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Carbohydrate Constituents of the Marine Algae of Sri Lanka Part II. Composition and Sequence of Uronate Residues in Alginates from some Brown Seaweeds

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(*Date of receipt: 22 March 1983*)
(*Date of acceptance: 14 August 1984*)

Abstract: The ratio of mannuronic acid residues to guluronic acid residues (M/G ratio) of sodium alginate extracted from *Cystoseira trinodis*, *Turbinaria conoides* and *Sargassum* sp. was determined using high resolution ^{1}H-NMR spectroscopy. The intensities of the signals due to H-5 of guluronate residues and H-1 of both guluronate and mannuronate residues were used. The alginate samples were found to be rich in guluronate residues, and the polymer chains are likely to be composed of long blocks of guluronate residues, short blocks of mannuronate residues and a small proportion of blocks containing both uronide residues.

1. Introduction

Alginic acid is a mucilaginous polysaccharide which has been found in all species of brown seaweeds examined, but is not present in any other plant tissue.[9] The polysaccharide is a linear glycuronan which consists of (1→4)-linked residues of D-mannuronic acid and *L*- guluronic acid arranged in a block fashion in the polymer chain. Blocks containing one type of residue (MM blocks and GG blocks) are separated by segments in which the two residues alternate (Figure 1).[5,6,7] Physical properties of alginates depend on its uronic acid composition, i.e. the ratio of mannuronic acid residues to guluronic acid residues (M/G ratio), and also upon the relative proportion of the three types of blocks (MM, GG and MG). Both the M/G ratio and the monomer sequence distribution changes from one species of brown alga to another.

Penman and Sanderson[8] found that ^{1}H-NMR spectroscopy could be used to distinguish between signals due to H-1 and H-5 in the guluronic acid residues and H-1 from mannuronic acid residues in homopolymeric blocks obtained by partial hydrolysis of alginates. Grasdalen *et al*[2] using high resolution ^{1}H-NMR spectroscopy were able to distinguish between H-5 of guluronic acid residues with a mannuronic acid neighbour (GM sequence) from those with a guluronic acid neighbour (GG sequence). In this paper we describe the results obtained using this method, in analysing alginate samples isolated from four species of brown seaweeds collected from the coastal regions of Sri Lanka.

2. Results and Discussion

The ^{1}H-NMR spectra of the partially depolymerised alginate samples were interpreted using the method described by Grasdalen *et al.*[2] The intensities of (i) the doublet centred at 5.1 ppm due to the H-1 of the G-residues (I_A) (see Figure 2), (ii) the singlet at 4.7 ppm due to H-1 of the M-residues and H-5 of GM residues. (I_B) and (iii) the singlet at 4.5 ppm due to H-5 of GG residues (I_C) were measured. The M/G ratios as well as the doublet frequencies were calculated and are given in Table 1 for the alginates from the four species of brown algae examined by us.

The ^{1}H-NMR spectra of the samples from *Turbinaria conoides* and *Sargassum* sp. (oval) were re-run and amplified. In these two samples the intensities of the signals A, B and C were also obtained by planimetry. These values were found to be different and are considered to be more accurate than those obtained by integration. They were also found to agree with preliminary results obtained from ^{13}C-NMR spectroscopy[3,4] where intensities of the signals were calculated by planimetry (see Table 1).

TABLE 1. Composition of Alginates

Seaweed		*Composition*		*Doublet frequency*				*M/G ratio*
		F_M	F_G	F_{MM}	F_{MG}	F_{GM}	F_{GG}	
1. Cystoseira trinodis	a	0.19	0.81	0.05	0.14	0.14	0.67	0.23
2. Turbinaria conoides	a	0.35	0.65	0.28	0.07	0.07	0.58	0.54
	b	0.24	0.76	0.13	0.11	0.11	0.64	0.32
	c	0.25	0.75	0.19	0.06	0.06	0.69	0.33
3. Sargassum sp. (linear)	a	0.35	0.65	0.29	0.06	0.06	0.59	0.54
4. Sargassum sp. (oval)	a	0.26	0.74	0.20	0.06	0.06	0.68	0.35
	b	0.33	0.67	0.25	0.08	0.08	0.59	0.49
	c	0.34	0.66	0.27	0.07	0.07	0.59	0.52

a ^{1}H-NMR, int. by integration

b ^{1}H-NMR, int. by planimetry

c ^{13}C-NMR, int. by planimetry

The results indicate that all four alginate samples are rich in guluronic acid residues, and the doublet frequencies give an idea of the block character of each alginate. Therefore these four samples of sodium alginate probably contain long blocks of G, shorter blocks of M and very little alternate MG and GM blocks.

3. Methods/Experimental

Sodium alginate was isolated from four species of brown seaweeds *Cystoseira trinodis, Turbinaria conoides* and two unidentified species of *Sargassum* referred to as *Sargassum* sp. (linear) and *Sargassum* sp. (oval) with respect to the shape of their fronds. These seaweeds were washed, sundried and milled. Samples of seaweed (50 g) were extracted successively as follows (i) twice with 2% $CaCl_2$ solution (300 ml) at room temperature for 4h; (ii) twice with 2% $CaCl_2$ solution (300 ml) at 70° C for 4 h; (iii) four times with dil. HCl (300 ml, pH 2) at 70°C for 4h; (iv) five times with 3% Na_2CO_3 solution (300 ml) at 50° C for 4h. The combined Na_2CO_3 extract was poured with stirring into ethanol (6 l). The precipitate was filtered, dried, dissolved in water and stirred with 2% $CaCl_2$ solution until precipitation was complete. The calcium alginate was suspended in 0.5 M HCl, stirred occasionally for 3h and filtered. The filtrate was tested for Ca^{++} ions. The residue was washed with 0.5 M HCl until the filtrate was free of Ca^{++} ions. The alginic acid was suspended in water and titrated with 0.1M NaOH until the pH reached 7, when all the alginic acid was dissolved. The solution was dialysed for two days and then freeze dried to give a white powder. The M/G ratio and monomer sequence distribution of each sample were determined by PMR spectroscopy (t ~ 6 secs). The spectra were recorded at 90° C in order to increase the spectral resolution and to shift the solvent peak upfield away from the low field spectral region. ^{1}H-Chemical shifts were expressed in ppm downfield from the internal standard sodium 3-(trimethylsilyl) propane sulphonate. The area under each peak in the low field region was found by integration, and in two cases by planimetry.

