lithologically controlled. The River Mahaweli has played a major role in the formation of the principal axial head of the canyon. Another axial head is developing at the mouth of the present Mahaweli River. As suggested by Bush and Bush[2] it is possible that the sharp bend in the canyon valley, inner harbour head and the second head at the Koddiyar Bay is due to a probable fault zone.

Acknowledgements

Dr. W. S. Wickramaratne helped by mapping a part of the study area. Messrs. S. R. Amaratunge and Danton Silva assisted in the field. The Director, Geological Survey Department of Sri Lanka made their unpublished Trincomalee and Nilaveli reconnaisance geological maps available for this study. Grateful thanks are due to Dr. M. M. J. W. Herath for his valuable suggestions. This paper is published with the kind permission of the Chairman of the National Aquatic Resources Agency, Colombo.

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INCIDENCE OF PLASMID MEDIATED ANTIBIOTIC RESISTANCE AMONG ISOLATES FROM TOOTH INFECTIONS IN A DEVELOPING COUNTRY, (SRI LANKA)

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(Date of acceptance : 17 February 1986)

Abstract : Out of 55 isolates from tooth infections, the majority were enteric strains. Further, more than 90% of them exhibited multiple drug resistance. However, the incidence of strains carrying transferable resistance was very low (<2%). Therefore, it is inferred that the source of these causal organisms could be the contaminated water which exhibited a similar pattern of antibiotic resistance and transferability. Such incidence of strains in the buccal cavity could facilitate the spread of resistance to other sensitive strains of the nasopharynx.

1. Introduction

Tooth infections are mainly caused by gram positive nasopharyngeal flora e.g. *Staphylococcus aureus, Streptococcus pyogens.*[6] In addition, it was reported[7] that gram negative bacilli such as *Klebsiella, Proteus* and *Escherichia coli* could bring about tooth infections. These organisms enter the mouth via contaminated food and water. Studies carried out[5] show that the carrier rate of *Klebsiella* in the throat of a "normal population" is high. Enteric strains isolated from clinical samples, water sources and from rectal swabs of normal healthy adults from this area exhibited a high incidence of multiple resistance and significant percentages of transferable resistance to most of the common antibiotics.[9] The presence of such enteric strains in the nasopharyngeal region could render a greater chance for the rest of the sensitive "normal flora" to acquire resistance. This study was carried out to assess the incidence of plasmid mediated antibiotic resistance among enteric strains isolated from tooth infections.

2. Materials and Methods

2.1 Collection of Samples

Tooth swabs were collected from patients suffering from tooth infections. These swabs were collected from patients visiting private dental clinics and

the dental clinic attached to the General Hospital, Jaffna. The samples were collected by the dental surgeon in sterile peptone water using sterile swabs. These swabs were incubated in peptone water at 37°C for 5h. Subsequently, they were streaked on MacConkey agar medium and incubated for 15 h at 37°C. Colonies appearing on these plates were subcultured and identified.[2]

2.2 Antibiotic Sensitivity Test

Isosensitest agar medium (oxoid) was used as the test medium. Bacterial resistance to antibiotics were determined by the paper disc method.[3] A single colony of the pure culture was suspended in 4.5 ml of 0.9% sterile saline. This was diluted 1:10 in the same diluent (adjusted to) standard turbidity and streaked evenly on the test medium using sterile absorbent cotton wool swabs. The plates were incubated at 37°C for 15 min. This was followed by the application of antibiotic discs on the inoculated surface and the plates were left at room temperature (28°C) for 15 min. They were then incubated for 15 h at 37°C. The diameter of the zone of inhibition was measured using a vernier caliper. Selection plates were prepared by incorporating sulphamethoxazole (500 μg/ml) nalidixic acid (30 μg/ml) in isosensitive test agar medium. The list of antibiotics used are given in Table 1.

Table 1 : List of Antibiotics used.

Antibiotics		Amount of antibiotic per disc
1. Nalidixic acid	(NA)	30 μ g
2. Ampicillin	(Ap)	10 μ g
3. Chloramphenicol	(Cm)	30 μ g
4. Tetracycline	(Tc)	30 μ g
5. Nitrofurantoin	(Ni)	30 μ g
6. Sulphamethoxazole	(Su)	23.2 μ g
7. Trimethoprim	(Tp)	1.3 μ g
8. Erythromycin	(Em)	15 μ g
9. Gentamicin	(Gm)	30 μ g

2.3 R–Plasmid Transfer by Conjugation

E. coli K12 strain EC 1005 (met^- , nal^r) was used as the recipient strain. This strain was supplied by Institute of Pharmaceutical Microbiology University of Uppsala, Sweden, (*E. coli* K12 met^- rif^r) was used as the recipient when conjugation with nalidixic acid resistant donors was carried out. A single colony of the recipient was suspended in 50 ml of Luria broth in 150 ml Erlmeyer flask. The broth was diluted to O.D. (optical density) of 0.23 at 600 nm in the same broth and incubated to O.D. 0.42 at the same wavelength. 0.4 ml of this broth was mixed with the presumptive donor (in 0.2 ml of Luria broth) which was previously incubated for 1 h. The mixture was incubated at 37°C for 15 h and transferred by a sterile multiple incubator on to selection plates. The selection plates were incubated for 48 h and colonies appearing on these plates were restreaked to individual colonies on the same selection plates and subsequently tested for recipient auxotrophic marker by culturing them on methionine supplemented minimal salt medium M9. An antibiotic sensitivity test was carried out on these transconjugants and transferable antibiotic resistance patterns were discerned.

3. Results

A total of 55 aerobic gram negative bacterial strains was isolated from 53 tooth infections. The majority of the isolates (49%) were *Klebsiella* (Table 2). The 55 isolates were found to exhibit resistance to more than one antibiotic. The majority of the isolates were resistant to ampicillin , sulphamethoxazole and trimethoprim. Further, significant amounts (58%) of the isolates were resistant to nitrofurantoin. Though none of the isolates were resistant to gentamicin , a few were resistant to tetracycline and chloramphenicol. Thirty-four different resistance patterns were observed among strains isolated from tooth infections (Table 3). Resistance patterns were observed carrying resistance markers up to 8. Out of the different resistance patterns exhibited by *Klebsiella*, resistance to ampicillin , sulphamethoxazole, nitrofurantoin and trimethoprim was predominant (37%). All isolates of *E. coli* carried resistance to ampicillin , sulphamethoxazole and trimethoprim. This particular combination of resistance genes was also observed among *Paracolon, Proteus* and *Klebsiella*. All isolates exhibiting antibiotic resistance were conjugated with *E. coli* K12 EC1005 (met^-, nal^r) and selected with nalidixic acid (50 μg/ml) and sulphamethaxazole (500 μg/ml). A *Proteus* strain carrying resistance to ampicillin , tetracycline, sulphamethoxazole, erythromycin, chloramphenicol, nitrofurantoin and trimethoprim was found to transfer resistance to sulphamethoxazole.

Table 2. Frequency of antibiotic resistance genes among enteric bacterial species isoalted from tooth infections

Bacterial Genera	No. of isolates	No. of multiple drug resistance	Frequency of antibiotic resistance genes								
			Na	Ap	Tc	Su	Em	Cm	Ni	Tp	Gm
Klebsiella	27	26	0	24	2	26	6	2	19	20	0
Proteus	10	10	0	6	2	7	4	2	7	9	0
Escherichia coli	5	5	0	5	0	5	0	0	0	5	0
Paracolon	4	4	0	2	0	2	0	0	1	4	0
Alcaligenes	2	2	1	2	1	2	1	2	2	2	0
Pseudomonas	1	1	1	1	1	1	1	1	1	1	0
Unidentified	6	4	0	3	0	3	0	1	2	5	0
Total	55	52	2	43	6	46	12	8	32	46	0

Table 3. Frequency of antibiotic resistance patterns among enteric bacteria isolated from tooth infections

Bacterial species	Antibiotic Resistance patterns		Number of Isolates	
Klebsiella	Ap–Tc–Su–Em–Cm–Ni–Tp	=	1	
	Ap–Su–Em–Ni–Tp	=	3	
	Ap–Tc–Su–Tp	=	1	
	Ap–Su–Ni–Tp	=	10	
	Ap–Su–Tp	=	2	
	Ap–Su–Em	=	1	
	Su–Ni–Tp	=	1	
	Ap–Su–Ni	=	2	
	Su–Tp	=	1	
	Su–Ni	=	1	
	Ap–Su	=	3	26
Proteus	Ap–Tc–Su–Em–Cm–Ni–Tp	=	1	
	Ap–Su–Em–Tp	=	1	
	Ap–Tc–Su–Ni	=	1	
	Su–Em–Ni–Tp	=	1	
	Ap–Su–Ni–Tp	=	1	
	Cm–Ni–Tp–	=	1	
	Ap–Ni–Tp	=	1	
	Su–Em–Tp	=	1	
	Ap–Su–Tp	=	1	
	Ni–Tp	=	1	10
Paracolon	Ap–Su–Tp	=	1	
	Su–Tp	=	1	
	Ap–Tp	=	1	
	Ni–Tp	=	1	4
Alcaligenes	Na–Ap–Tc–Su–Em–Cm–Ni–Tp	=	1	
	Ap–Su–Cm–Ni–Tp	=	1	2
Escherichia coli	Ap–Su–Tp	=	5	5
Pseudomonas	Na–Ap–Tc–Su–Em–Cm–Ni–Tp	=	1	1
Unidentified	Ap–Su–Cm–Ni–Tp	=	1	
	Ap–Ni–Tp	=	1	
	Ap–Su	=	1	
	Su–Tp	=	1	
	Tp	=	2	6
		Grand Total		54

4. Discussion

Incidence of multiple drug resistance strains among tooth infections suggest that these organisms could have originated from antibiotic loaded environments. Such environments could be either the clinical source, human or animal intestinal flora. Further, these isolates share common resistance patterns with that of the corresponding strains isolated from water sources.[8] Earlier studies [9] showed that the resistant enteric strains isolated from water sources did not transfer their resistant traits to sensitive strains. Non-transferability of these resistant genes could be due to the loss of transfer genes responsible while they are in a non-selective medium such as water. A similar phenomenon was observed among the isolates from tooth infections where inspite of the high incidence of resistant isolates only one out of 55 isolates transferred these resistance genes to sensitive strains. This further shows that tooth infections could also be caused by resistant enteric strains of human origin and could spread in the community via contaminated water.

Recently it has been reported that R-plasmid transfer by conjugation could occur between *Staphylococcus* and *E. coli.*[1] The presence of a high incidence of resistant strains in the nasopharyngeal region could increase the chances of other sensitive normal flora such as *Neisseria, Staphylococcus, Streptococcus* acquiring such resistance. The non-parental use of antibiotics during tooth extraction as a prophylactic agent could remove the normal sensitive organisms from the nasopharynx and their place could be occupied by resistant enteric strains, thus bringing about chronic soreness. Stabilization of strains like *Klebsiella flexeneri* in the nasopharynx could render the chance of the individual suffering from pneumonia caused by the same organism.

Thus steps should be taken to prevent the access of enteric strains to the mouth and nasopharynx. This could be achieved by the use of treated water and maintaining high standards of personal hygiene. Further the use of antibiotics in the community should be reduced so that the incidence of resistant strains would be low.

Acknowledgement

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AN EVALUATION OF A COLORIMETRIC PROCEDURE FOR THE ESTIMATION OF GLYCOSYLATED HAEMOGLOBIN AND THE ESTABLISHMENT OF REFERENCE VALUES FOR SRI LANKA

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(Date of acceptance : 17.02.86)

Abstract : The importance of the measurement of glycosylated haemoglobin as a quantitative index reflecting metabolic control in diabetics during the preceeding four to six weeks is now well established. The suitability of the colorimetric method of Fluckiger and Winterhalter as a technique adaptable for developing countries has been evaluated. Incubation with oxalic acid for one hour indicated good precision with coefficient of variation within assay of 3.19 (n=20) and between assay of 2.8% (n=15) for normals and 1.8% for diabetics. β–D–fructose was also used in addition to 5–hydroxy methyl furfuraldehyde (HMF) as standards. This gives a measure of efficiency of the reaction. The non-specific blank value for all samples were a constant. Whole blood samples could be stored at room temperature (30 ± 3°C) for 5 days and for nine days at 4°C. Haemolysates were stable at 4°C for 5 days and for 30 days at −20°C. A good correlation coefficient of r = 0.92 was obtained with a microcolumn test kit (n=20, $p < 0.001$). The normal mean (±SD) for glycosylated haemoglobin (HbA_1) for Sri Lanka was found to be 5.85% ± 0.79 for males (n=70) and 5.88% ± 0.79 for females (n=30). A significant difference was not observed between males and females. The overall mean for normals was 5.9% ± 0.79 (or 0.39% ± 0.05 μM HMF/g Hb). Mean for non-insulin dependent diabetics was 10.83% ± 3 (or 0.68 ± 0.20 μM HMF/g Hb). The mean %HbA_1 for pregnant women (n=15) in the 3rd trimester of pregnancy was 7.0% ± 0.7 The colorimetric method meets many of the criteria for an ideal laboratory test. It proves to be the most suitable method for the measurement of glycosylated haemoglobin in developing countries.

1. Introduction

The minor haemoglobins (also referred to as fast haemoglobins[2] – HbA_1) accounting for about 8% of total haemoglobin in blood arise from non-enzymatic post translational modifications of haemoglobin A (HbA) (Figure 1). HbA_{1c} constitutes the major fraction.

HbA_{1c} is formed from HbA by the chemical condensation of a molecule of glucose specifically with the NH_2–terminal of the β–chain of HBA.[4] It is a slow process occuring during the entire life span of the erythrocyte[5] and is dependent on *in vivo* concentration of glucose. HbA_{1c} levels are therefore elevated in diabetics.

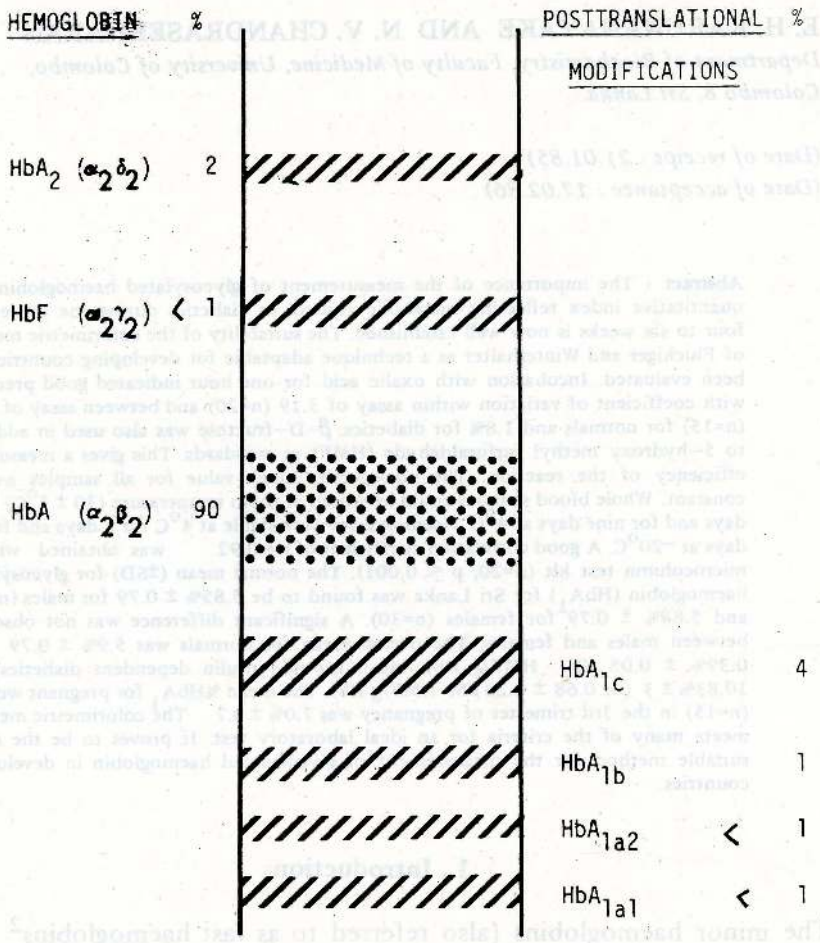

Figure 1. Electronic pattern of haemoglobin components in normal red blood cells.

The measurement of HbA_{1c} approximately reflects the time averaged serum glucose concentration in the preceeding four to six weeks[17] and hence gives a precise reflection of metabolic control in diabetes over a long period of time.

Methods described for the measurement of glycosylated haemoglobin include electrophoresis,[19] ion exchange chromatography,[25] high pressure liquid chromatography (HPLC),[8] affinity chromatography,[18] immunoassay,[16] fluorometry[13] and colorimetry.[11]

Prior to the present investigation no studies have been carried out in Sri Lanka on glycosylated haemoglobin. We have therefore evaluated a suitable colorimetric technique originally described by Fluckiger & Winterhalter[11] and subsequently modified by Worth *et al*[28] and established the reference values for Sri Lanka.

In this method the carbohydrate moeity is cleaved by acid hydrolysis to yield 5–hydroxy methyl furfuraldehyde (5–HMF) which is subsequently complexed with thiobarbituric acid. The resulting chromogen has a maximal absorbance at 443 nm.

The colorimetric method determines all glycosylated haemoglobins. Ideally HbA_{1c} should be the fraction that should be quantitated. However, the determination of total glycosylated haemoglobin has been shown to correlate well with the measurement of HbA_1[28] and HbA_{1c}[22] by column chromatography.

2. Materials and Methods

All reagents used were of analytical grade. Spectrophotometer readings were obtained on a Pye Unicam UV/VIS spectrophotometer (Model SP6 – 450 UV/VIS). Bench centrifuge was used for all centrifugation purposes. All experiments were carried out at room temperature ($30^{\circ}C \pm 3^{\circ}$) unless otherwise specified.

2.1 Standard haemoglobin solutions

Standard haemoglobin solutions were prepared according to Van Kampen and Zijlstra[26] (Hemiglobincyanide method) and standardised according to Cannan.[7] These prepared solutions were stored in brown vials at 4°C after standardising with commercially available haemoglobin standards (Acuglobin–Ortho diagnostic systems U.S.A.).

2.2 Collection of Blood Samples

All blood samples (5 ml) were obtained into heparinised vacutainers. Normoglycaemic samples for males (average age 26.1 ± 5.86, n = 70) and females (average age 24.01 ± 5.6, n = 30) were collected from the Central Blood Bank, General Hospital, Colombo. Blood samples from diabetic patients of both sexes (average age 47 ± 13.5, n = 107) were obtained from the General Hospital, Colombo.

2.3 Determination of Haemoglobin

Samples of blood (5 ml) collected into heparinised vacutainers were centrifuged (1500g, 10 min) and the plasma removed. The red blood cells were washed twice in an equal volume of physiological saline (0.154M). The cells were haemolysed by the addition of one or two volumes of distilled water and carbon tetrachloride (0.25 vol). The mixture was vortexed for 5 min and centrifuged (1500g, 15 min). The clear haemolysate was collected and the haemoglobin concentration of the haemolysate was determined by the method of Van Kampen and Zijlstra[26] by adding haemolysate (20 µl) to hemiglobincyanide reagent (5 ml). After at least 3 min the optical density was measured at 540 nm and the haemoglobin concentration (g/l) calculated by the use of already prepared standards or O.D. x 377.Blank used was distilled water. Samples were then accurately adjusted to 50 g/l total haemoglobin concentration by the addition of distilled water.

2.4 Determination of glycosylated haemoglobin

Oxalic acid (1 ml, 0.3M) was added to an aliquot (2 ml) of adjusted haemolysate, mixed and placed immediately in a boiling water bath at 100°C for exactly 60 min. Evaporation was minimised by placing glass marbles on each test tube. After incubation samples were cooled in cold water for 2 min and deproteinisation carried out by the addition of trichloroacetic acid (1 ml, 40% w/v). The tubes were vortexed (30 seconds) and then centrifuged (1500g, 15 min). Thiobarbituric acid (0.5 ml, 0.05M) was added to the clear supernatant (2 ml), mixed and incubated (40°C, 60 min). The colour developed was read at 443 nm.

Included in each assay were a blank using distilled water instead of haemolysate, aqueous standards of 5–HMF (0.01 mM/L to 0.05 mM/L), aqueous standards of fructose (1 mM/L to 4mM/L) and diabetic and normal pooled haemolysates previously stored at −20°C.

2.5 Correlation with column method

Twenty samples of blood (8 normals and 12 diabetic) were assayed both by the ion-exchange column procedure and by the colorimetric method.

Commercial microcolumns were obtained from Bio-rad laboratories, Richmond, California.

2.6 Effect of storage of samples

Whole blood, washed packed erythrocytes, and haemolysates (50 g/l) were stored at various temperatures and assayed periodically. Determinations were performed in triplicate.

2.7 Washing for the removal of glucose

Aliquots (2 ml) of 20 haemolysates (all diabetics), the haemoglobin concentration of which were previously adjusted (50 g/l) were analysed for the presence of glucose by the glucose oxidase method.[15]

2.8 Effect of Haemoglobin concentration on colour development

Pooled normal haemolysates were adjusted to total haemoglobin concentrations varying from 15 g/l to 100 g/l. These were assayed and the colour developed read at 443 nm. Determinations were performed in triplicate.

2.9 Effect of Incubation time with 0.3 M oxalic acid on colour development

Aliquots (2 ml) of normal pooled haemolysate (50 g/l) were incubated with oxalic acid (2 ml, 0.3 M) and periodically samples were removed from the incubation chamber and assayed. Determinations were performed in duplicate.

2.10 Stablility of prepared haemoglobin standards

Haemoglobin standards were prepared[7] and standardised with commercially available Acuglobin (Orthodiagnostic systems, USA). The standards were stored in coloured vials at 4°C. The optical density at 540 nm was determined at various time intervals, ranging over six months.

2.11 Variation in the total haemoglobin adjustment to 50 g/l

Unadjusted haemolysate was obtained after washing of the red cells. An aliquot (20 μl) of the haemolysate was added to hemiglobincyanide reagent (5 ml) and the colour developed was read at 540 nm after at least 3 minutes. Twenty such determinations were performed.

2.12 Effect of concentration of oxalic acid on colour development

The effect of the molarity of oxalic acid on colour development was investigated on pooled normal haemolysates (50 g/l). Determinations were performed in triplicate.

2.13 Effect of incubation time with thiobarbituric

Twenty aliquots (2 ml) of supernatant (obtained after digestion with oxalic acid) were incubated with thiobarbituric acid (0.5 ml, 0.05 M) at 40°C. The optical density at 443 nm were measured at various time intervals.

2.14 Standards

Both 5–HMF and β–D–fructose in appropriate concentrations were used as standards in duplicate. Fructose standards were used to measure the efficiency of the reaction.

2.15 Effect of heating 5–HMF with 0.3 M oxalic acid at 100°C

Varying concentrations of 5–HMF (2 ml) were heated with oxalic acid (1 ml, 0.3 M) in a water bath (100°C, 1 hour) and the normal assay was performed. To identical varying concentrations of 5–HMF were added oxalic acid (1 ml, 0.3 M) but was not heated (100°C, 1 hour) and the normal assay performed. The colour developed was read at 443 nm.

2.16 Recovery of Added 5–HMF

Normal and diabetic pooled haemolysates were adjusted to 100 g/l total haemoglobin concentration. To the haemolysate (1.0 ml) was added varying concentrations of 5–HMF (1 ml), so that the final concentration of haemoglobin was 50 g/l. The haemolysates were then assayed. Determinations were done in triplicate.

2.17 Intra assay coefficient of variation

Multiple (n=20) analysis of blood obtained from one donor was carried out in a single assay.

2.18 Inter assay coefficient of variation

Pooled haemolysate from normal and diabetic subjects stored at −20°C were assayed in 15 consecutive runs during a period of a month. Also included were aliquots of standard fructose (4 mM). All results were obtained in duplicate.

2.19 Blank values and non-specific colour production

Haemolysate (50 ml) was prepared and haemoglobin concentration adjusted to 50 g/l. Aliquots were then analysed as described below.

a) i. Five aliquots (2 ml) were assayed as described previously.
ii. The non-specific colour produced was determined by adding distilled water (0.5 ml) instead of thiobarbituric acid to the supernatant.
iii. Five aliquots (2 ml) were assayed as described except that water (1 ml) was added instead of oxalic acid (1 ml).
iv. Five aliquots (2 ml) were assayed as described except that the samples were not heated at 100°C.

b) Adjusted haemolysate (30 ml) was ultrafiltered under centrifugation (2000 g, 30 min) using Centricon Microconcentrator Membranes (purchased from Amicon Corporation) to obtain a protein free ultrafilterate.
i. Two aliquots (2 ml) of the ultrafilterate were assayed as for glycosylated haemoglobin.
ii. The non-specific colour produced by the ultrafilterate was determined by adding distilled water (0.5 ml) instead of thiobarbituric acid.

2.20 Validation of modified method

Haemolysates (50 g/l) from diabetics and normals were mixed in varying proportions to obtain a final volume of 2 ml. The different combinations were now assayed and colour developed read at 443 nm.

3. Results and Discussion

The importance of the measurement of glycosylated haemoglobin for the evaluation of long term glycaemic control is apparent from studies carried out so far. Numerous methods for its quantitation have been made available since its importance had been recognised. A cheap but sensitive and reproducible method that could be standardised between laboratories is the colorimetric method originally described by Fluckiger and Winterhalter[11] and subsequently modified by Worth *et al.*[28] However, very few attempts have been made to standardize the method so that results could be compared from all laboratories.

This investigation centred around the evaluation of a number of critical factors of the colorimetric technique, and its usefulness as a routine assay. The study on the effect of storage of samples on glycosylated haemoglobin content prior to assay showed that whole blood could be stored over a week at 4°C and 5 days at room temperature (30 ± 3°C). Worth *et al.*[28] have reported it to be stable for 2 weeks at room temperature and 4°C.

Haemolysates were found to be stable for only 30 days at −20°C. It has also been reported to be stable upto 70 days.[23] Pecararo[21] although has commented about the stability of frozen samples but has failed to indicate the temperature at which it was stored. According to Worth *et al.*[28] haemolysates were stable upto 6 months at −70°C. In the absence of deep freezing facilities in most laboratories in Sri Lanka, it is advisable not to attempt to store the haemolysates, but whole blood can be stored upto 6 days and assayed in one batch. Washed packed cells were stable at room temperature for only 3 days and is consistent with the results of Fischer *et al.*[10] At 4°C and −20°C the washed packed cells were stable only upto 9 days. The stability of whole blood and haemolysates are of great practical importance for a routine assay.

Initial dialysis has been carried out prior to the assay.[20,23] This is a serious setback of the assay because of the time factor involved. However, the assay of the haemolysate for glucose by the glucose oxidase method in the present study did not reveal any detectable levels of glucose. It therefore seems unnecessary to include a prior dialysis step.

The precision of the method is dependent on the initial accurate adjustment of haemoglobin concentration to 50 g/l. Worth *et al.*[28] have reported a conversion factor of 377 by which the optical density at 540 nm is multipled to give the haemoglobin concentration of unadjusted haemolysate in g/l. The accuracy of this was checked using standard Acuglobin vials (Ortho diagnostic systems, USA) available commercially and was found to be in fair agreement. However, as the pH of the hemiglobincyanide reagent affects the optical density, it should be adjusted accurately. Using the haemoglobin standards prepared in our laboratory, the coefficient of variation was found to be 2.8% (n=20). Results on the stability of prepared haemoglobin standards which were stored for over 6 months and assayed periodically were acceptable.

The study on the effect of haemoglobin concentration on colour development at 443 nm indicated a linear response upto 75 g/l (Figure 2) followed by flattening of the curve above this concentration. This is consistent with the findings previously reported.[28] A linear response between haemoglobin concentration (5 g/l to 80 g/l) has also been reported.[10] Apparent non-linearity in colour development has also been reported.[20,27] Pecoraro[21] observed a linear relationship upto 20 g/l. From the results obtained in the present studies an optimum haemoglobin concentration of 50 g/l as proposed by Worth *et al.*[28] which gives adequate colour development and ensures linearity was selected for the assay.

The study of the effect of oxalic acid concentration on colour development showed (Figure 3) a linear response upto 0.3 M and a fall off above this concentration. Based on our investigation we have used an

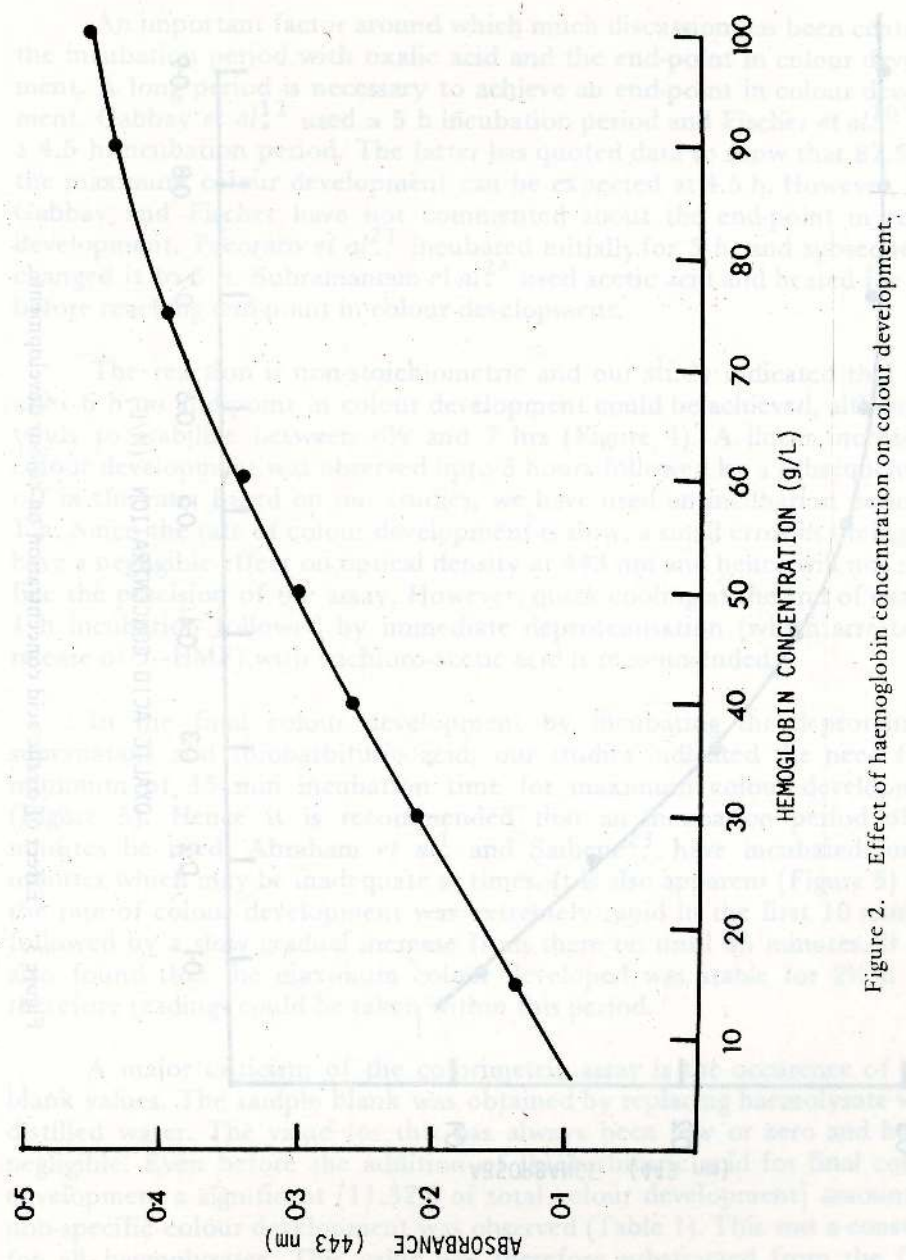

Figure 2. Effect of haemoglobin concentration on colour development.

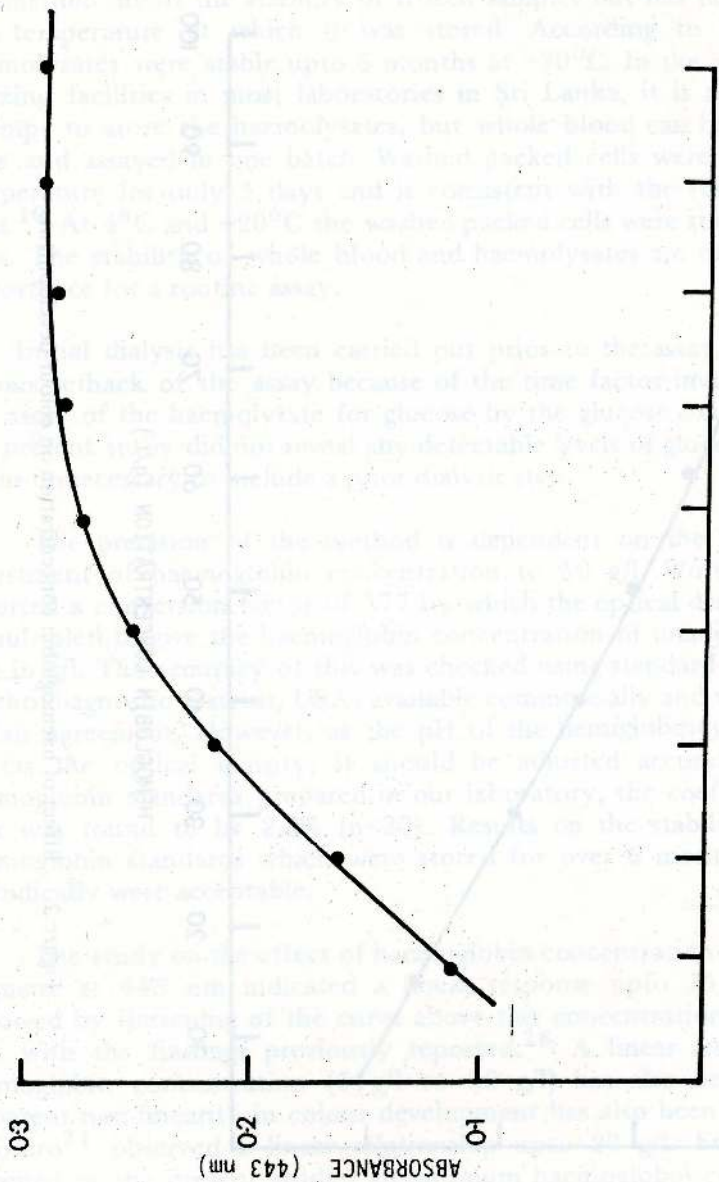

Figure 3. Effect of oxalic acid concentration on colour development.

optimum oxalic acid concentration of 0.3 M which gives a linear response as well as adequate colour at 443 nm. This is in agreement with Worth *et al.*[28]

An important factor around which much discussion has been centred is the incubation period with oxalic acid and the end-point in colour development. A long period is necessary to achieve an end-point in colour development. Gabbay *et al.*[12] used a 5 h incubation period and Fischer *et al.*[10] used a 4.5 h incubation period. The latter has quoted data to show that 87.5% of the maximum colour development can be expected at 4.5 h. However, both Gabbay and Fischer have not commented about the end-point in colour development. Pecoraro *et al.*[21] incubated initially for 3 h, and subsequently changed it to 5 h. Subramaniam *et al.*[24] used acetic acid and heated for 16 h before reaching end-point in colour development.