3.1 Calculation

The M/G ratios and the doublet frequencies were calculated as follows. Quantitatively the mole fraction of G(F_G) and the doublet frequency (F_{GG}) are related to the intensities (I) of the respective lines by the following relationships.

$$F_G = \frac{I_A}{I_B + I_C}, \qquad F_{GG} = \frac{I_C}{I_B + I_C}$$

The mole fraction of M is derived from the normalization condition

$$F_G + F_M = 1$$

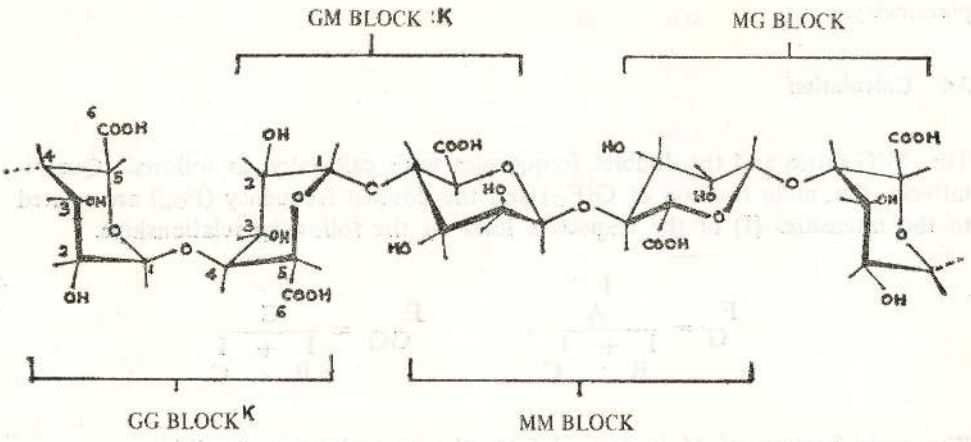

FIGURE 1 — Structure of Alginic Acid showing the block character of the Uronic Acid Residues.

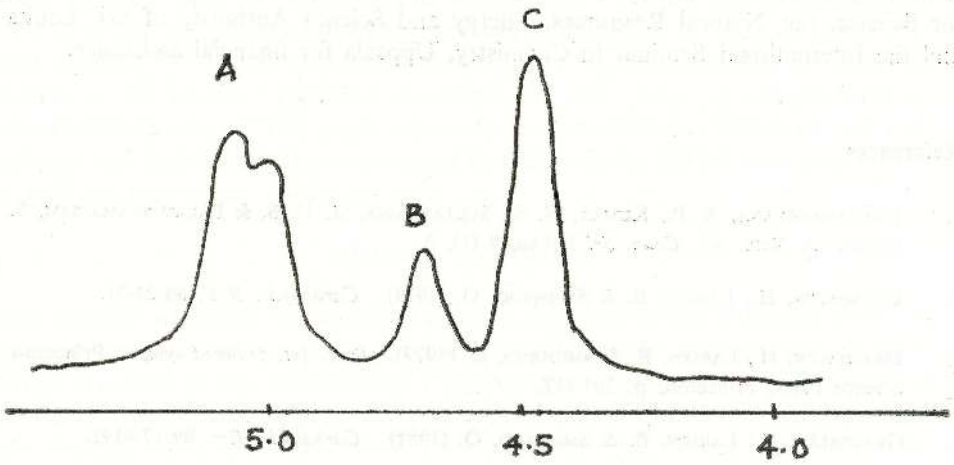

FIGURE 2 — The Low Field Region of the 99.6 MHz FT — ^{1}H-N.m.r. Spectrum of a Partially Depolymerized Alginate Rich in Guluronic Acid Residues.
A = H—1 of G Residues
B = H—1 of M Residues+H—5 of GM Residues
C = H—5 of GG Residues

The relationship between the doublet frequencies and the mole fractions are given by

$$F_{GG} + F_{GM} = F_G \text{ and } F_{MM} + F_{MG} = F_M$$

For long chains where the average degree of polymerization, $\bar{d}p_n > 20$, corrections for the reducing end residues may be neglected so that,

$$F_{MG} = F_{GM}$$

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Spectrophotometric End Point Assay for Serum Cystyl Amino Peptidase

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(*Date of receipt: 14 March 1984*)
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Abstract: A spectrophotometric end point assay for serum cystyl amino peptidase (CAS) activity was established in this laboratory. The within batch and between batch reproducibility of the method was good, the maximum coefficient of variation being 2.1% and 3.0% respectively. The enzyme was found to be stable at 8°C there being no loss of activity over a period of 21 days storage at this temperature. The enzyme was found to be inhibited by 5 mM EDTA.

1. Introduction

Cystyl-aminopeptidase (CAS) is an enzyme produced by the placenta that degrades cystine peptides such as oxytocin and vasopressin. During normal pregnancy, serum CAS activity progressively increases and its level can be used to assess placental function.[2,3] It was decided to establish this useful parameter of placental function in Sri Lanka. Durham[1] described an end point spectrophotometric method for CAS assay. This paper reports the reproducibility of this assay method. Studies on the stability of the enzyme and its inhibition by EDTA were also carried out and the results are published here.

2. Materials and Methods

Blood samples are taken from women on their first visit to the antenatal clinic, to screen for venereal disease. A small aliquot (approximately 1.0 ml) of each of these samples was sent to the Biochemistry Department of the Faculty of Medicine for CAS assay. Some samples, especially those taken in the latter half of pregnancy, were obtained from in-patients of an obstetric ward. All women included in the study were normal and showed no evidence of any complications such as pre-eclamptic toxaemia or essential hypertension. Subjects who were 'small for dates' were excluded from the study; those with abnormal presentations were, however, included.

Blood samples were allowed to clot and the serum separated after centrifugation in a clinical centrifuge at 1000 rpm and stored at 8°C in the refrigerator. The assay was carried out within 24 hrs of sample collection. The assay was carried out in duplicate at a pH of 7.4 according to the method of Durham.[1] A mixture of 50 μl of serum and 1.75 ml of phosphate buffer, 0.1 mol/litre, pH 7.4

was allowed to equilibrate to a temperature of 37°C. The reaction was initiated by addition of 0.2 ml of the substrate (S benzyl-L-cysteine-4 nitroanilide, 6 m·mol/litre in acetone/methanol, 10/90 by vol.). The contents of the tubes was mixed on a votary mixer and incubated at 37°C for 20 min. The reaction was stopped by the addition of 1 ml of the protein precipitant — 10% trichloroacetic acid (TCA). The tubes were mixed and centrifuged at 3000 rpm for 5 min. The absorbance at 400 nm was measured in a Unicam SP 800 spectrophotometer against the reagent blank consisting of 2 ml of buffer pH 7.4 and 1 ml of TCA. The activity in U/litre was read from the calibration curve obtained by diluting the working standard of 4 nitro aniline (1 m.mol/litre) with buffer pH 7.4 and TCA in the proportions shown in Table 1. (1 unit of enzyme activity produces 1 μmol of product,4 nitro-aniline, per min at 37°C).