The reaction is non-stoichiometric and our study indicated that even after 6 h no end-point in colour development could be achieved, although it tends to stabilize between 6½ and 7 hrs (Figure 4). A linear increase in colour development was observed upto 3 hours followed by a subsequent fall off in the rate. Based on our studies, we have used an incubation period of 1 h. Since the rate of colour development is slow, a small error in timing will have a negligible effect on optical density at 443 nm and hence will not sacrifice the precision of the assay. However, quick cooling at the end of exactly 1 h incubation followed by immediate deproteinisation (which arrests the release of 5–HMF) with trichloro-acetic acid is recommended.

In the final colour development by incubating the deproteinized supernatant and thiobarbituric acid, our studies indicated the need for a minimum of 45 min incubation time for maximum colour development (Figure 5). Hence it is recommended that an incubation period of 60 minutes be used. Abraham *et al.*[1] and Saibene[23] have incubated for 40 minutes which may be inadequate at times. It is also apparent (Figure 5) that the rate of colour development was extremely rapid in the first 10 minutes followed by a slow gradual increase from there on until 45 minutes. It was also found that the maximum colour developed was stable for 2½ h and therefore readings could be taken within this period.

A major criticism of the colorimetric assay is the occurence of high blank values. The sample blank was obtained by replacing haemolysate with distilled water. The value for this has always been low or zero and hence negligible. Even before the addition of thiobarbituric acid for final colour development a significant (11.32% of total colour development) amount of non-specific colour development was observed (Table 1). This was a constant for all haemolysates. This value was therefore substracted from the final optical density at 443 nm.

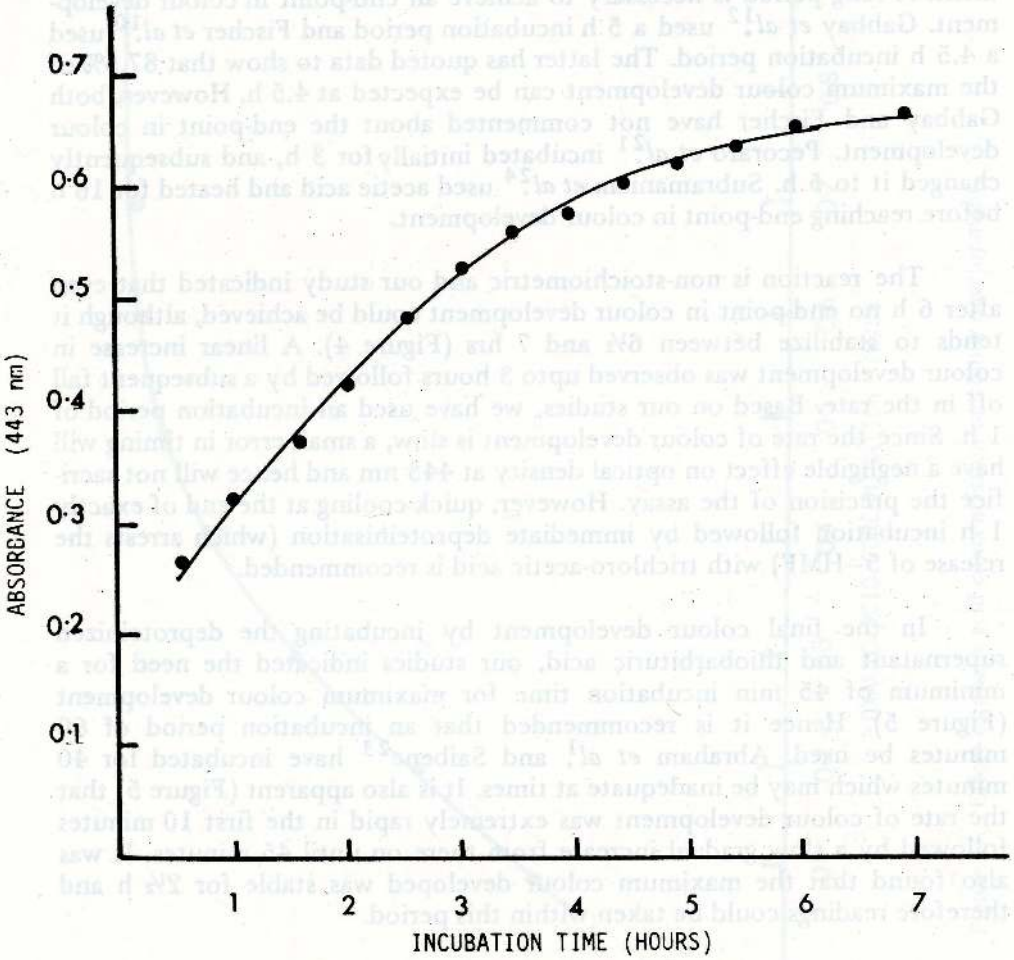

Figure 4. Effect of incubation time with oxalic acid (0.3M) on the colour development.

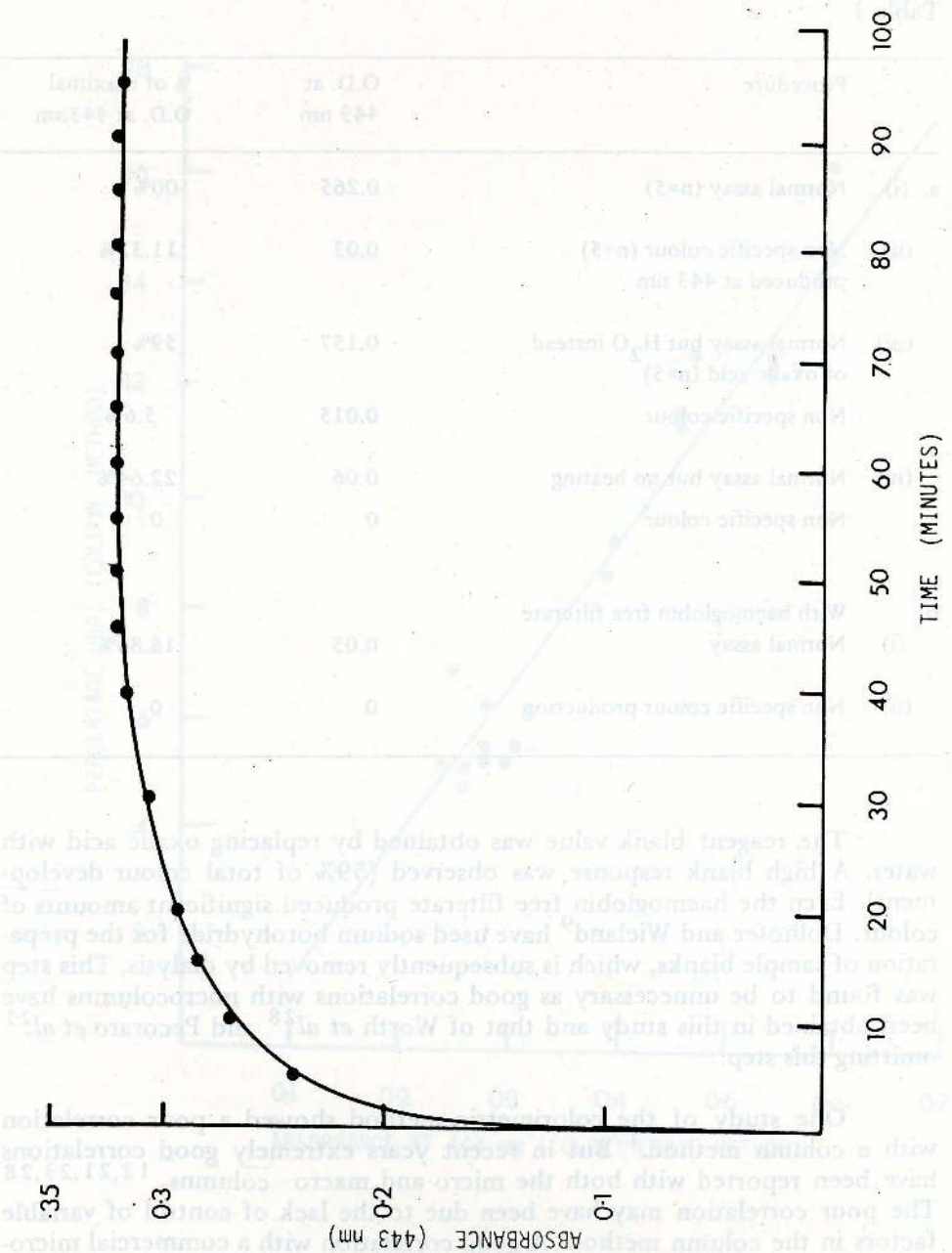

Figure 5. Effect of incubation time with thiobarbituric acid on colour development.

Table 1

	Procedure	O.D. at 443 nm	% of maximal O.D. at 443nm
a. (i)	Normal assay (n=5)	0.265	100%
(ii)	Non specific colour (n=5) produced at 443 nm	0.03	11.32%
(iii)	Normal assay but H_2O instead of oxalic acid (n=5)	0.157	59%
	Non specific colour	0.015	5.6%
(iv)	Normal assay but no heating	0.06	22.64%
	Non specific colour	0	0
b.	With haemoglobin free filterate		
(i)	Normal assay	0.05	18.86%
(ii)	Non specific colour production	0	0

The reagent blank value was obtained by replacing oxalic acid with water. A high blank response was observed (59% of total colour development). Even the haemoglobin free filterate produced significant amounts of colour. Dolhofer and Wieland[9] have used sodium borohydride for the preparation of sample blanks, which is subsequently removed by dialysis. This step was found to be unnecessary as good correlations with microcolumns have been obtained in this study and that of Worth *et al*.[28] and Pecoraro *et al*.[21] omitting this step.

One study of the colorimetric method showed a poor correlation with a column method.[1] But in recent years extremely good correlations have been reported with both the micro and macro columns.[12,21,23,28] The poor correlation may have been due to the lack of control of variable factors in the column method. A good correlation with a commercial microcolumn kit was obtained in this study (r=0.92, n=20). This was used as the basis for the conversion of optical density values at 443 nm to the generally known per cent HbA_1 values. The regression line (Figure 6) intersects the X axis. This is because the colorimetric assay detects glycosylation not only at the N–terminal amino group of the β-chains, but also the substantial glyco-

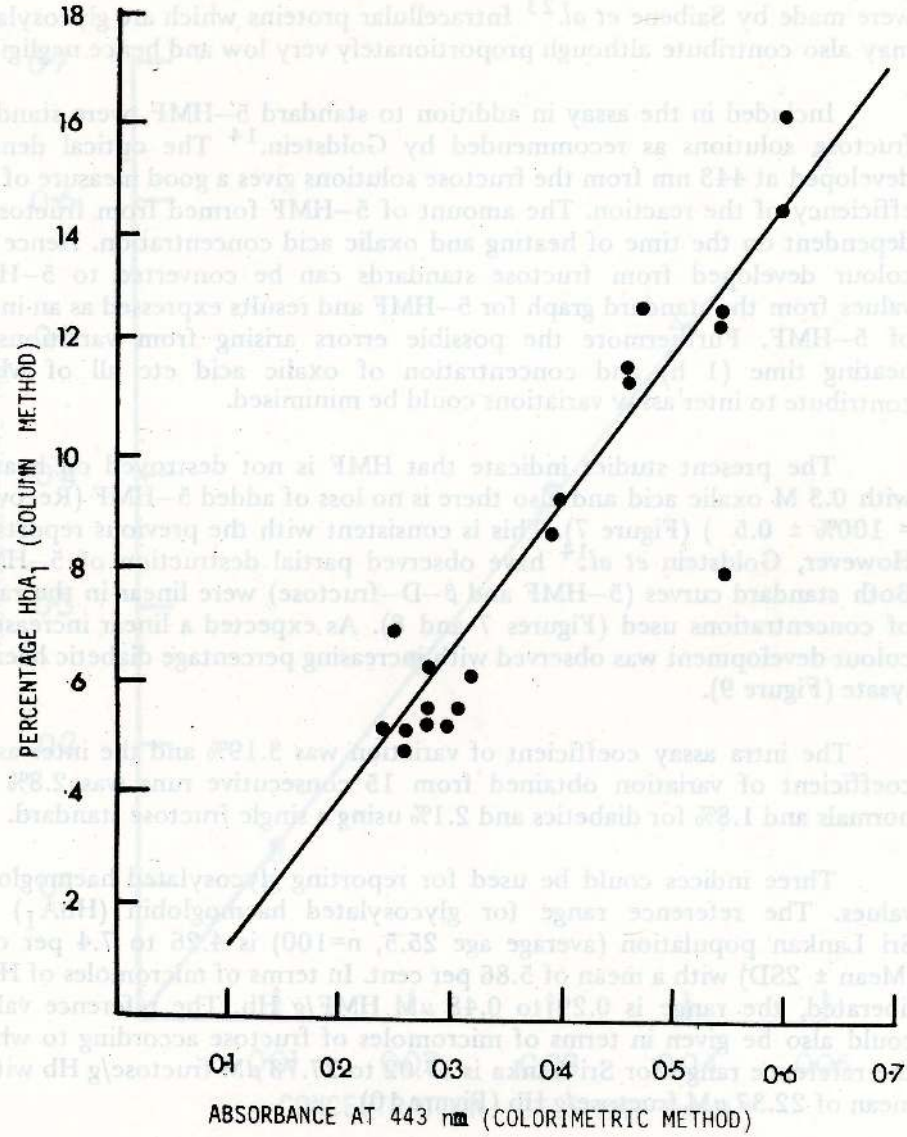

Figure 6. Correlation between HbA_1 determination by the colorimetric method and column method (Bio rad).

sylation of the N–terminal amino groups of the α chains and the ε amino groups of the lysine residues in both α and β chains. Similar observations were made by Saibene *et al.*[23] Intracellular proteins which are glycosylated may also contribute although proportionately very low and hence negligible.

Included in the assay in addition to standard 5–HMF, were standard fructose solutions as recommended by Goldstein.[14] The optical density developed at 443 nm from the fructose solutions gives a good measure of the efficiency of the reaction. The amount of 5–HMF formed from fructose is dependent on the time of heating and oxalic acid concentration. Hence the colour developed from fructose standards can be converted to 5–HMF values from the standard graph for 5–HMF and results expressed as an index of 5–HMF. Furthermore the possible errors arising from variations in heating time (1 h) and concentration of oxalic acid etc all of which contribute to inter assay variations could be minimised.

The present studies indicate that HMF is not destroyed on heating with 0.3 M oxalic acid and also there is no loss of added 5–HMF (Recovery = 100% ± 0.5) (Figure 7). This is consistent with the previous reports.[28] However, Goldstein *et al.*[14] have observed partial destruction of 5–HMF. Both standard curves (5–HMF and β–D–fructose) were linear in the range of concentrations used (Figures 7 and 8). As expected a linear increase in colour development was observed with increasing percentage diabetic haemolysate (Figure 9).

The intra assay coefficient of variation was 3.19% and the inter assay coefficient of variation obtained from 15 consecutive runs was 2.8% for normals and 1.8% for diabetics and 2.1% using a single fructose standard.

Three indices could be used for reporting glycosylated haemoglobin values. The reference range for glycosylated haemoglobin (HbA_1) for Sri Lankan population (average age 25.5, n=100) is 4.26 to 7.4 per cent (Mean ± 2SD) with a mean of 5.86 per cent. In terms of micromoles of HMF liberated, the range is 0.29 to 0.48 μM HMF/g Hb. The reference values could also be given in terms of micromoles of fructose according to which the reference range for Sri Lanka is 17.02 to 27.73 μM fructose/g Hb with a mean of 22.37 μM fructose/g Hb (Figure 10).

There was no significant difference between males and females. The mean for non-insulin dependent diabetics (Average age 47, n=107) was 10.83% HbA_1 or 0.68 μM HMF/g Hb or 39.4 μM fructose/g Hb.

The reference values in the present studies for Sri Lanka are in close agreement with those quoted for other countries.

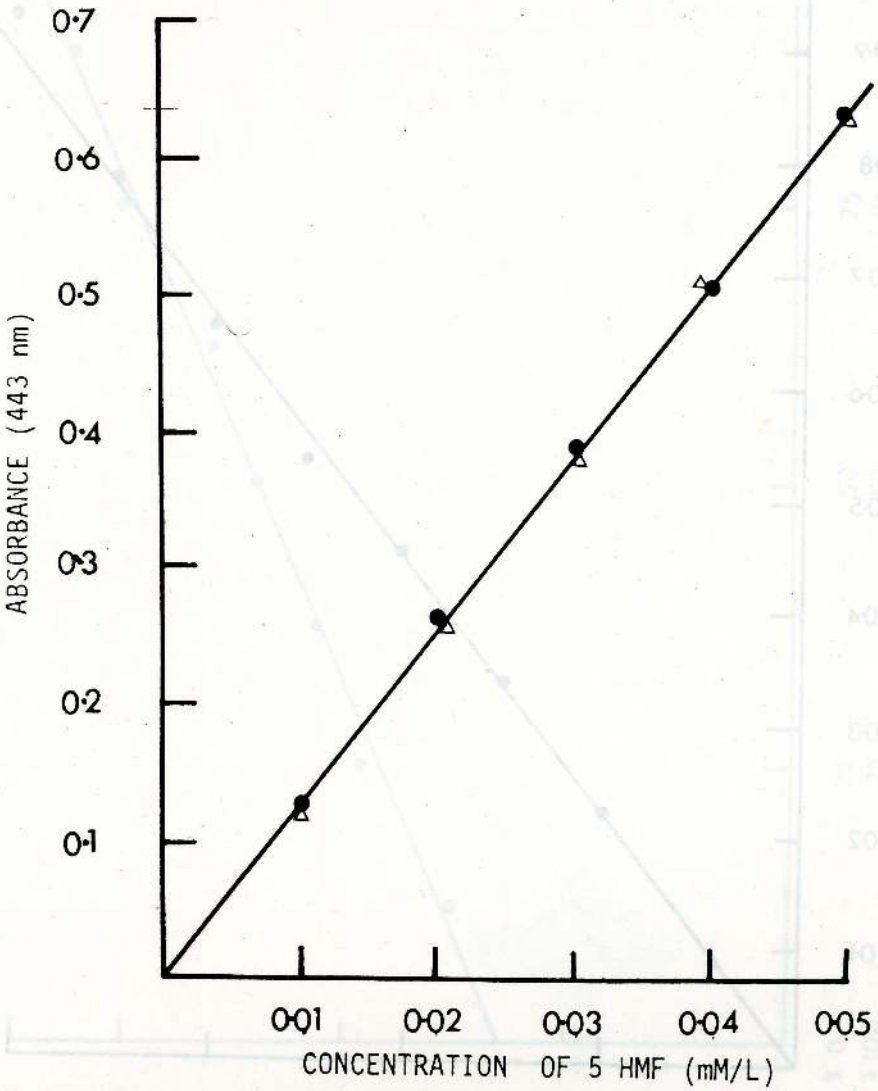

Figure 7. Standard curve for 5—HMF
- ● Standards carried right through the assay
- △ Standards carried right through the assay without heating.

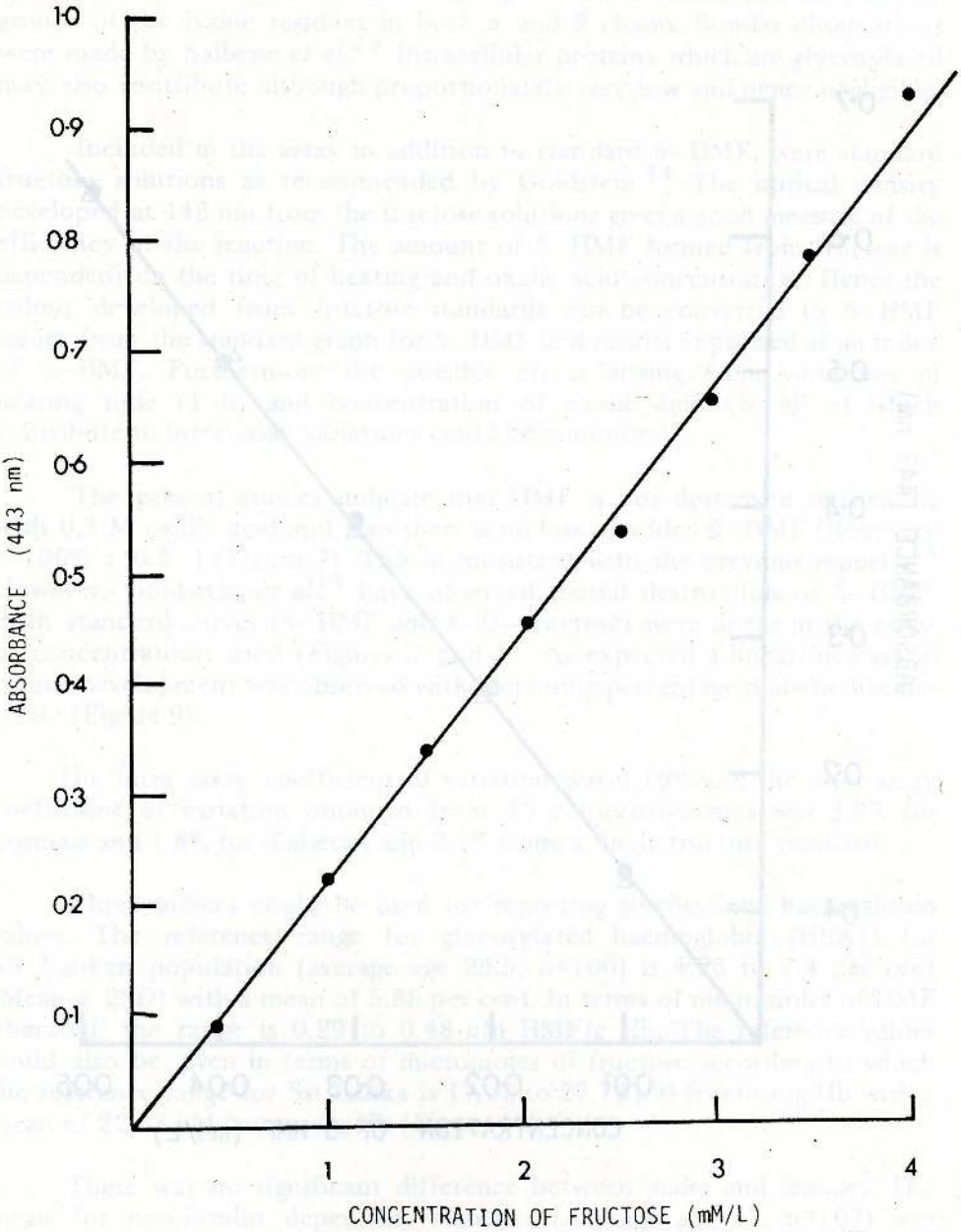

Figure 8. Standard curve for β–D–fructose.

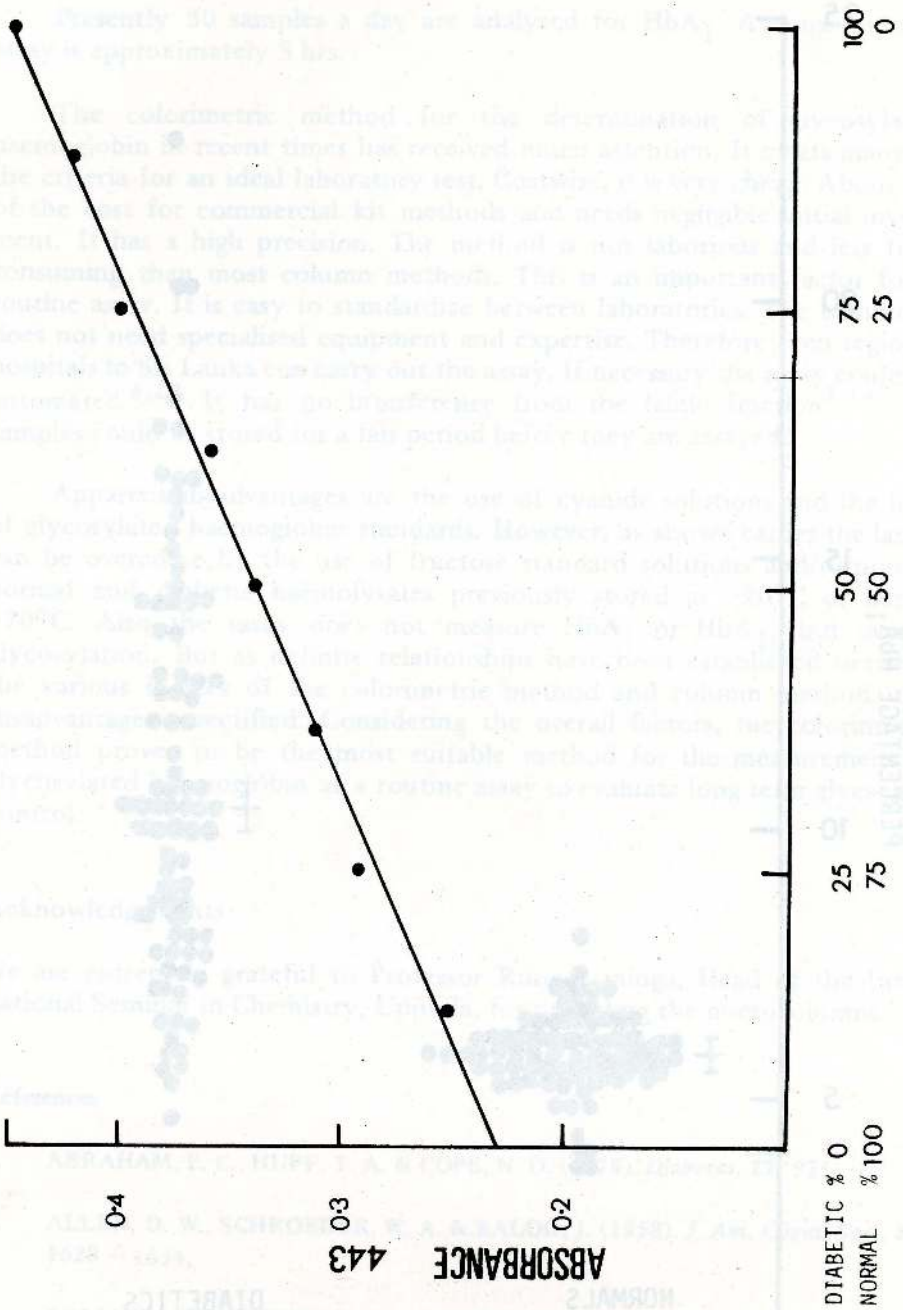

Figure 9. Effect on colour development with increasing percentage diabetic haemolysate.

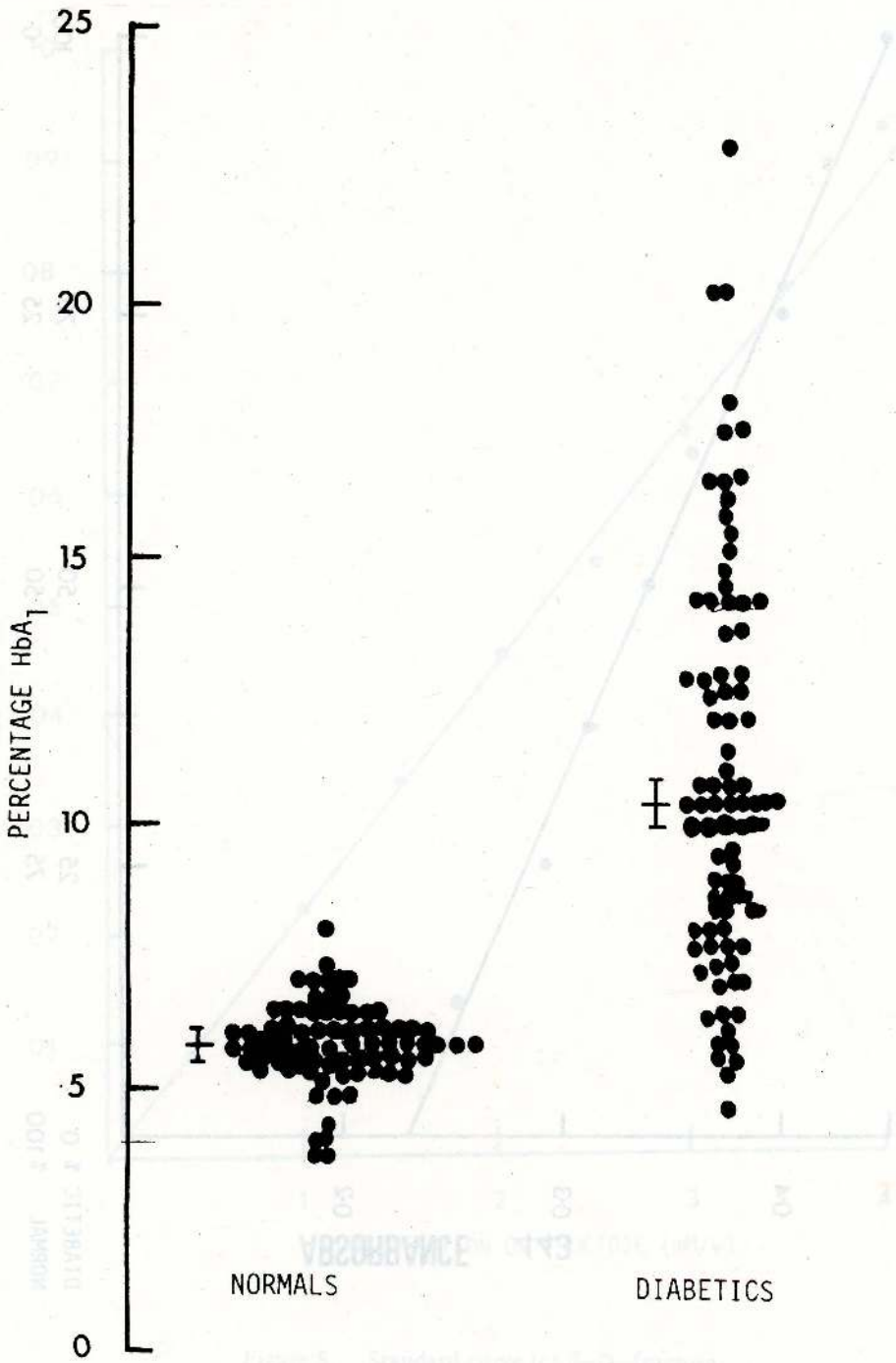

Figure 10. Glycosylated haemoglobin levels in 107 diabetic subjects and 100 normals Mean ± SEM are indicated by the bars.

Presently 30 samples a day are analysed for HbA_1. Average time of assay is approximately 3 hrs.

The colorimetric method for the determination of glycosylated haemoglobin in recent times has received much attention. It meets many of the criteria for an ideal laboratory test. Costwise, it is very cheap. About 2% of the cost for commercial kit methods and needs negligible initial investment. It has a high precision. The method is not laborious and less time consuming than most column methods. This is an important factor for a routine assay. It is easy to standardize between laboratories. The technique does not need specialised equipment and expertise. Therefore even regional hospitals in Sri Lanka can carry out the assay. If necessary the assay could be automated.[6,22] It has no interference from the labile fraction[3,14] and samples could be stored for a fair period before they are assayed.

Apparent disadvantages are the use of cyanide solutions and the lack of glycosylated haemoglobin standards. However, as shown earlier the latter can be overcome by the use of fructose standard solutions and/or pooled normal and diabetic haemolysates previously stored at −20°C or better −70°C. Also the assay does not measure HbA_1 or HbA_{1c} but overall glycosylation. But as definite relationships have been established between the various indices of the colorimetric method and column method, this disadvantage is rectified. Considering the overall factors, the colorimetric method proves to be the most suitable method for the measurement of glycosylated haemoglobin as a routine assay to evaluate long term glycaemic control.

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A NOVEL ELECTRON SOLVATION PHENOMENON IN MOLTEN POTASSIUM THIOCYANATE

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Abstract : Potassium thiocyanate when heated above the melting point is found to acquire a bright blue color that deepens with increase of temperature. Optical absorption spectra and electronic conductivity measurements indicate that this phenomenon results from thermal generation of solvated electrons. A simple theory is given to correlate the observations.

1. Introduction

Polarons the 'self-trapped' electrons in an ionic lattice, whose existence first postulated by Landau,[12] having resolved many problems in condensed matter physics,[1,15] continue to arouse the interest of workers in a number of different fields.[6,16,17] Now it is well established that polarons are also formed in molecular solids[1] liquids[9,25] and gases.[13,18] The best known systems where solvated electrons (polarons in a liquid are commonly referred to as solvated electrons) exist are solutions of alkali metals in liquid ammonia.[3,14,22,25] When these metals are dissolved in liquid NH_3, the solution acquires a blue color. Absorption spectra, electronic transport and phase transitions observed here can all be explained on the assumption that alkali metal atoms dissociate into ions and solvated electrons.[3,14,22,25]

In this letter we report our experimental results and theoretical interpretation of a novel phenomenon observed in molten potassium thiocyanate, that could be explained as due to thermal generation of solvated electrons.