TABLE 1. Protocol for preparation of Calibration Curve

	CAS activity U/litre			
Reagent	*Blank*	*100*	*200*	*400*
Working standard, ml	0	0.25	0.5	1.0
Phosphate buffer pH 7.4, ml	5	4.75	4.5	4.0
Trichloroacetic acid, ml	2.5	2.5	2.5	2.5
Mix and read absorbance at 400 nm.				

The standard curve was prepared by diluting the working standard of 4 nitroaniline (1 mmol/L) with buffer pH 7.4 and TCA in the proportions shown. 1 μ of enzyme activity produces 1 μmmol of product per min at 37° C.

2.1 Reproducibility of Assay

The within batch reproducibility of the assay was tested by assaying in duplicate, 5 or 6 replicate samples. The between batch reproducibility of the assay was ascertained by testing aliquots of the serum stored at -20°C on 5 separate days.

2.2 Stability of the enzyme

A chance observation led to the study of the stability of the enzyme at 8°C. Aliquots of serum stored at 8°C were tested at intervals up to 21 days after collection.

2.3 Inhibition by ethylene diaminetetra acetate (disodium salt)-EDTA

As most peptidase enzymes have been shown to be metallo proteins, it was decided to investigate the metal ion requirement of this enzyme. A preliminary step would be to study the effect of a chelating agent such as EDTA. Hence the effect of EDTA was tested by comparing the enzyme activity in the presence of and in the absence of EDTA. This was added to the buffer so that the final concentration in the assay mixture was 5 mM/L.

3. Results and Discussion

Table 2 gives the within batch and between batch reproducibility of the assay. It can be seen that the method is highly reproducible as the maximum coefficient of variation observed within a batch was 2.1% and between batches was 3.0%. These figures are comparable to those observed by Durham.[1]

TABLE 2. Reproducibility of the Assay

MeanU/litre	*S.D.*	*C.V.* %	*Number of observations**
	Within batch		
435.3	3.0	0.7	6
356.4	7.4	2.1	5
228.6	4.2	1.8	5
255.3	5.0	2.0	6
	Between Batch		
231.0	6.7	2.9	5
257.0	7.5	2.9	5
431.6	12.8	3.0	5
361.8	7.0	1.9	5

*Each observation is the mean of duplicate values.

The within batch reproducibility of the assay was tested by assaying in duplicate, 5 or 6 replicate samples. The between batch reproducibility of the assay was ascertained by testing aliquots of the serum stored at –20° C on 5 separate days.

Table 3 shows the effect of storage of the enzyme at 8°C up to a period of 21 days. The differences in activity on storage were compatible with the between batch variation of the assay. In one instance the C.V. was 6.8% but the number of observations was small (3) and the enzyme activity was greater on day 21

compared with day O. Hence it can be concluded that the enzyme is remarkably stable at this temperature, thus allowing serum samples to be conveniently stored at this temperature rather than at -20°C, while awaiting assay. This feature of serum CAS activity has not been previously reported.

TABLE 3. Stability of the Enzyme at 8°C

Sample	*Activity U/L on Day O*	*Activity U/L on Day (n)*	*Mean**	*S.D.**	*C.V.**
1	121	116(2)	—	—	—
2	355	370(4)	360.7	8.1	2.3
		357(9)			
3	223	233(3)	231.2	6.0	2.6
		233(5)			
		228(8)			
		239(9)			
4	209	238(19)	226.7	15.5	6.8

* These were calculated on the basis that storage had no significant effect on enzyme activity.

Aliquots of serum stored at 8°C were tested at intervals up to 21 days after collection.

TABLE 4. Effect of 5mM EDTA

Activity U/L		*% Inhibition by EDTA*
No EDTA	*5mM EDTA*	
238	91	61.8
491	150	69.5
362	136	62.5

The effect of 5mM EDTA on enzyme activity was ascertained.

Table 4 shows the effect of 5mM EDTA. This inhibited enzyme activity to the extent of 60% - 70%. This suggests that the enzyme has a metal ion cofactor requirement and this aspect is being currently investigated. This aspect of CAS activity has not been previously reported.

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Preliminary Studies on the Iodine Content of some Marine Algae from Coastal Areas of Jaffna Peninsula

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Abstract: The iodine content of twenty seven species of marine algae collected from different coastal regions of the Jaffna Peninsula was determined. Of the species analysed, *Gracilaria opuntia* (1277 ppm), *Gracilaria crassa* (889 ppm) and *Turbinaria ornata* (810 ppm) have relatively high iodine contents. The iodine content of *Gracilaria opuntia* is comparable with the amount of iodine present in caliche deposits (1500 ppm) in northern Chile which is the principal source of iodine.

1. Introduction

Iodine is considered[9] as one of the essential elements for the proper functioning of the hormones of human and animal thyroid glands. In many parts of the world simple goitre develops because of deficiency of iodine in water or food supply. An iodine deficient goitrous mother may give birth to a cretinous baby[9] because the foetus requires an adequate secretion of thyroxine during the later stages of pregnancy. Thyroxine is formed[9] by the reaction of tyrosine with iodine.

To prevent simple goitre a dietary iodine intake of 100 - 200 μg daily[9] is required. In places where manioc is used as a part of the diet the daily intake of iodine should be greater than the normal requirement. It is believed that cyanide in the manioc is converted to thiocyanate in the body which apparently displaces iodide from the reaction site. All iodine is converted to iodide in the gut.[9] Normally iodine is supplied from water.

In some places iodine content of water may not be enough to meet daily requirement of iodine. Seaweeds are good sources to meet dietary requirements of iodine. Goitre disease caused by iodine deficiency is less prevalent in countries where marine algae form a part of the diet.[1,7]

The iodine has wide and varied uses and is of high demand. Attempts are being made by various workers and companies to extract iodine from various natural sources. Caliche deposits in northern Chile are the principal sources for the production of iodine.[1] In Japan, Norway, France and Russia, iodine is extracted in small amounts from seaweeds.[6,8] Valuable data on the iodine content of marine algae occurring in different parts of the world are available.[3,5] But information on the iodine contents of the species of algae from Sri Lankan coastal area is not available. Therefore as an initial study, the amounts of iodine present in twenty seven species of green, brown and red algae collected from Jaffna coastal areas were estimated.

2. Experimental Methods and Materials

The localities and habitats of the algae studied are given in Table 1. The freshly collected seaweed samples were washed free from extraneous matter and air dried at room temperature under fans. The air dried samples (30 - 50 g), weighed accurately, were dried in an oven at 110°C to constant weight and the moisture contents determined. The oven dried samples were ground and the iodine contents were estimated by the alcoholic potash method[2] as follows:

Accurately weighed powdered samples (5 - 10 g) were refluxed with alcoholic potash (10%, 30 - 60 ml) for 24 hours, evaporated and ashed at 500°C. The water extract of the ash was acidified, oxidised with bromide and titrated with standard sodium-thiosulphate.

3. Results and Discussion

The results of analysis (carried out in triplicate) are given in Table 2. This table also gives the corresponding values for unwashed samples for a few species.

The above results show that of those species investigated, *Gracilaria opuntia*, *Gracilaria crassa* and *Turbinaria ornata* have reasonable amounts of iodine. To prevent simple goitre a dietary iodine intake of 100 - 200μ g daily is sufficient. Therefore a vegetarian can easily get the required amount of iodine from properly processed marine algae.

The most important natural source, caliche deposits, found in Northern Chile which exports iodine to all parts of the world contains 0.15% (1500 ppm) of iodine[1], *Gracilaria opuntia* has comparable amount of iodine (1277 ppm), *Gracilaria crassa* (889 ppm) and *Turbinaria ornata* (810 ppm) also have fairly large amounts of iodine. These three species would prove to be of commercial value.

Out of the three areas investigated marine algae from Mandaitivu coastal area have more iodine. It is significant that the sea water from this area has more iodine compared to the other two areas (Table 3). The iodine contents of *Ulva lactuca*, *Codium* species and *Sargassum* species are nearly the same as those reported[3] for the same species from the Gujarat coast of India (Table 4).

4. Conclusion

The amount of iodine present in certain species (e.g. *Gracilaria opuntia*, *Gracilaria crassa*, *Turbinaria ornata*) of marine algae from coastal areas in the Jaffna Peninsula is comparable with the most important natural source, caliche deposits. These seaweeds could be exploited for the commercial extraction of iodine. Several other species have reasonable amounts of iodine and these could be used in the manufacture of fortified cattle feed and for preparation of high iodine food items for human consumption.

TABLE 1. Localities and Habitats of the algae

	Species	*Locality*	*Habitat*
1.	Gracilaria opuntia	Mandaitivu	Muddy lagoons
2.	Gracilaria edulis	Mandaitivu	Protected inshore lagoons
3.	Gracilaria crassa	Mandaitivu	Lagoon, erect tree like
4.	Gracilaria confervoides	Keerimalai	Calcareous reef
5.	Laurencia obtusa	Mandaitivu	Lagoon, attached by small discs
6.	Jania natalensis	Mandaitivu	Lagoon, attached
7.	Hypnea musciformis	Mandaitivu	Protected inshore lagoon
8.	Acanthophora delile	Mandaitivu	Lagoon
9.	Centroceras clavulatum	Mandaitivu	Lagoon, attached
10.	Gelidiella acerosa	Mandaitivu	Lagoon, erect prostrate
11.	Padina pavonica	Mandaitivu	Lagoon, attached
12.	Turbinaria ornata	Mandaitivu	Lagoon, attached
13.	Pocockiella variegata	Nainativu	Inshore waters
14.	Stoechospermum marginatum	Mandaitivu	Lagoon, attached
15.	Cystophyllum muricatum	Mandaitivu	Lagoon, attached
16.	Dictyota species	Mandaitivu	Lagoon, attached
17.	Sargassum tenerrimum	Mandaitivu	Lagoon, attached
18.	Sargassum polycystum	Mandaitivu	Lagoon, attached
19.	Hormophysa triquetra	Mandaitivu	Lagoon, attached
20.	Struvea anastamosans	Mandaitivu	Lagoon, attached
21.	Codium species	Nainativu	Inshore waters, floating
22.	Acetabularia crenulata	Casuarina	Protected inshore waters, attached.
23.	Chaetomorpha species	Mandaitivu	Lagoon, floating
24.	Ulva reticulata	Mandaitivu	Lagoon grows intermingled with other algae
25.	Ulva lactuca	Mandaitivu	Lagoon
26.	Valoniopsis pachynema	Mandaitivu	Lagoon
27.	Thalasia hemprichi	Mandaitivu	Coral lagoon, rooted