2. Experimental

We have observed that KCNS heated well above the m.p ($\simeq$ 446 K) gradually acquires a bright blue color that deepens with the increase of temperature. The effect is completely reversible provided the heating is carried in vacuum and the decomposition temperature ($\sim$ 773 K) is not exceeded. The optical absorption spectrum of the molten salt at different temperatures is given in Figure 1. It is seen that the spectrum has a broad absorption band with a

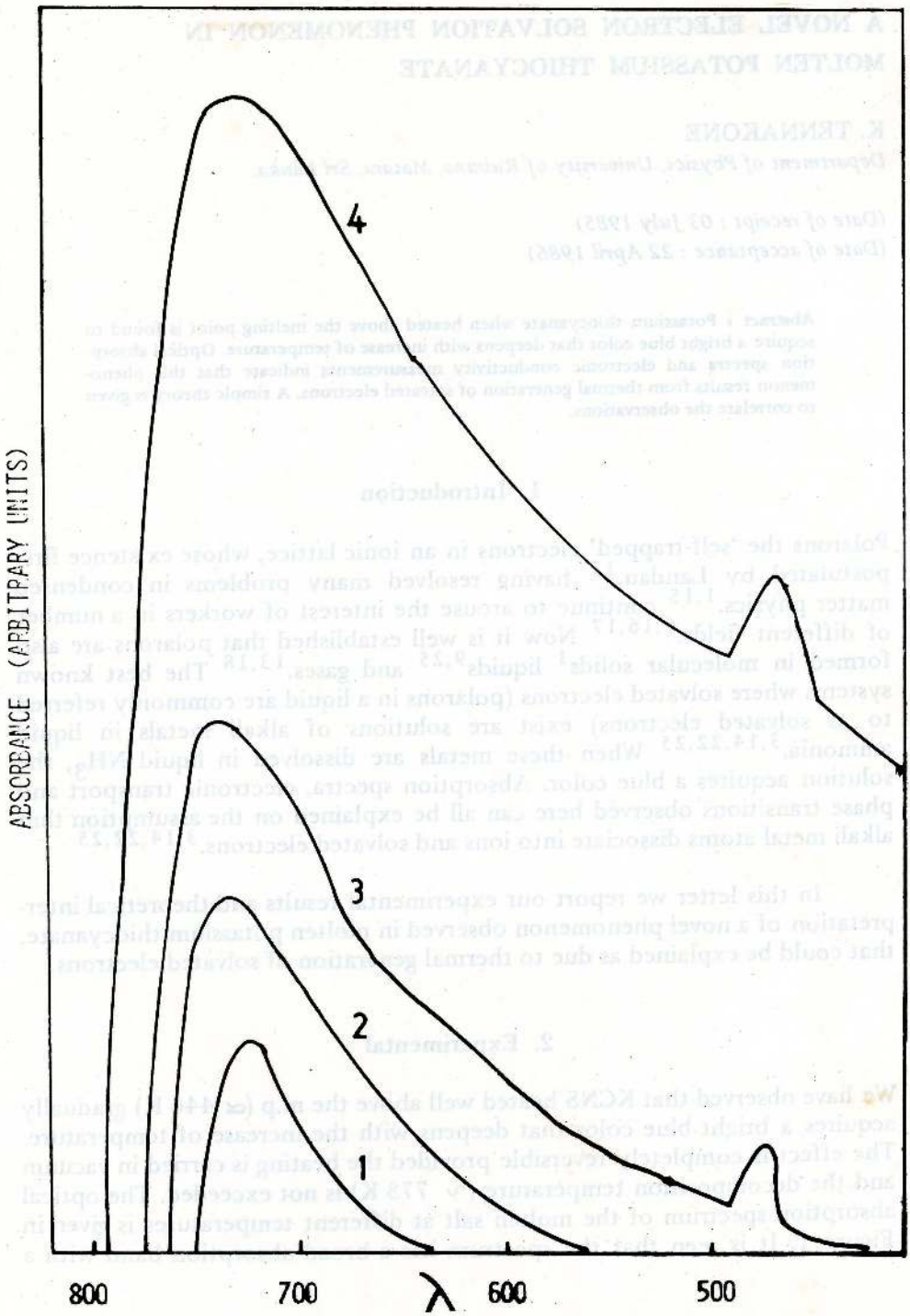

Figure 1. Absorption spectra of molten KCNS resulting from solvated electrons (1) 523K (2) 548 K (3) 573 K (4) 623 K. The small peak near 475 nm comes from the $(CNS)^{-2}$ ion (λ in nm).

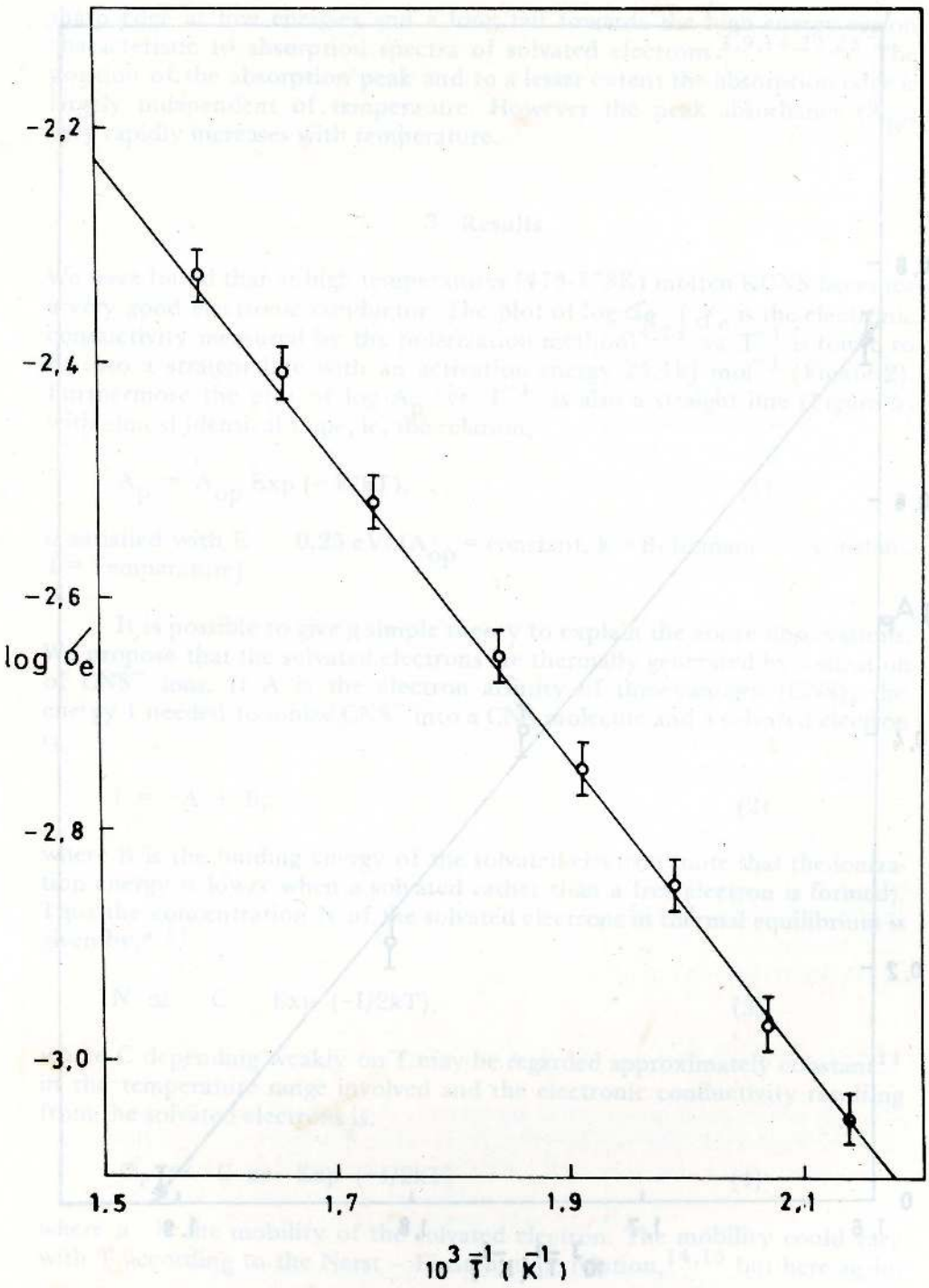

Figure 2. Plot of log σ_e (Ω^{-1} cm^{-1}) vs T^{-1}.

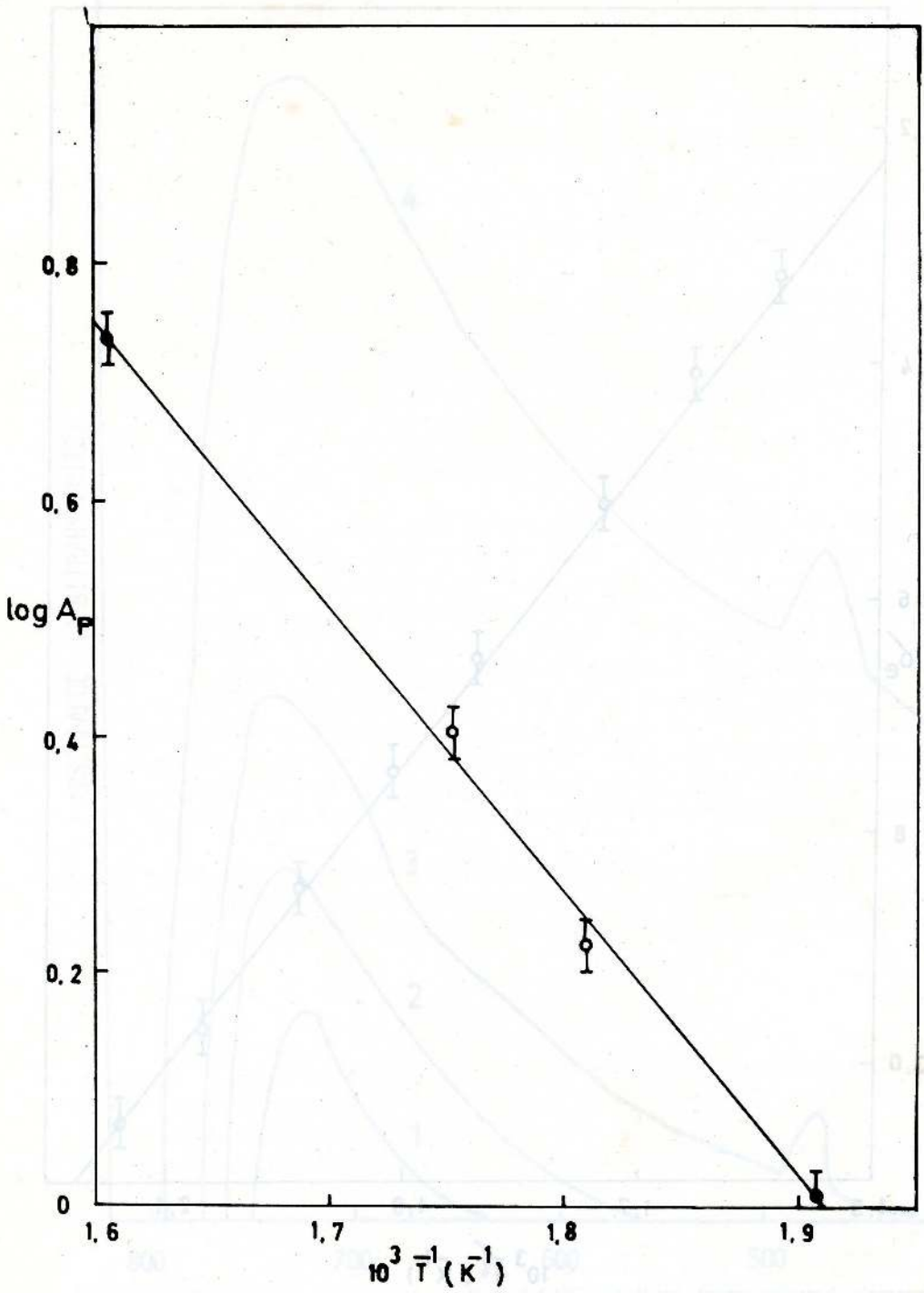

Figure 3. Plot of log A_p (peak absorbance A_p in arbitrary units) vs T^{-1}.

sharp edge at low energies and a long tail towards the high energy region characteristic to absorption spectra of solvated electrons.[3,9,14,22,25] The position of the absorption peak and to a lesser extent the absorption edge is largely independent of temperature. However the peak absorbance (A_p), very rapidly increases with temperature.

3. Results

We have found that at high temperatures (473-773K) molten KCNS becomes a very good electronic conductor. The plot of log σ_e (σ_e is the electronic conductivity measured by the polarization method)[4,23] vs T^{-1} is found to fit into a straight line with an activation energy 23.1kJ mol^{-1} (Figure 2). Furthermore the plot of log A_p vs T^{-1} is also a straight line (Figure 3) with almost identical slope, ie, the relation,

$$A_p = A_{op} \text{ Exp } (- E/kT), \qquad (1)$$

is satisfied with E 0.25 eV. (A_{op} = constant, k = Boltzmann constant, T = Temperature)

It is possible to give a simple theory to explain the above observations. We propose that the solvated electrons are thermally generated by ionization of CNS^- ions. If A is the electron affinity of thiocyanogen (CNS), the energy I needed to ionize CNS^- into a CNS molecule and a solvated electron is,

$$I = -A + B, \qquad (2)$$

where B is the binding energy of the solvated electron (note that the ionization energy is lower when a solvated rather than a free electron is formed). Thus the concentration N of the solvated electrons in thermal equilibrium is given by,* [11]

$$N \simeq C \text{ Exp } (-I/2kT), \qquad (3)$$

where C depending weakly on T may be regarded approximately constant[11] in the temperature range involved and the electronic conductivity resulting from the solvated electrons is,

$$\sigma_e \simeq C \mu e \text{ Exp } (-I/2kT) \qquad (4)$$

where μ is the mobility of the solvated electron. The mobility could vary with T according to the Nerst – Einstein type relation,[14,15] but here again,

* The calculation of the equilibrium concentration in this case is completely equivalent to thermal ionisation of charge carriers from donor levels in a semiconductor.

the T dependence of the term in front of the exponential factor in (4) is not very significant. Hence the plots of log A_p (A_p is proportional to N) vs T^{-1} and log σ_e vs T^{-1} should have the same slope as observed and we deduce that $I \simeq 0.48$ eV. The observed electron affinity of a CNS molecule in vacuum[17, 18] is 200.8 kJ mol^{-1}, hence from (1) we obtain $B \simeq 1.69$ eV and the peak is expected to occur at $\lambda_p \simeq hc/B \simeq 735$ nm. The observed value lies between 715 – 750 nm, agreeing quite well with the predicted value.

Yet another observation that supports the idea we have proposed is the detection of $(CNS)_2^-$ ions formed by combination of thermally generated CNS with CNS^-. The $(CNS)_2^-$ ions are known to have characteristic absorption peak at $\sim$ 475 nm.[1] We have noted that molten KCNS has an absorption peak centered near this point (Figure 1).

The effect is rather insensitive to common impurities other than water. However in all experiments we have used KCNS purified by several recrystallizations. Solvated electrons are highly reactive; water, oxygen and certain other impurities tend to induce some decomposition if the salt is kept in the molten state (473 – 673K) for prolonged intervals. Again it is interesting to note that NaCNS having a higher melting point ($\sim$ 523K) exhibits the same phenomenon with almost identical features.

Several attempts have been made to construct models to interpret the detailed structure of the absorption spectra of solvated electrons.[2,5,8,10,21] Most of them are based on the assumption that the electron experiences a coulomb like potential,[2,3,5,8,10,21,25]

$$V(r) = e^2 (K_\alpha^{-1} - K_s^{-1}) r^{-1}, \qquad (5)$$

where K_α, K_s are the optical and static dielectric constants of the liquid, for molten KCNS (473–573K), we have noted $K_\alpha \simeq 1.5$ and $K_s \simeq 3.3$ and the hydrogenic ionization energy* turns out to be $\sim$ 172.8 kJ mol^{-1} (1s – 2p, transition energy $\sim$ 1.4 eV).

4. Conclusions

Though not in good quantitative agreement, the slight shift of the absorption edge towards the red region (Figure 1) with the increase of temperature could result from decrease of K_s with the increase of temperature. However, none of the above arguments are sufficient to explain all features in the absorption profile.

* In these models it is uncertain whether, the binding energy is to be taken as ionization energy or 1s – 2p transition energy.

Molten KCNS is even a more vivid example of electron solvation than liquid ammonia. Further studies on this easily observed effect could elucidate electron trapping and other equally fascinating problems in molten salt systems.[24]

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අඳුනින් බිහිවන නියුට්‍රෝන තාරකාවකට නියුට්‍රිනෝ විමෝචනයෙන් සිසිල් විය හැකි වේගය ට වඩා ශීඝ්‍රයෙන් නියුට්‍රෝන වාෂ්පීකරණය මගින් සිසිල් විය හැකි බව පෙන්නුම් කෙරේ. නියුට්‍රෝන වාෂ්පීකරණයෙන් පිටවන ස්කන්ධ භාගය ඇස්තමේන්තු කෙරේ.