TABLE 2. Iodine contents of Marine Algae

Algae	*Locality*	*Date of collection*	*Moisture in the air-dried algae (%) (washed)*	*Iodine (ppm) i.e. mg of iodine/kg air-dried algae*	
				Washed	*Unwashed*
a) Family: Rhodophyceae					
01. Gracilaria opuntia	Mandaitivu	10.12.1982	24.4	1277	
02. Gracilaria edulis	Mandaitivu	10.12.1982	3.7	318	
	Nainativu	01.01.1983	13.9	134	147
03. Gracilaria crassa	Mandaitivu	10.12.1982	13.3	889	
04. Gracilaria confervoides	Keerimalai	13.02.1983	10.1	no detectable amount	no detectable amount
05. Laurencia obtusa	Mandaitivu	10.12.1982	15.1	421	
06. Jania natalensis	Mandaitivu	10.12.1982	3.2	101	
07. Hypnea musciformis	Mandaitivu	10.12.1982	13.5	277	
08. Acanthophora delile	Mandaitivu	13.02.1983	15.9	115	
	Keerimalai	13.02.1983	10.0	110	78
09. Centroceras clavulatum	Mandaitivu	31.12.1982	16.7	249	351
	Keerimalai	13.02.1983	8.1	133	
10. Gelidiella acerosa	Mandaitivu	31.12.1982	14.1	524	401
b) Family: Phaeophyceae					
14. Padina pavonica	Mandaitivu	10.12.1982	11.1	196	
15. Turbinaria ornata	Mandaitivu	31.12.1982	19.4	810	
13. Pocockiella variegata	Nainativu	01.01.1983	13.4	533	
14. Stoechospermum marginatum	Mandaitivu	13.02.1983	13.1	58	56
15. Cystophyllum muricatum	Mandaitivu	13.02.1983	13.8	176	
16. Dictyota sp.	Mandaitivu	13.02.1983	7.1	10	
17. Sargassum tenerrimum	Mandaitivu	10.12.1982	16.0	205	
18. Sargassum polycystum	Mandaitivu	31.12.1982	17.1	180	253
19. Hormophysa triquetra	Mandaitivu	13.02.1983	13.3	62	62
c) Family: Chlorophyceae					
20. Struvea anastamosans	Mandaitivu	31.12.1982	12.2	437	
21. Codium sp.	Nainativu	01.01.1983	16.4	46	73
22. Acetabularia crenulata	Casuarina	13.02.1983	4.7	no detectable amount	no detectable amount
23. Chaetomorpha sp.	Nainativu	01.01.1983	17.3	44	80
	Keerimalai	13.02.1983	4.5	no detectable amount	no detectable amount
	Mandaitivu	10.12.1982	17.9	119	
24. Ulva reticulata	Mandaitivu	31.12.1982	20.6	259	
	Nainativu	01.01.1983	20.9	47	24
25. Ulva lactuca	Mandaitivu	10.12.1982	12.7	21	
	Casuarina	25.12.1982	16.4	101	
	Keerimalai	13.02.1983	14.8	no detectable amount	14
26. Valoniopsis pachynema	Mandaitivu	10.12.1982	2.8	30	
d) Angiosperm					
27. Thalasia hemprichi	Mandaivitu	10.12.1982	16.4	178	
	Nainativu	01.01.1983	9.2	54	26

TABLE 3. Iodine content in sea-water samples

Locality	*Date of collection*	*Iodine (mg/litre)*
Mandaitivu	10.12.1982	0.876
Mandaitivu	11.01.1983	0.738
Keerimalai	19.01.1983	0.067
Nainativu	23.01.1983	0.054

TABLE 4. Iodine contents reported[8] of some algae from the Gujarat coast of India

Species	*Iodine contents in ppm (mg/kg)*
Ulva lactuca	19.86
Ulva rigida (C.A. Agardh)	40.94
Codium dwarkense Boergesen	50.5
Sargassum cinereum (J.Agar)	206.1
Sargassum johnstonii setch and Gard	244.6
Gracilaria folifera	151.8
Myriogloea sciuru (Harv.) Kuck	1045.00

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Mineral and Protein Contents of some Marine Algae from the Coastal Areas of Northern Sri Lanka

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Abstract: Protein and mineral contents of twenty-five species of marine algae from the coastal areas of Northern Sri Lanka are reported. Species such as *Centroceros clavulatum, Ulva lactuca, Hypnea musciformis, Acanthophora delilei* and *Gracilaria edulis* are found to have high protein content which are comparable to that in food materials such as cereals, eggs and fish. Algae such as *Gracilaria edulis, Laurencia obtusa, Sargassum polycystum, Ulva lactuca* and *Gracilaria crassa* and *Thalasia hemprichi* (angiosperm) have fairly large amounts of nitrogen, phosphorus and potassium and hence could be used as fertilizers.

1. Introduction

Marine algae and sea grasses are two of the important groups of marine plants occurring in the sea. They contain several inorganic elements and a complex mixture of organic substances synthesised from them. Due to the presence of these chemical substances marine algae find a variety of uses, some of which are briefly indicated below.

Marine algae are used [3] to prepare alginic acid and agar. Fresh dried and processed seaweeds are utilised as human food [11, 14, 15] in Japan, Indonesia, China, Philippines, India and other south east Asian countries. Seaweeds such as *Porphyra, Ulva, Chlorella, Gracilaris* and *Chondrus* are commonly used as ingredients for soups and as meat flavourings. [11, 14, 15] Countries like Japan have large industries based on edible seaweeds. The algal carbohydrates are not easily digestible and hence the food value of the seaweeds depends on the minerals, trace elements, proteins and vitamins present in them. The seaweed meal is nutritious due to its high mineral and protein content. Seaweeds are used [11, 14, 15] to stock feed sheep and cattle in maritime districts.

Seaweeds contain reasonable quantities of nitrogen, phosphorus and potassium and they are extensively used, either directly or in the form of compost with cowdung as manure for vegetables in India.[13] In seaweeds, the minerals and trace elements occur in water soluble form [13] and hence these could be easily taken up by the plants. The carbohydrates and other organic constituents of the seaweeds are reported [13] to increase the moisture holding capacity of soils. The marine algae are also a good source of potash and soda.

During certain seasons fairly large quantities of seaweeds are found in the coastal areas of the Jaffna Peninsula. In order to make the best use of these seaweeds a knowledge of their chemical composition is essential. Therefore as an initial step, a study of the mineral, protein and vitamin contents of the seaweeds found in Northern Sri Lanka was started. Our results on the estimation of the moisture, ash and protein contents and of the amounts of some inorganic elements present in twenty five species of seaweeds are given below.

2. Experimental Methods and Materials

The seaweeds were collected from Mandaitivu, Nainativu and Keerimalai, washed well and air dried for three days. The moisture contents were determined by drying them in an oven at 105°C to constant weight. The ash contents were 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 and protein content was calculated by multiplying the total nitrogen content by 6.25.

2.1. Preparation of Test Solutions

Seaweed 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 the amounts of sodium, potassium, calcium, magnesium and trace elements.

2.2. Determination of the amounts of Sodium and Potassium

Sodium and potassium were determined using a Corning Model 400 flame photometer using appropriate interference filters. The flame intensities for sodium were corrected for interference by calcium by the standard addition method. [17]

2.3. Determination of the amounts of Calcium and Magnesium

The amount of calcium present in seaweeds was determined[12] by titrating a known volume of the test solution with standard EDTA with Patton-Reeder's indicator and using potassium cyanide as the masking agent.

The amount of magnesium present in seaweeds was estimated as follows: The total amount of magnesium and calcium present was determined by titrating known volumes of test solution with standard EDTA solution with Eriochrome Black T as indicator and using potassium cyanide as masking agent.[12] The amount of magnesium is obtained by subtracting the amount of calcium present from this value.

2.4. Determination of Iron in Seaweeds

The test solution was prepared in 0.6M HCl as described above. The amount of iron present in the test solution was determined[8] by measuring the density of the colour produced by the addition of 1,10—orthophenanthroline on a Corning model 252 colorimeter using a 490nm filter.

2.5. Determination of Trace Elements

Amounts of trace elements copper, manganous, nickel, zinc, cadmium, cobalt and chromium were determined using the test solution [prepared as described above] on a Varian Model 1275 atomic absorption spectrophotometer.

2.6. Determination of the amount of Lead in Seaweeds

Samples of known weight were subjected to wet oxidation with concentrated nitric acid and concentrated sulphuric acid by the reported procedure. [10] The resulting solution was used to prepare the test solution. The amount of lead present was determined [10] using Corning Model 252 colorimeter after complexing with dithizone.

2.7. Determination of Phosphorus in Seaweeds

Dried seaweed samples [1-2g] were weighed accurately, ashed with magnesium nitrate,[6] the ash was dissolved in $2(NH_4)_2 SO_4$ (10ml) and the solution made up to 50ml. The amount of phosphorus present in this solution was determined[6] by measuring the density of the colour produced on complexing with vanadomolybdate reagent on a Corning Model 252 colorimeter using 430, 470 and 490nm filters.

2.8. Determination of Total Sulphur in Seaweeds

The amount of total sulphur in seaweeds was determined by the reported method.[6] Accurately weighed sample (1-2g) of seaweed was treated with concentrated nitric acid (10ml) and the mixture was allowed to stand overnight at room temperature. The resulting mixture was evaporated to dryness and the residue was ashed in a muffle furnace at 450° C. The ash was dissolved in a minimum volume of 25% nitric acid and the solution made up to 50ml in a volumetric flask. A known volume of this solution was treated with an excess of standard barium chloride. The unreacted barium chloride was determined by titration with standard EDTA. The amount of sulphate was estimated by the method of difference.

2.9. Determination of the amount of Chloride in Seaweeds

Accurately weighed powdered seaweed (1.2g) was ashed at 450° C with an equal weight of sodium carbonate. The ash was dissolved in minimum amount of 25% nitric acid and the solution made up to 50ml in a volumetric flask. The amount of chloride present in this solution was determined by Vollard method.[16]

3. Results and Discussion

The amounts of moisture, ash, total nitrogen and protein found in twenty five species of the seaweeds from the coastal areas of Northern Sri Lanka are given in Table 1. The results show that some of the algae such as *Gracilaria edulis, Gracilaria confervoides, Hypnea musciformis, Acanthophora delilei, Centroceros clavulatum* and *Ulva lactuca* have between 13-26% protein and this amount is comparable or even

somewhat higher than the reported[4] protein content of food materials like cereals, eggs and fish. Algal proteins are reported[11,14,15] to have many of the essential aminoacids including iodine containing aminoacids and hence the above seaweeds, are a good source for protein rich food. Also, the above species of seaweeds could be added to foods which are deficient in protein. In India *Gracilaria edulis* is used[11,14,15] in the preparation of soup.

TABLE 1. Moisture, Ash, Nitrogen and Protein contents of Seaweeds. All values are expressed as g/100g of air dried samples of seaweeds

Alga	*Locality*	*Date of Collection*	*Moisture*	*Ash*	*Nitrogen*	*Protein*
a. Rhodophyta						
1. Gracilaria edulis	Mandaitivu	10.12.82	3.69	38.46	2.28	14.25
	Nainativu	01.01.83	13.9	24.86	1.89	11.81
2. Gracilaria crassa	Mandaitivu	10.12.82	13.31	49.85	1.33	8.31
3. Gracilaria confervoides	Keerimalai	13.02.83	10.07	8.80	2.30	14.38
4. Laurencia obtusa	Mandaitivu	10.12.82	15.07	34.30	1.70	10.63
5. Jania natalensis	Mandaitivu	10.12.82	3.21	69.79	0.75	4.69
6. Hypnea musciformis	Mandaitivu	10.12.82	13.52	24.19	2.13	13.31
	Keerimalai	13.02.83	7.62	14.99	3.06	19.13
7. Acanthophora delilei	Keerimalai	13.02.83	9.98	25.94	2.69	16.87
8. Centroceros clavulatum	Mandaitivu	31.12.82	16.66	29.29	1.99	12.44
	Keerimalai	13.02.83	8.08	18.65	4.02	25.13
9 Gelidiella acerosa	Mandaitivu	31.12.82	14.12	12.07	1.67	10.44
b. Phaeophyta						
10. Padina pavonia	Mandaitivu	10.12.82	11.15	42.78	1.80	11.25
11. Turbinaria omata	Mandaitivu	31.12.82	19.43	24.63	1.38	8.63
12. Pocockiella variegata	Nainativu	01.01.83	13.37	19.82	1.18	7.38
13. Stoechospermum marginatum	Mandaitivu	13.02.83	13.09	21.94	1.49	9.31
14. Cystophyllum muricatum	Mandaitivu	13.02.83	13.84	35.14	1.45	9.06
15. Turbinaria conoides	Nainativu	01.01.83	14.13	16.95	0.93	5.81
16. Sargassum polycystum	Mandaitivu	31.12.82	17.07	35.51	1.61	10.06
	Nainativu	01.01.83	14.59	14.44	1.14	7.13
17. Sargassum tenerrimum	Mandaitivu	10.12.82	16.03	31.17	1.56	9.75
18. Hormophysa triquetra	Mandaitivu	13.02.83	13.06	46.91	0.91	5.69

(Contd.)

Table 1 (Contd.)

Alga	*Locality*	*Date of Collection*	*Moisture*	*Ash*	*Nitrogen*	*Protein*
c. Chlorophyta						
19. Struvea anastamosans	Mandaitivu	31.12.82	12.41	48.60	0.98	6.13
20. Codium sp.	Nainativu	01.01.83	16.41	26.22	1.41	8.81
21. Acetabularia crenulata	Casuarina	13.02.83	4.72	55.56	0.28	1.75
22. Chaetomorpha	Nainativu	01.01.83	17.27	38.92	1.44	9.00
sp.	Keerimalai	13.02.83	4.46	21.02	1.74	10.88
23. Ulva reticulata	Mandaitivu	13.02.83	11.56	20.11	1.57	9.81
	Nainativu	01.01.83	20.88	34.20	0.81	5.06
24. Ulva lactuca	Mandaitivu	10.02.82	12.73	29.71	3.17	19.81
	Casuarina	25.12.82	16.38	21.43	2.64	16.50
d. Angiosperm						
25. Thalasia	Mandaitivu	10.12.82	16.42	21.70	2.09	13.06
hemprichi	Nainativu	01.01.83	9.16	27.66	1.27	7.94

It is interesting to note that generally the seaweeds from the Keerimalai area have a higher protein content than those from the Mandaitivu coast, which in turn have a higher protein content than those from Nainativu coast.