ලංකාවේ ඇතැම් හොලොතූරිය විශේෂයන්ගේ රසායනික සංඝටක
රාජේස්වරී මාගේස්වරන් සහ වාසිතා බාලක්‍රිෂ්ණන්

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Holothuria scabra, Holothuria atra , Holothuria nobilis , Holothuria leucospilota, Bohadschia marmorata සහ **Sticopus chloronotus** යන හොලොතූරියා විශේෂයන් හි අන්තර්ගත සෝඩියම්, පොටෑසියම්, කැල්සියම්, යකඩ, මැග්නීසියම් සහ ෆොස්පරස් ප්‍රමාණයන් නිර්ණය කරන ලදි. සෝඩියම්, පොටෑසියම්, කැල්සියම් සහ මැග්නීසියම් අධිකතම ප්‍රමාණයන් (එනම්, පිළිවෙලින් 4.29%, 1.05%, 7.91% සහ 5.21% ක්) **H. scabra** වල අන්තර්ගත ව ඇත. සෝඩියම් සහ කැල්සියම් අවම ප්‍රමාණයන් (0.30% ක් සහ 2.05% ක්) දැක්වුනේ **B. marmorata** වලය. මැග්නීසියම් අවම ප්‍රමාණය (0.73%) **H. atra** වලද, පොටෑසියම් අවම ප්‍රමාණය (0.10%) **S. chloronotus** වලද වෙයි. තඹ සහ නිකල් අන්වේෂී මූලද්‍රව්‍ය අධිකතම ප්‍රමාණයන් (එනම් පිළිවෙලින් දශ ලක්ෂයට කොටස් 9 සහ දශ ලක්ෂයට කොටස් 36) **H. scabra** වල අන්තර්ගත වූ අතර මැංගනීස් සහ සින්ක් උපරිම ප්‍රමාණයන් (දශ ලක්ෂයට කොටස් 7 සහ 340 ක්) වූයේ **B. marmorata** වලය. වාණිජමය වශයෙන් වැදගත් වන විශේෂයන් දෙක අතුරින් **H. atra** වල ප්‍රෝටීන් ප්‍රමාණය (61 - 65%) **H. scabra** වල ප්‍රෝටීන් ප්‍රමාණය (36 - 38%) ට වැඩිය. පැසුරුම් කිරීමෙන් **H. atra** සහ **H. scabra** වල අන්තර්ගත ප්‍රෝටීන් ප්‍රමාණය කෙරෙහි ඇතිවූ බලපෑම පිළිබඳව විමර්ශනය කෙරේ. ශ්‍රී ලංකාවේ උතුරු වෙරළෙන් ලබාගෙන පැසුරුම් කළ **H. atra** වල සහ **H. scabra** වල දකුණු ගාන්තිකර දුපත් වලින් ලබාගත් පැසුරුම් කළ **H. scabra** වලට වැඩි ප්‍රෝටීන් ප්‍රමාණයක් (පිළිවෙලින් 73 - 76% ක් සහ 59% ක්) අඩංගු වෙයි. අන්තර්ගත ඛණිජ ප්‍රමාණය පදනම් කරගෙන **H. scabra** සහ **H. atra** වෙන් කොට හඳුනාගත හැකි ක්‍රමයක් ද ඉදිරිපත් කෙරේ.

මන්ඩතිවු සහ කිරින්ද වෙරළවලින් ලබාගත් සාගර ඇල්ගී වල බෝරෝන් ප්‍රමාණය සහ කිරින්ද වෙරළින් ලබාගත් ඇල්ගී විශේෂ නවයක ඛණිජ ද්‍රව්‍ය ප්‍රමාණය

රාජේස්වරී මාගේස්වරන්, එසිතා බාලකිෂ්ණන් සහ එස්. බාලසුබ්‍රමානියම්

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මන්ඩතිවු සහ කිරින්ද වෙරළවලින් ලබාගත් සාගර ඇල්ගී විශේෂ 18 ක අන්තර්ගත බෝරෝන් ප්‍රමාණය පිළිබඳව මෙයින් වාර්තා වේ. අංශු මාතෘ මූල ද්‍රව්‍යයක් වන බෝරෝන්, ශාකයන්ගේ වැඩීමට අත්‍යවශ්‍යය. **Gracilaria crassa, Gracilaria edulis, Gracilaria corticata, Centroceros clavulatum,** සහ **Sarcodia ceylanica** වැනි, බෝරෝන් දශ ලක්ෂයට කොටස් 200 ට අධික ප්‍රමාණයක් අඩංගු ඇල්ගී වර්ග, ශාකයන් ට අවශ්‍ය බෝරෝන් සහ වෙනත් ඛණිජ වර්ග සපයන පොහොර වශයෙන් යොදා ගැනීමේ ශක්‍යතාව සාකච්ඡාවට භාජනය කෙරේ. කිරින්ද වෙරළෙන් ලබාගත් මුහුදු ඇල්ගී වර්ග නවයක අන්තර්ගත අයඩින්, ෆොස්ෆරස්, යකඩ, සෝඩියම්, පොටෑසියම්, කැල්සියම්, මැග්නීසියම්, ක්ලෝරයිඩ් (අයනික) සහ ගෙන්දගම් (සමස්ත) ප්‍රමාණයන් වාර්තා කෙරෙන අතර ඒවා උතුරු වෙරළෙන් ලබාගත් ඇල්ගී වර්ගවල එකී සාධක හා සසඳ ඇත. ශ්‍රී ලංකාවේ වෙරළවලින් ලබාගත් සාගර ඇල්ගී වලින් වාර්තා වී ඇති උපරිම අයඩින් ප්‍රමාණය (දශ ලක්ෂයට කොටස් 3990 ක්) ලැබී ඇත්තේ **Gracilaria fergusoni** වලිනි.

ඇතැම් ප්ලම්බපින් ලෝහ සංකීර්ණයන් පිළියෙල කිරීම සහ ඒවායේ ගුණාංග

ඒ. පී. මානෙල් දංගල්ල සහ ඕ. ඒ. ඉලේපෙරුම

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ස්ථායීකාව පිහිටන නැප්තක්ටිනොනයක් වන ප්ලම්බපින් සහ **Cu (II), Ni (II), Co (II) Mn (II), Zn (II)** සහ **Hg (II)** අයන වලින් සෑදෙන සංකීර්ණයන් පිළියෙල කිරීම සහ ලක්ෂණීකරණය පිළිබඳ කරුණු වාර්තාවේ. ද්‍රාවණයේ දී මෙකී සංකීර්ණයන්ගේ ස්ථායිතා නියතයන් විභවමානික අනුමාපන ක්‍රම භාවිතයෙන් නිර්ණය කර ඇත. ස්ථායිතා නියතයන් සඳහා අධික අගයයන් නිරීක්ෂණය කර තිබීම, ශාක වසින් ලෝහ අයන උකහා ගැනීමට අතැම් වාහක අණු සම්බන්ධ වන බවට පවතින කල්පිතය සනාථ කිරීමට අදාළ විය හැකිය.

ශ්‍රී ලංකාවේ භූගත ජලයෙහි භූ රසායනික වර්ගීකරණය

සී. බී. දිසානායක සහ එස්. වී. ආර්. වීරසූරිය

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මෙම ලිපියෙන් ශ්‍රී ලංකාවේ භූගත ජලය පිළිබඳ සවිස්තර භූරසායනික වර්ගීකරණයක් ඉදිරිපත් කෙරේ. ශ්‍රී ලංකාවේ ජනගහනයෙන් 85% ක් පමණ පානීය ජලය සඳහා ළිං ජලය සහ නල මාර්ගික නොවන වෙනත් ජලය භාවිතා කරන බැවින් භූගත ජලයෙහි රසායන විද්‍යාව පිළිබඳ තොරතුරු අත්‍යාවශ්‍යයය. රසායනික ව, ශ්‍රී ලංකාවේ භූගත ජලය කැල්සියම්, මැග්නීසියම්, සෝඩියම්/ පොටෑසියම් සහ අම්ලමූල කැටායන අන්තර්ගත ජලය යනුවෙන් ප්‍රධාන වර්ග 4 කට බෙදෙ ඇත. මෙකී එක් එක් ප්‍රධාන වර්ගය උප කාණ්ඩ 2 කට හෝ 4 කට බෙදෙ වෙන් කරනු ලැබේ. භූගත ජලයෙහි රසායනය, එහි පරිසරය මත මෙන්ම භූ ලක්ෂණ මත ද බොහෝ දුරට රඳ පවතින බැවි හෙළි විය. විශේෂයෙන් ම සෝඩියම්/ පොටෑසියම් කාණ්ඩයේ ජලය වියළි කලාපයේ බහුල වෙයි. මේ අතර, තෙත් කලාපයේ කැල්සියම් සහ අම්ලමූල කැටායන වර්ගයේ ජලය බහුල විය. ජලයෙන් පැතිරෙන සොඛ්‍ය උපද්‍රව වලට පහසුවෙන් ගොදුරුවන ප්‍රදේශ සළකුණු කිරීමේ දී යෝජිත වර්ගීකරණය ප්‍රයෝජනවත් අන්දමින් උපයෝගි කරගත හැකි බව ද පෙන්නුම් කෙරේ.

ඇතැම් සුලභ ආහාර වර්ගයන් හි අන්තර්ගත විටමින් ඒ සහ β- කැරටින් ප්‍රමාණය

ටී. එම්. එස්. අතුකෝරාල

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ශ්‍රී ලංකාවේ සුලභ ඇතැම් ආහාර වර්ගයන් හි අන්තර්ගත විටමින් ඒ සහ එහි පූර්වගය වන β-කැරටින් ප්‍රමාණයන් නිර්ණය කරන ලදි. නොපිසූ ආහාර සාම්පලවල ඛාද්‍ය කොටස විශ්ලේෂණය සඳහා යොදෙ ගැණිණ. විටමින් ඒ සහ β - කැරටින් සාන්ද්‍රණ පිළිගත් ක්‍රම අනුව ප්‍රතිදීප්තියෙන් සහ අධිශෝෂක වර්ණාවලී දිප්තිමාපනයෙන් නිර්ණය කෙරිණ.

විටමින් ඒ වඩාත් ම බහුල වූයේ මත්ස්‍ය සහ ගව අක්මාවෙහි ය. බිත්තර සහ කිරි හැරුණුකොට අනෙකුත් මාංශ ආහාරයන් හි අන්තර්ගත විටමින් ඒ ප්‍රමාණයෙන් ශ්‍රී ලාංකිකයන් දෛනිකව ගන්නා විටමින් ඒ ප්‍රමාණයට සැළකිය යුතු කොටසක් එක් නොවේ. පළාවන් එළවළු වල අන්තර්ගත β- කැරටින් ප්‍රමාණය ug/g 61.0-99.5 දක්වා විය. මෙය වෙනත් එළවළු සහ පළතුරු වල අන්තර්ගත වූවාට වඩා දෙගුණයකින් හෝ තුන් ගුණයකින් වැඩි විය. දෛනික ආහාරයේ තිබිය යුතු විටමින් ඒ ප්‍රමාණයෙන් විශාල කොටසක් β - කැරටින් රූපයෙන් පළාවන් එළවළු වලින් ලබා ගත හැකිය.

Gracilaria edulis ඒගාර් ශාකය පිළිබඳ අධ්‍යයන - පරීක්ෂණ ක්ෂේත්‍ර වගාවන් සහ අස්වැන්න හා තත්වය වැඩි දියුණු කිරීමේ ක්‍රම

ඒ. සිවපාලන් සහ කේ. පෙයිවෙන්දිරාජා

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ශ්‍රී ලංකාවේ සුලභ රතු ඇල්ගී වර්ග පහකින් නිස්සාරණය කරගත් අපයිකොකොලොයිඩ පිළිබඳව කළ මූලික පරීක්ෂණයන් හිදී. **Gracilaria edulis** ඒගාර් නිෂ්පාදනය සඳහා සුදුසු මූලාශ්‍රයක් වන බැව් හෙළි විය. මේ නිසාද, මෙම ඇල්ගී විශේෂය ව්‍යාපේක්ෂ වශයෙන් බහුලව පැවතීම නිසා ද එය වගාකිරීම සහ ඉන් ඒගාර් නිස්සාරණය කර ගැනීමේ ක්‍රම පිළිබඳ පරීක්ෂණ අරඹන ලදි.

වගාවේදි රෝපණ ද්‍රව්‍ය වශයෙන් භාවිතා කරන ලද්දේ ශාක අග්‍රයේ වර්ධක කොටස්ය. 1982 ඔක්තෝබර් සිට 1983 ජූනි දක්වා ඇල්ගී වගාව කරන ලදුව, සෑම මාසයක දිම ඒ ඒ මාසයේ රැස් කරගන්නා ලද ඇල්ගී භාවිතයෙන් පරීක්ෂණයක් අරඹන ලදි. මාස 2 1/2 ත් 3 ත් අතර ඇල්ගී දිගින් සෙ. මී. 30 - 35 දක්වා වූ උපරිම ප්‍රමාණයක ට වැඩිණ. ඒවායේ අමු බර ග්‍රෑම් 20 - 30 අතර ද, වියළි බර ග්‍රෑම් 1.5 - 2.5 අතර ද විය.

රෝපණය කළ **G. edulis** වල අන්තර්ගත ඒගාර් ප්‍රමාණය සහ ඒවායින් ලබාගත් ඒගාර්වල ජෙල් ශක්තිය නිර්ණය කරන ලදි. ඇල්ගී වල වර්ධනය වැඩිවීමත් සමග ඒගාර් ප්‍රමාණය ඉහළ ගියේය. එහෙත් ඒගාර්වල ජෙල ශක්තියෙ හි වැදගත් වෙනස්කම් සිදු නොවිණ. ස්වාභාවික ව බිහිවන **G. edulis** හා සසඳ, බලන විට මෙම දත්ත සතුටුදායක වෙයි.

ස්වාභාවිකව බිහිවන **G. edulis** විවිධ පෙර පිළියම් වලට භාජනය කිරීමෙන් අස්වැන්න සහ ජෙල ශක්තිය කෙරෙහි ඇතිවන බලපෑම් අධ්‍යනය කරන ලදි. මුලින් තෙත් ඇඹරුම ට භාජනය කිරීමෙන් ඒගාර්වල අස්වැන්න මෙන්ම ජෙල ශක්තිය ද වැඩි වූ අතර, කල්තබා පෙහවීමෙන් ඒගාර් වල කිසිදු දියුණුවක් නොවීය. පිඨනය යටතේ නිස්සාරණය කිරීමෙන් වැඩි අස්වැන්නක් සහ ජෙල ශක්තියක් ගෙන දෙන නිෂ්පාදනයක් බිහිවිය.

මෙම මුහුදු පැලෑටිය කල්තබා ක්ෂාර පිළියම ට භාජනය කිරීමෙන් ජෙල ශක්තිය වැඩි වූ අතර 4% දක්වා වූ පොටෑසියම් ක්ලෝරයිඩ් සාන්ද්‍රණයකින් පෙර පිළියම් කිරීමෙන් ජෙල ශක්තිය සැළකිය යුතු ප්‍රමාණයින් ඉහළ ගියේය.

ශ්‍රී ලංකාවේ ත්‍රිකුණාමල කැනියමේ ශීර්ෂ අවට භූ විද්‍යාත්මක පිහිටීම

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ත්‍රිකුණාමල කැනියමේ මූලාරම්භය සෙවීමේ ප්‍රයත්නයක් වශයෙන් එහි ශීර්ෂ අවට භූමියේ සවිස්තර භූ විද්‍යාත්මක සිතියම්කරණය අරඹන ලදි. මෙම කැනියම මහවැලි ව්‍යාකෘති ප්‍රදේශය එක එල්ලව පිහිටා ඇත. අවට පිහිටි පාෂාණයන්ගේ නිරාශ්විකාව ට සමාන ප්‍රවණතාවක් පෙන්වන මෙහි. ත්‍රිකුණාමල අභ්‍යන්තර වරායේ එකත් ද, කෝඩියාර් වරායේ දෙකත් ද, යනුවෙන් ප්‍රධාන ශීර්ෂ තුනක් ඇත. අභ්‍යන්තර වරායේ ඇති ශීර්ෂය වරායට ගිණිකොනින් ඇති දැදුරු ප්‍රදේශය හා සම්බන්ධතාවයක් පෙන්වයි. ප්‍රධාන ශීර්ෂ දෙක සහ කෝඩියාර් වරායේ අනු ශීර්ෂ සැදීමේ ලා මහවැලි නදිය බෙහෙවින් බලපා ඇත. කැනියම් ශීර්ෂයන්ගේ හැඩය, ප්‍රදේශයේ භූ විද්‍යාව ට අනුව සැකසී ඇති බැව් සමීක්ෂණයෙන් පෙනේ.