Amounts of the minerals sodium, potassium, calcium and magnesium present in twenty five species of seaweeds were determined by the methods indicated above and our results are given in Table II. *Gracilaria edulis, Gracilaria crassa, Laurencia obtusa, Turbinaria ornata* and *Sargassum tenerrimum* have fairly large amount of potassium. *Jania natalensis, Acetabularia crenulata, Padina pavonia, Sturvea anastamosans, Thalasia hemprichi, Pocockiella variegata, Laurencia obtusa, Hypnea musciformis* and *Ulva reticulata* have reasonably large quantity of calcium. It is interesting to note that *Jania natalensis*, which is capable of accumulating calcium and depositing it in the form of a calcareous skeleton, has the highest amount of calcium. *Jania natalensis, Chaetomorpha sp, Padina pavonia, Laurencia obtusa, Ulva reticulata* and *Thalasia hemprichi* have more than 1% magnesium.

TABLE 2. Amounts of Sodium, Potassium, Calcium and Magnesium present in Seaweeds. All values are expressed in g/100g of air dried samples of seaweeds.

Alga	*Locality*	*Date of collection*	*Sodium*	*Potassium*	*Calcium*	*Magnesium*
a. Rhodophyta						
1. Gracilaria edulis	Mandaitivu	10.12.82	1.61	13.49	3.55	0.68
2. Gracilaria crassa	Mandaitivu	10.12.82	0.75	7.63	2.02	0.23
3. Gracilaria confervoides	Keerimalai	13.02.83	0.10	0.128	1.50	0.69

(Contd.)

(*Table 2 Contd.*)

Alga	*Locality*	*Date of Collection*	*Sodium*	*Potassium*	*Calcium*	*Magnesium*
4. Laurencia obtusa	Mandaitivu	10.12.82	1.22	4.32	4.99	1.35
5. Jania natalensis	Mandaitivu	10.12.82	0.70	0.28	23.85	2.71
6. Hypnea	Mandaitivu	10.12.82	0.50	0.58	4.83	0.38
musciformis	Keerimalai	13.02.83	0.13	0.106	3.00	0.74
7. Acanthophora	Keerimalai	13.02.83	0.10	0.106	1.57	0.45
delilei						
8. Centroceros	Mandaitivu	31.12.82	1.20	3.26	2.53	0.46
clavulatum	Keerimalai	13.02.83	0.10	0.103	2.97	0.72
9. Gelidiella	Mandaitivu	31.12.82	0.25	0.19	1.58	0.34
acerosa						
b. Phaeophyta						
10. Padina pavonia	Mandaitivu	10.12.82	0.59	1.13	10.96	1.36
11. Turbinaria	Mandaitivu	31.12.82	1.81	6.30	2.12	0.28
ornata						
12. Pocockiella	Nainativu	01.01.83	0.30	0.15	5.21	0.43
variegata						
13. Stoechospermum	Mandaitivu	13.02.83	0.25	1.10	2.08	0.07
marginatum						
14. Cystophyllum	Mandaitivu	13.02.83	0.10	0.58	2.46	0.15
muricatum						
15. Turbinaria	Nainativu	01.01.83	0.49	1.68	2.28	0.35
conoides						
16. Sargassum	Mandaitivu	31.12.82	2.62	3.93	3.15	0.56
polycystum	Nainativu	01.01.83	0.54	1.17	2.01	0.45
17. Sargassum	Mandaitivu	10.12.82	0.82	5.97	3.06	0.84
tenerrimum						
18 Hormophysa	Mandaitivu	13.02.83	0.09	0.68	2.67	0.42
triquetra						
c. Chlorophyta						
19. Sturvea	Mandaitivu	31.12.82	3.16	1.80	9.61	0.41
anastamosans						
20. Codium sp.	Nainativu	01.01.83	1.78	0.23	2.31	0.83
21. Acetabularia	Casuarina	13.02.83	0.14	0.27	16.06	0.39
crenulata						
22. Chaetomorpha	Nainativu	01.01.83	1.71	0.81	2.40	1.94
sp.	Keerimalai	13.02.83	0.21	0.10	2.88	1.27
23. Ulva reticulata	Mandaitivu	13.02.83	0.31	0.31	4.82	0.48
	Nainativu	01.01.83	0.77	0.38	3.79	1.35
24. Ulva lactuca	Mandaitivu	10.12.82	0.85	1.85	2.44	0.17
	Casuarina Beach	25.12.82	0.96	2.25	3.60	0.25
d. Angiosperm						
25. Thalasia	Mandaitivu	10.12.82	3.84	4.09	3.57	1.16
hemprichi	Nainativu	01.01.83	0.57	0.41	7.46	0.84

Our results on the colorimetric estimation of the amounts of iron and phosphorus are shown in Table III. It is seen that species such as *Gracilaria edulis, Padina pavonia, Pocockiella variegata, Chaetomorpha sp, Sargassum polycystum* and *Jania natalensis* are rich in iron. Also the seaweeds from the Nainativu and Mandaitivu areas generally have more iron content than those from Keerimalai area *Gracilaria edulis, Gracilaria crassa, Gracilaria confervoides, Hypnea musciformis. Codium sp, Chaetomorpha sp, Ulva lactuca* and *Thalasia hemprichi* have relatively large amounts of phosphorus.

TABLE 3. Amounts of Iron and Phosphorus present in seaweeds. All values are expressed in mg/kg of air dried samples of seaweeds.