ශ්‍රී ලංකාවේ (සංවර්ධනය වන රටක) දන්ත අසාදනයන්ගේ විසංගතයන් ප්ලාස්මිඩ මාධ්‍ය කොටගත් ප්‍රතිජීවකයන ට ප්‍රතිරෝධී වීම

ටී. විනයාගමූර්ති

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දන්ත අසාදනයන්ගේ විසංගතයන් 55 ක් අතුරින් රැඩි කොටස ෆාන්ත්‍රික මාදිලි විය. තවද ඒ අතුරින් 90% කට රැඩි ප්‍රමාණයක් ඖෂධ රාශියක ට ප්‍රතිරෝධී විය. එසේ වුවත්. බෝවිය හැකි ප්‍රතිරෝධිතා ව සහිත මාදිලි ප්‍රමාණය ඉතා ස්වල්ප (2%) විය. එහෙයින් මෙම උත්පාදක වෙන්දිකයන්ගේ මූලාශ්‍රය මෙබඳුම ප්‍රතිජීවී ප්‍රතිරෝධතා රටවක් සහ බෝවීමේ ප්‍රවණතාවක් පෙන්නුම් කළ දුෂිත ජලය යයි අනුමාන කෙරේ. මෙබඳු මාදිලි මුඛ කුහරයෙ හි තිබීමෙන් නාසා ශ්‍රසනිකාවෙ හි වෙනත් සංවේදි මාදිලි කරා ප්‍රතිරෝධිතාව පැතිරීම පහසු විය හැකිය.

ග්ලයිකොසයිලේටඩ හිමොග්ලෝබින් තක්සේරු කිරීම සඳහා වර්ණ මාපක ක්‍රියාවලියක් අගැයීම සහ ශ්‍රී ලංකාව සඳහා යොමු අගයන් ස්ථාපනය කිරීම

කරුණානායක ඊ. එච්. සහ චන්ද්‍රසේකරන් එන්. වී.

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දියවැඩියා අන්තර් කලාප මර්ධනයේ ප්‍රමාණාත්මක සුචියක් වශයෙන් පූර්ව සති හතරේ සිට හය දක්වා කාලය තුල ග්ලයිකොසයිලේටඩ හිමොග්ලොබින් මැණීමේ හි වැදගත් කම දැන් මැනවින් තහවුරු වී ඇත. සංවර්ධනය වන රටවල් සඳහා අනුගමනය කළ හැකි ක්‍රමයක් වශයෙන් ප්ලූකිගර් සහ වින්ටර්හෝල්ටර් වර්ණමාපක ක්‍රමයෙ හි ඇති යෝග්‍යතාවය අප විසින් අගයා ඇත. ඔක්සැලික් අම්ලය හා පැයස් බියොෂණය කිරීමෙන්, විවල්‍යතා සංගුණක අභ්‍යන්තර ආර්ඝනය 3.19 (n = 20) ක්ද, අන්තර් ආර්යනය සාමාන්‍ය පුද්ගලයින් සඳහා 2.8% (n = 15) ක්ද, දියවැඩියා රෝගීන් සඳහා 1.8% ක්ද, සහිත ව මනා යතත්‍යතාවක් පෙන්නුම් කෙරිණ. ප්‍රමිති වශයෙන් 5 හයිඩ්‍රොක්සි මීතයිල් ෆර්ෆියුරැල්ඩිහයිඩ් (HMF) වලට අතිරේකව B - D ග්ලූකෝස් ද හාවිතා කරන ලදි. ප්‍රතික්‍රියාවේ කාර්යක්ෂමතාව මෙයින් මැනගත හැකිය. සියළුම සාම්පලවල නිශ්චිත නොවූ නිස්කඩ අගය නියතයක් විය. පූර්ණ රුධිර සාම්පල, කාමර උෂ්ණත්වයේ දී (සෙ. 30 + 3°) දින පහක් ද සෙ.4° ක උෂ්ණත්වයේ දිදින නවයක් ද ගබඩා කර තැබිය හැකි විය. හිමොලයිසේට සෙ.4° දිදින 5 ක්ද සෙ.20° දිදින 30 ක්ද ස්ථායි විය. මයික්‍රොකොලම් පරීක්ෂණ සට්ටලයකින් r = 0.92 (n = 20, P < 0.001) වූ මනා සහසම්බන්ධ සංගුණකයක් ලැබිණ. ශ්‍රී ලංකාව සඳහා ග්ලයිකොසයිලේටඩ හිමොග්ලොබින් (HbA 1) සඳහා සාමාන්‍ය මධ්‍යන්‍යය (± SD) පුරුෂයින්ට 5.85% ± 0.79 (n = 70) සහ ස්ත්‍රීන්ට 5.88% ± 0.79 (n = 30) විය. පුරුෂයින් සහ ස්ත්‍රීන් අතර සැලකිය යුතු වෙනසක් දක්නට නොලැබිණ. සාමාන්‍ය පුද්ගලයින් සඳහා සමස්ත මධ්‍යන්‍යය 5.9% ± 0.79% (නැතහොත් 0.39 ± 0.05 μM HMF/g Hb) විය. ඉන්සියුලින් කෙරෙහි රැදි නොසිටින දිය රැඩියා රෝගීන් සඳහා මධ්‍යන්‍යය 10.83 ± 3% (නැතහොත් 0.68 ± 0.20 μM HMF/g Hb) විය. ගර්භනීභාවයේ තුන්වන තෙමසෙ හි පසුවන ගැබිණි ස්ත්‍රීන් ගේ මධ්‍යන්‍යය % HbA 7.0% - 6.7% (n = 15) විය. ප්‍රශස්ත පරීක්ෂණාගාර පරීක්ෂණයකට අවශ්‍ය නිර්ණායක රාශියක් වර්ණමාපක ක්‍රමයෙන් සැපිරේ. එය සංවර්ධනය වන රටවල ග්ලයිකොසයිලේටඩ හිමොග්ලොබින් මැණීම සඳහා සුදුසු තම ක්‍රමය වෙයි.

උණුකළ පොටැසියම් තයෝසයනේට් වල දාව ගතව ඉලෙක්ට්‍රෝන බිහිරිමේ නවෘ සංසිද්ධියක්

සේ. පෙන්නකෝන්

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පොටැසියම් තයෝසයනේට් ද්‍රවාංකය ඉක්මවා උණුකළ විට. දිප්තිමත් නිල් පැහැයක් ගෙන උෂ්ණත්වය වැඩිවීමත් සමඟ වඩාත් තද පැහැ ගැන්වෙන බව පෙනී යයි. මෙම සංසිද්ධිය තාපජ වශයෙන් ද්‍රවගත ඉලෙක්ට්‍රෝන ජනනය වීමෙන් සිදුවන බැව් ද ප්‍රකාශ අවශෝෂණ වර්ණාවලි සහ විද්‍යුත් සන්නායකතා මිණුම් වලින් පෙනී යයි. නිරීක්ෂණ සම්බන්ධනය කිරීම සඳහා සරළ න්‍යායක් ඉදිරිපත් කෙරේ.

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இந்த இதழின் கட்டுரைகளின் சுருக்கங்கள்

1. நியூற்ரோன் விண்மீன்களின் மேற்பரப்பிலிருந்து நியூற்ரோன் ஆவியாதல்.

கே. தென்னகோன்
பௌதிகவியற் பகுதி,
உருகுணை பல்கலைக்கழகக் கல்லூரி,
மாத்தறை,
சிறீலங்கா.

J. Natn. Sci. Coun. Sri Lanka 1985 13(2): 107 – 114

புதிதாகத் தோற்றமெடுத்த நியூற்ரோன் விண்மீன் ஒன்று நியூற்ரோன் வெளிப்பாடு காரணமாகக் குளிர்ச்சி அடையும் வேகத்திலும்விட அதிக வேகத்தில் நியூற்ரோன் ஆவியாதல் காரணமாகக் குளிர்ச்சியடையலாமென்பது காட்டப் பெற்றுள்ளது. நியூற்ரோன் ஆவியாதலால் ஏற்படும் பொருண்மை இழப்பு மதிப்பிடப் பெற்றுள்ளது.

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2. இலங்கையில் காணப்பெறுகின்ற ஓலோதூரியன் இனங்கள் சிலவற்றிலுள்ள இரசாயனக் கூறுகள்

இராஜேஸ்வரி மகேஸ்வரன்,
வசீதா பாலகிருஷ்ணன்,
இராசாயனவியற்பகுதி, யாழ்ப்பாணப் பல்கலைக் கழகம், யாழ்ப்பாணம், சிறிலங்கா.

J. Natn. Sci. Coun. Sri Lanka 1985 13(2): 115 – 130

எச். ஸ்கப்ரு, எச். அற்ரு, எச். நொபிலிஸ், எச்.லியு கொஸ்பிலோடா, பீ, மர்மொரூட்ட, எஸ். குளோரேஞ்ஞெற்றுஸ் ஆகிய ஆறு ஓலோதூரியன் இனங்களிலுள்ள சோடியம், பொற்ருசியம், கல்சியம், இரும்பு, மகனீசியம், பொசுபரசு அளவுகள் அறுதியிடப் பெற்றுள்ளன. எச். ஸகப்ருவில் சோடியம் (4.29%), பொற்ருசியம் (1.05%), கல்சியம் (7.91%) மகனீசியம் (5.21%) ஆகியவை மிகுந்து காணப்பட்டன. மிகக்குறைவான சோடியமும் (0.30%) கல்சியமும் (2.05%) பீ. மர்மொரூட்டாவில் காணப்பட்டன. மிகக்குறைவான மகனீசியம் (0.73%) எச். அற்ருவில் உண்டு. மிகக்குறைவான பொற்ருசியம் (0.10%) எச். குளோரேஞ்ஞெற்றுஸ்ஸில் அமைந்திருந்தது. எச். ஸ்கப்ருவில் மிக்குயர் செம்புத் தடயங்களும் (9ppm) நிக்கல் தடயங்களும் (36ppm) காணப்பட்ட தோடு பீ. மர்மோரூட்டாவில் மிக்குயர் மங்கனீசு (7pmm) ம் துத்தநாகமும் (340ppm) காணப்பெற்றன. வாணிபத்துறைக்குரிய இரண்டு இனங்களான எச். அற்ருவில் 1மிக்குயர் புரதப்பொருள் (61-65%)

அமைந்திருந்தது. மற்ற இனமான எச். ஸ்கப்ருவில் காணப்பெற்ற புரதப்பொருள் அளவு (36-38%) ஆகும். எச். அற்ரு, எச். ஸ்கப்ரு ஆகியவற்றிலுள்ள கனிப்பொருள் மற்றும் புரதப் பொருள் சீரிடலின் விளைவுகளும் தரப் பெற்றுள்ளன. இலங்கையின் வட கடலோரத்திலிருந்து பெற்றுச்சீரிடப்பெற்ற எச். அற்ரு, எச். ஸ்கப்ரு ஆகியவற்றில் தென் பாசிபிக் தீவுகளிலிருந்து பெற்றுச் சீரிடப்பெற்ற எச். ஸ்காப்ருவில் உள்ளதைவிட அதிக புரதப் பொருள் அமைந்துள்ளது. இலங்கை வடகடலோர இனங்களில் (73-76%) புரதமும் பாசிபிக் தீவு இனங்களின் (59%) புரதமும் காணப்பட்டது. கனிப் பொருள் அளவு அடிப்படையில் எச். ஸ்கப்ரு, எச். அற்ரு ஆகிய இரண்டு இனங்களை வேறுபடுத்தும் முறையொன்றும் சுட்டிக் காட்டப்பட்டுள்ளது.

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3. மண்டைத்தீவு, கிறிந்தை கடலோரங்களைச் சேர்ந்த கடல் அல்காக்களின் பொரென் அமைப்பும் கிறிந்தை கடலோரத்தைச் சேர்ந்த ஒன்பது அல்கா இலங்கைகளின் கனிப்பொருள் அமைப்பும்

இராஜேஸ்வரீ மகேஸ்வரன், வசீதா பாலகிருஷ்ணன்,
இராசாயனவியற் பகுதி,
யாழ்ப்பாணப் பல்கலைக்கழகம்,
யாழ்ப்பாணம், சிறீலங்கா.

எஸ். பாலசுப்பிரமணியம்,
தாவரவியற் பகுதி, பேராதனைப்பல்கலைக்கழகம்,
பேராதனை, சிறீலங்கா.

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மண்டைத் தீவு, கிறிந்தை கடலோரங்களிலிருந்து சேர்க்கப் பெற்ற பதினெட்டு கடல் அல்கா இனங்களிலுள்ள பொரென் அளவு இங்கு அறிக்கையிடப்பட்டுள்ளது. பொரென் எனப்படுவது நுண் ஊட்டச் சத்தாகும். அது தாவர வளர்ச்சிக்கு இன்றியமையாதது, கிரசிலாரியா கிராஸ்ஸா, ஜீ. எதுலிஸ், ஜீ. கோர்டிகாற்ரு, சென்ரோ செரோஸ் கிளாவுலாற்றும், சார்கோடியா செலானிக்கா முதலிய அல்கா இனங்களைப் பொரென் மற்றும் பிற கனிப்பொருள் தேவைகளைப் பூர்த்தி செய்தற்கியன்றவாறு பசளையாகப் பயன்படுத்துவதன் சாத்தியக்கூறு ஆராயப் பட்டுள்ளது. கிறிந்தைக் கடலோரத்தில் ஒன்பது கடல் அல்காவினங்களிலுள்ள அயடீன், போசுபரசு, இரும்பு, சோடியம், பொற்ருசியம், கல்சியம், மகனீசியம், குளோரைட்டு (அயன்சார்புடையது) கெந்தகம் (மொத்தம்) அளவுகள் தரப் பெற்றுள்ளன. அத்துடன் இவற்றின் பெறுமானங்கள் வட கடலோர அல்காக்களிலுள்ள பெறுமானங்களுடன் ஒப்புநோக்கப் பெற்றுள்ளன. கிராசிலாரியா பெர்கியுசோனியில், இலங்கைக் கடலோர கடல் அல்காக்களில் இதுவரை கண்டறிந்த அளவுகளுடன் ஒப்பு நோக்குமிடத்து அயடீன் மிகுந்த அளவில் (3990ppm) அமைந்துள்ளது.

4. சில பிலம்பகின் உலோக செறிதேக்கங்களின் பண்புக்கூறுகளும் அவற்றைத் தயாரிக்கும் முறையும்

ஏ.சி. மானெல் தங்கல்லே, ஏ.ஏ. இளையபெருமா,
இரசாயனவியற் பகுதி,
பேராதனைப் பல்கலைக்கழகம், பேராதனை,
சிறிலங்கா.

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Cu (11), Ni(11), Co(11), Mn(11), Zn(11), Hg(11), ஆகிய அயன்களுடன் இயற்கையாகத் தோன்றுகின்ற நப்தாகுயினேன் பொருளாகிய பிலாம்பகின் காரணமாக உருவாகின்ற செறிதேக்கங்களின் தயாரிப்பும், பண்புருவருணனையும் இங்கு ஆராயப்பட்டுள்ளது. கரைசலிலுள்ள இச் செறிதேக்கங்களின் உறுதிமாறுமதிப்பளவைகள் மின்னழுத்த ஆற்றல் மானி இணைமக் கூறளவு மதிப்பாய்வு முறையினைப் பயன்படுத்தி தீர்மானிக்கப்பட்டுள்ளன. உறுதிமாறுமதிப்பளவைகள் தொடர்பில் அவதானிக்கப் பெற்ற அதி உயர் பெறுமானங்கள், தாவரங்களினுல் உலோக அயன்களை உட்கோடலுடன் காவி மூலக்கூறுகள் சில உறவுகொண்டாடுகின்றன என்னும் புனைவு, கோளினை நிலை நாட்டுதற்கு ஆதாரமாய் உள்ளன எனலாம்.

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5. இலங்கையின் நிலநீர் சார் புவியிரசாயன வகைப் பாடு.

சி.பீ. திசாநாயக்கா, எஸ்.வீ.ஆர். வீரசூரியா.
புவியியல் பகுதி, பேராதனைப் பல்கலைக்கழகம்,
பேராதனை, சிறிலங்கா.

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இலங்கையின் நிலநீர் சார் புவியிரசாயன வகைப்பாடு பற்றிய அகல் விரிவான விளக்க மொன்று இக்கட்டுரையில் தரப்பட்டுள்ளது. இலங்கையின் சனத் தொகையில் அண்ணளவாக 85% வீதமானோர் கிணற்று நீரினையும் குழாய் மூலம் பெறப் படாத நீரினையும் தமது அருந்து நீராகப் பயன் படுத்துவதனை உற்று நோக்குமிடத்து நிலநீரின் இரசாயன ஆய்வுகள் இன்றியமையாதனவாகும். இரசாயன பண்புக் கூறுகளுக்கேற்ப இலங்கையின் நிலநீர் நான்கு பேர் இனங்களுக்குப் பிரித்துக் காட்டப் பெற்றுள்ளது. அவையாவன Ca, Mg, Na/k, பெருவழக்காறு அற்ற கற்றயன் ஆகியவகைகளாகும். இம் முக்கிய பகுதிகள் ஒவ்வொன்றும் 2 அல்லது 4 உப பகுதிகளுக்குப் பகுக்கப்பட்டுள்ளது அடிப்படையான புவியியற் பண்புகளுக்கும் தரைநிலைக்கும் ஏற்ப நிலநீரின் இரசாயனம் பெரிதும் அமைந்துள்ள தென்பது புலனாகும். குறிப்பாக உலர் வலயத்தில் Na/k வகை நிலநீர் மிகுந்து காணப்படுவதுடன் ஈர வலயத்தில் Ca வகையும் பெரு வழக்காறு அற்ற கற்றயன் வகைநீரும் மிகுந்து காணப்படுகிறது. நீரின் ஊடாக ஏற்படும் நல இடர்களுக்கு எளிதில் ஆளாகக்கூடிய பிரதேசங்களை சித்தரித்துக் காட்டுதற்கு உத்தேச வகைப்பாடு எங்ஙனம் உதவுகின்ற தென்பதும் சுட்டிக் காட்டப்பட்டுள்ளது.

6. அன்றாட உணவுகள் சில வற்றின் விட்டமின் A, உம் β -கறற்றீனும்.

ரீ.எம்.எஸ். அத்துகோரளா
உயிர் இரசாயனப் பகுதி
மருத்துவப் பீடம்,
கொழும்பு பல்கலைக்கழகம்,
கொழும்பு. 8, சிறிலங்கா.

J. Natn. Sci. Coun. Sri Lanka 1985 **13**(2): 187 – 196

இலங்கையில் பொதுவாகக் கிடைக்கப் பெறுகின்ற உணவுகள் சிலவற்றில் கணப்பெறுகின்ற "ஏ" விட்டமின் பதார்த்தமும் அதன் முன்மூலப் பொருளான β- கறற்றீன் பதார்த்தமும் அறுதியிடப்பட்டுள்ளன. சமைக்காத உணவு மாதிரிகளின் உண்ணத்தகு பகுதி ஆய்வுக்கு உட்படுத்தப்பட்டுள்ளது. விட்டமின் A யினதும் β - கற்றீனதும் செறிவுகள் தாபிக்கப் பெற்ற முறைகளின் வண்ணம் நிறமாலை ஒளிமானியின் உதவியைக் கொண்டு வண்ண ஒளிகாலல், உட்கோடல் என்பவற்றின் மூலம் தீர்மானிக்கப் பெற்றுள்ளன.

மீன் ஈரலிலும் மாட்டு ஈரலிலும் விட்டமின் "ஏ"- மிகுந்த செறிவுடன் காணப்படுகின்றது. இலங்கையில் அன்றாட உணவு அருந்துவோருக்குப் போதிய அளவில் விட்டமின் "ஏ"- கொடுத்துதவும் வகையில், முட்டை, பால் ஆகியவற்றைத் தவிர, ஏனைய அன்றாட உணவுகள் அமைவனவன்று. கடும் பச்சை நிறமுடைய இலைமரக்கறி உணவுகளில் β - கறற்றீன 61.0-99.5 வரை அமைந்திருப்பதுடன் ஏனைய மரக்கறி, பழங்களை விட இரண்டு முதல் மூன்று மடங்குவரை அதிகமாகவும் இருக்கிறது. அன்றாட உணவுத் தேவையான விட்டமின் "ஏ" பதார்த்தத்தின் பெரும் பகுதியை β - கறற்றீன் செறிந்துள்ள பச்சை நிற இலைமரக்கறி உணவுகளை அருந்துவதனுல் பெற்றுக் கொள்ளலாம்.

7. கிராசிலாரியா ஏதுலிஸ் - கடற்கோரை பற்றிய ஆய்வுகள் பரீட்சார்த்தகளப் பயிரிடுகையும் அகார் விளைச்சல், பண்புநலப் பெருக்குவழிகளும்

ஏ. சிவபாலன், கே. தெய்வேந்திரராசா,
தாவரவியற் பகுதி,
யாழ்ப்பாணப் பல்கலைக்கழகம்
யாழ்ப்பாணம், சிறி லங்கா.

J. Natn. Sci. Coun. Sri Lanka 1985 **13**(2): 197 – 212

கிராசிலாரியா ஏதுலிஸ் - என்னும் கடற் கோரை அகார் உற்பத்திக்கு ஏற்றதோர் மூலமாகத் திகழுமென்பதை, இலங்கையில் பொதுவாகக் கிடைக்கும் ஐந்து செந்நிற அல்காக்களிலிருந்து பிரித்தெடுக்கப் பெற்ற பைகோ கொலொய்ட்டுக்களின் மீது மேற்கொள்ளப் பெற்ற தொடக்கநிலை நுண்ணாய்வுகள் காண்பித்துள்ளன. மேற்கூறியதும் இந்தக் கோரை எங்கும் மலிந்திருப்பதும் அக்கடற் கோரையின் பயிரிடுகை, அதிலிருந்து அகாரைப் பிரித்தெடுப்பு ஆகியவைபற்றி மேலும் ஆய்வு செய்வதற்கு எம்மை ஊக்கு வித்தன.

பயிரிடல் விதைப் பொருளாக இந்தக் கோரைத் தாவரத்தின் மேல்நூதியிலிருந்து எடுக்கப் பெற்ற வளர்சக்தி கொண்ட துணுக்குகள் பயன்படுத்தப்பட்டன. 1982 ஒக்டோபர் மாதம் முதல் 1983 யூன் மாதம் வரை அல்காப் பயிரிடல் இடம் பெற்றதுடன் அந்தந்த மாதங்களில் சேகரிக்கப் பெற்ற அல்காக்களைப் பயன்படுத்தி மாதாந்தப் பரிசோதனை யொன்றும் மேற்கொள்ளப்பட்டது. ஏறக்குறைய 2 1/2 முதல் 3 மாதங்களில் அல்காத் தாவரம் முழுவளர்ச்சி யடைந்தது. அதன் நீளம் 30-35 செ.மீற்றர்வரையிருந்தது. பச்சை எடையும் உலர் எடையும், முறையே, 20-30 கிராம்களாகவும் 1.5-2.5 கிராம்களாகவும் அமைந்திருந்தன.

பயிரிடப் பெற்ற ஜீ. ஏதுலிஸ் கடற் கோரையிலிருந்து பிரித்தெடுக்கப் பெற்ற அகார் பொருளின் அடக்கமும் அகாரின் ஜெலற்றீன் வன்மையும் துணியப் பெற்றுள்ளன. அல்காத் தாவரத்தின் வளர்ச்சிக்கேற்ப அகார் உள்ளடக்கம் அதிகரித்ததெனினும் ஜெலற்றீன் வன்மை சார் வித்தியாசம் எதுவும் தென்படவில்லை. இத்தரவுகள் இயற்கைச் சூழலில் வளரும் ஜீ. ஏதுலிஸ் தாவரத்தின் தரவுகளுடன் முற்றுகவே ஒத்திருந்தன.

இயற்கைச் சூழலில் வளரும் ஜீ. ஏதுலிஸ் தாவரத்தின் விளைச்சல், ஜெல் வன்மை அறிதற்கியன்ற பல்வேறு முன் தொழிற்படவிடல் பரிசோதனைகளின் விளைவுகள் ஆராயப் பெற்றுள்ளன. அகாரின் விளைச்சலும் ஜெல் வன்மையும் முன் ஈர அரைத்தலால் அதிகரித்ததெனினும் முன் ஊறவைப்பு காரணமாக அகார் அதிகரிப்பு எதுவும் ஏற்படவில்லை. அழுத்தத்தின் கீழ் பெறப்பெற்ற விளைவுப் பொருளின் விளைச்சல் வீதமும் ஜெல் வன்மையும் அதிகமாகவே காணப்பட்டது.

இக்கடற் பாசி முன்காரத்தொழிற்பட விடலுக்கு உட்படுத்தப் பட்டபோது ஜெல் வன்மை அதிகரித்தது. அதுவும் 4 சதவீத செறிவு வரை kcl தொழிற்படவிடலுக்கு உட்படுத்தப்பட்ட போது ஜெல் வன்மை குறிப்பிடத் தக்க அளவில் அதிகரித்தது.

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8. இலங்கையின் திருகோணமலை விடர் முகடுகளின் சுற்றுப் புறத்துப் புவிச்சரிதவியல் பின்னணி.

என்.பீ. விஜயானந்தா,
பெருங்கடலியல் கூறு, தேசிய நீர்வள முகமை,
கொழும்பு-15, சிறிலங்கா.

J. Natn. Sci. Coun. Sri Lanka 1985 **13**(2): 213 – 226

இது திருகோணமலை விடர்முகடுகளை அடுத்துள்ள நிலப்பகுதி எங்ஙனம் உருவான தென்பதைத் துணிந்து கூறுதற்கு அந்நிலப் பகுதியின் அகல் விரிவான நிலப்படமொன்றை வரைதற்கு மேற்கொண்ட முயற்சி ஆகும். இந்த விடர் மகாவலி ஆற்றின் கத்தரிப்பு வலயத்துடன் ஒருநிலைப்பாட்டில் அமைந்துள்ளது. நாட்டுப் பாறைகளுக்குப் பொதுவான படுகைக் கிடைமட்டவரைக்குச் சமமான போக்கு இதற்கு உள்ளது. அத்துடன் திருகோணமலை உள்துறைமுகத்தில் முகடு ஒன்றும் கோட்டியார் வளைகுடாவில் முகடுகள் இரண்டுமாக அதற்கு மூன்று முகடுகள் உள்ளன. உள்துறைமுகத்தில் அமைந்த முகடும் வளைகுடாவின் தென்கிழக்குப் பகுதியில் அமைந்த முகடும்

ஒருபோது முறிவு வலயமொன்றைப் பின் பற்றுவதாக இருக்கலாம். மகாவலி கங்கை ஆருனது இரண்டு பெரிய முகடுகளும் கோட்டியார் வலீகுடாவிலுள்ள உப-முகடுகளும் உருப்பெறுதற்குத் துணை புரிந்திருக்கலாம். இவ் விடர் முகடுகளின் அமைப்பானது இந் நிலப்பகுதியின் புவியியல் கட்டுப் பாட்டுக்குள் இயங்கிவருமென்பதை இந் நில அளவை காட்டுகின்றது.

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9. இலங்கையில் (வளர்முக நாட்டில்) பல் தொற்றுத் தூய உறுப்பீயிரிகளின் ஊனீர் இடைப்பட்ட உயிரெதிரித் தடைத்திறன் வீழ்தகவு.

ரீ. விஞ்ஞகமூர்த்தி,
நுண்ணுரியல் கூறு, தாவரவியற் பகுதி,
யாழ்ப்பாணப் பல்கலைக்கழகம்,
யாழ்ப்பாணம், சிறிலங்கா.

J. Natn. Sci. Coun. Sri Lanka 1985 **13**(2): 227 – 234

பல் தொற்றுநோய் சார் 55 தூய உறுப்புயிரிகளுட் பெரும்பாலானவை குடல் சார்பினங்களாகவே அமைந்திருந்தன. மேலும், இவற்றுள் 90 வீதத்திற்கு அதிகமானவை பன் ஒளடதத்தடைத்திறன் கொண்டனவாகத் தென்பட்டன. எனினும், மாறற்றகவுடைய தடைத்திறன் கொண்ட தூய உறுப்புயிரிகளின் வீழ்தகவு மிகக் குறைவான(2%) தாகும். எனவே, இதே பாங்கான உயிரெதிரித் தடைத்திறனையும் மாறற்றகவினையும் கொண்ட மாசுபட்ட நீர் இக் காரணவுறுப்புயிரிகளின் தோற்றுவாயாக இருக்கலாமென ஊகிக்கப்படுகிறது. கன்னக்குழிவில் உண்டாகும் அத்தகைய சார்பினங்களின் வீழ்தகவு மூக்குத் தொண்டைக்குழாயில் உள்ள ஏனைய கூருணர்வுடைய சார்பினங்களுக்கும் இத் தடைத்திறன் பரவுகையைத் தூண்டி விடலாம்.

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10. இனிப்புப் பொருள்நீரான ஈமொகுளோபின் மதிப்பீட்டுக்கு நிறமானிச் செயல்முறைப் பெறுமானங்காணலும் சான்றுதரவுப் பெறுமானங்கள் நிலைநாட்டுகையும்.

எ.எச். கருணதாயக்கா, என்.வீ. சந்திரசேகரன்,
இரசயானவியற்றுறை, மருத்துவ பீடம்,
கொழும்பு பல்கலைக் கழகம்
கொழும்பு.

J. Natn. Sci. Coun. Sri Lanka 1985 **13**(2): 235 – 258

நீரிழிவு நோயாளர்களது முதற்கட்டத்து நான்கு முதல் ஆறுமாதங்களில் அனுசேபக் கட்டுப் பாட்டினைக் காட்டுகின்ற ஓர் கணியச்சுட்டி என்ற வகையில் இனிப்புப் பொருள்நீரான ஈமோகுளோபின் அளவீடு இப்பொழுது முக்கிய நிலை அடைந்துள்ளது. வளர்முக நாடுகளில் இவ்வளவீட்டிற்கு அமைத்துக்கொள்ளக் கூடிய ஒரு தொழினுட்பமாக பிளுக்கிகோர், வின்றேர்கோல்றேர் நிறமானிமுறையின் ஏற்கத் தகவிற்கு இங்கு பெறுமானங் கண்டுள்ளோம். ஒட்சாலிக்கமிலத்தில் ஒரு மணி நேரம் நுண்மப் பெருக்கஞ் செய்த விடத்து 3.19 (n-20) பண்புத் தேரவெல்லைக் குள்ளாகவும் இயல்நிலையாளர் பொறுத்தவரை 2.8% (n-15) பண்புத் தேர்வுக்கும் நீரிழிவு

நோயாளர் பொறுத்தவரை 1.8% பண்புத் தேர்வுக்குமிடையிலும் அமைந்த மாறல் குணகத்துடன் சிறந்த துல்லியம் இருப்பது காணப்பட்டது. இப் பரீட்சையின் கட்டளைகளாக β-D புருக்டோசும் 5- ஐதரொட்சி மெதில் புர்புருல்த்தி கைட்டும் (Furfuraldehide) HMF பயன்படுத்தப்பட்டன. இதன்வழி எதிரியக்கத்தின் தகைத்திறம் பெறப்படலாம். எல்லா மாதிரிகளையும் பொறுத்தவரை விசேட மற்ற வெற்றுப் பெறுமானம் மாறுதிருந்தது. முழுக் குருதி மாதிரிகள் வீட்டறை வெப்பநிலையில் (30 ± 3°c) ஐந்து நாள் வரையும் 4° c வெப்பநிலையில் ஒன்பது நாள்வரையும் சேமித்து வைக்கப்பட முடிந்தன. குருதி நீர்மங்கள் 4°c வெப்பநிலையில் ஐந்து நாள்வரையும் - 20° c வெப்பநிலையில் 30 நாள்வரையும் மாற்றமுருமல் இருந்தன. நுண்நிரல் சோதனைத் தொகுதி (n - 20, P 0.001) யைக்கொண்டு r < 0.92 சிறந்த தொடர்வு படுத்துகைக் குணகம் பெறப்படலாயிற்று. இனிப்புப்பொருள் நீரான ஈமோகுளோபின் (H b A ₁) சார்ந்த செவ்வன்னிடை (± SD) இலங்கையின் ஆண்கள் (n = 70)விடயத்தில் 5.85% ± 0.79 ஆகவும் பெண்கள் (n = 30) விடயத்தில் 5.88% ± 0.79 ஆகவும் இருப்பது காணப் பெற்றது. ஆண்களுக்கும் பெண்களுக்குமிடையில் குறிப்பிடத்தக்க வித்தியாசம் அவதானிக்கப் படவில்லை. இயல்நிலையாளர்களுக்குரிய முழுதும் அளாவிய இடை 5.9% ± 0.79% (அல்லது 0.39 ± 0.05 µM HMF/g Hb) ஆகும் இன்சூலின் தேவைப்படாத நீரிழிவு நோயாளர்களுக்குரிய இடை 10.83 ± 3% (அல்லது 0.68 ± 0.20 um HMF/g Hb)ஆகும். கருத்தரித்த மூன்று மாதங்களில் இருந்த கருப்பவதிகளுக்குரிய (N = 15)% HbA இடையானது 7.0 ± 0.7%) ஆகும். நிறமானிமுறை முழுநிறை நலங் கொண்ட ஆய்வுகூட பரீட்சைக்கு வேண்டிய அளவைக் கட்டளைகளுள் பலவற்றை பூர்த்தி செய்கிறது. அது வளர்முக நாடுகளில் இனிப்புப் பொருள் நீரான ஈமோகுளோபின் அளந்தறிதற்கு மிகச் சிறந்த முறையெனத் தோன்றுகிறது.

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11. உருக்கலுற்ற பொற்ருசியம் தியோசயனேற்றின் புதியதோர் இலெத்திரன் கறைசலுறல் இயற்காட்சி.

கே. தென்னகோன்
பௌதிகவியற் பகுதி, உருகுணைப் பல்கலைக்கழகம்,
மாத்தறை, சிறிலங்கா.

J. Natn. Sci. Coun. Sri Lanka 1985 **13**(2): 259 266

பொற்ருசியம் தியோசயனேற்று உருகுநிலைக்கு மேல் சூடாக்கப்பெறின் அதிகரிக்கும் வெப்பநிலைக்கேற்பச் செறிவடைகின்ற ஒளிமயமான நீலநிறம் எடுக்குமென்பது கண்டறியப்பட்டுள்ளது. இவ்வியற் காட்சியானது கரைசலுற்ற இலெத்திரன்களின் வெப்பப் பிறப்பாக்கல் காரணமாக ஏற்படுகிற தென்பதை ஒளியுறிஞ்சல் நிறமாலைகளும் இலத்திரன் கடத்தி அளவுகளும் சுட்டிக்காட்டுகின்றன. இந்தக் கண்டு பிடிப்புகளைத் தொடர்புப்படுத்துவதற்கு எளிய கோட்பாடொன்று சமர்ப்பிக்கப்பட்டுள்ளது.

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