Alga	*Locality*	*Date of Collection*	*Iron*	*Phosphorus*
a. Rhodophyta				
1. Gracilaria edulis	Mandaitivu	10.12.82	405	764
	Nainativu	01.01.83	1240	989
2. Gracilaria crassa	Mandaitivu	10.12.82	267	888
3. Gracilaria confervoides	Keerimalai	13.02.83	262	1168
4. Laurencia obtusa	Mandaitivu	10.12.82	674	514
5. Jania natalensis	Mandaitivu	10.12.82	940	206
6. Hypnea musciformis	Mandaitivu	10.12.82	658	259
	Keerimalai	13.02.83	409	1338
7. Acanthophora delilei	Keerimalai	13.02.83	102	225
8. Centroceros clavulatum	Mandaitivu	31.12.83	450	508
	Keerimalai	13.02.83	447	643
9. Gelidiella acerosa	Mandaitivu	31.12.82	344	395
b. Phaeophyta				
10. Padina pavonia	Mandaitivu	10.12.82	1266	477
11. Turbinaria ornata	Mandaitivu	31.12.82	372	252
12. Pocockiella variegata	Nainativu	01.01.83	1213	411
13. Stoechospermum marginatum	Mandaitivu	13.02.83	134	608
14. Cystophyllum muricatum	Mandaitivu	13.02.83	391	727
15. Turbinaria conoides	Nainativu	01.01.83	306	472
16. Sargassum polycystum	Mandaitivu	31.12.82	490	476
	Nainativu	01.01.83	373	469
17. Sargassum tenerrimum	Mandaitivu	10.12.82	925	540
18. Hormophysa triquetra	Mandaitivu	13.02.83	394	217
c. Chlorophyta				
19. Sturvea anastamosans	Mandaitivu	31.12.82	738	175
20. Codium sp.	Nainativu	01.01.83	602	877
21. Acetabularia crenulata	Casuarina	13.02.83	250	190
22. Chaetomorpha sp.	Nainativu	01.01.83	1179	951
	Keerimalai	13.02.83	593	716
23. Ulva reticulata	Mandaitivu	13.02.83	201	354
24. Ulva lactuca	Mandaitivu	10.12.82	219	1224
	Casuarina	25.12.82	542	633
d. Angiosperm				
25. Thalasia hemprichi	Mandaitivu	10.12.82	392	1326
	Nainativu	01.01.83	655	1316

The amounts of nitrogen, potassium and phosphorus present in selected species of seaweeds are shown in Table IV. It is interesting to note that *Gracilaria edulis*, *Laurencia obtusa*, *Padina pavonia*, *Ulva lactuca*, *Thalasia hemprichi*, *Gracilaria crassa*, *Sargassum polycystum* and *Sargassum tenerimum* have fairly large amounts of nitrogen, phosphorus and potassium and hence these could be used as fertilizers. Also other species which are rich in nitrogen, phosphorus or potassium could be mixed together to form a good fertilizer.

TABLE 4. The amounts of nitrogen, potassium and phosphorus present in selected species of seaweeds. All values are expressed in mg/kg of air dried samples.

Species	*Locality*	*Date of Collection*	*Nitrogen*	*Phosphorus*	*Potassium*
1. Gracilaria edulis	Mandaitivu	10.12.82	22800	764	134900
2. Gracilaria confervoides	Keerimalai	13.02.83	23000	1168	1280
3. Laurencia obtusa	Mandaitivu	10.12.82	17000	514	43200
4. Hypnea musciformis	Mandaitivu	10.12.82	21300	259	5800
	Keerimalai	13.02.83	30600	1338	1060
5. Acanthophora delilei	Keerimalai	13.02.83	26900	225	1060
6. Centroceros clavulatum	Keerimalai	13.02.83	40200	643	1030
	Mandaitivu	31.12.82	19900	508	32600
7. Gelidiella acerosa	Mandaitivu	31.12.82	16700	395	1900
8. Padina pavonia	Mandaitivu	10.12.82	18000	477	11300
9. Sargassum polycystum	Mandaitivu	31.12.82	16100	476	39300
10. Chaetomorpha sp.	Keerimalai	13.02.83	17400	716	1000
11. Ulva lactuca	Mandaitivu	10.12.82	31700	1224	18500
	Casuarina	25.12.82	24600	633	22500
12. Thalasia hemprichi	Mandaitivu	10.12.82	20900	1326	40900
13. Gracilaria crassa	Mandaitivu	10.12.82	13300	888	76300
14. Turbinaria ornata	Mandaitivu	31.12.82	13800	252	63000
15. Sargassum tenerrimum	Mandaitivu	10.12.82	15600	540	59700

Seaweeds also contain trace elements. These are a group of elements which are needed in infinitely small amounts and these are very essential for the growth of plants and animals. Some of the important trace elements are Fe, Cu, Zn, Mn, Co, B and Mo. Some of the trace elements form complexes with enzymes and catalyse in metabolic reactions. The element copper is found in the enzyme polyphenol oxidase and the respiratory pigment of invertebrates, homocyanin. The enzymes such as tyrosinase, laccase and ascorbic acid oxidase use copper to catalyse reactions.[1,9] Copper and cobalt are essential for health and productivity of animals. These two elements are associated with iron in the production of haemoglobin.[1,9]

The element cobalt, in addition to being an essential element of Vitamin B_{12} is important in the metabolism of sulphur containing aminoacids. Elements such as Zn, Mn, Mo, Cr and Cd are also involved in the biological processes.[13] Even though the trace elements have a vital function for human and animals they become toxic if present in relatively large amounts. The general recommended[10] limits for some of the elements are given below.

Element	Pb	Ni	Cr	Cu	Zn
Recommended limit/ppm	2	100	100	20	50

The amounts of Cu, Zn, Mn, Ni, Cd, Co and Cr present in twenty three species of marine algae were determined using Varian Model 1275 Atomic Absorption Spectrophotometer. The amount of lead present in these samples were determined colorimetrically after complexing with dithizone. No detectable amount of cobalt or chromium was found in any of these twenty three species. Our results, which are given in Table V, show that (i) *Padina pavonia* and *Sturvea anastomosans* have relatively large amounts of copper while the species *Stoechospermum marginatum*, *Sargassum polycystum* and *Thalasia hemprichi* have reasonable amounts of copper, (ii) the element zinc is found in relatively large amounts in *Sturvea anastomosans*, *Dictyota species*, *Padina pavonia*, *Stoechospermum marginatum* and *Hypnea musciformis* (iii) Manganese is found in relatively large amounts in red algae (iv) the species *Sturvea anastomosans*, *Gracilaria edulis*, *Centroceros clavulatum*, *Jania natalensis*, *Hormophysa triquetra*, *Sargassum polycystum* and *Thalasia hemprichi* have relatively high Ni content (v) the element Pb is found in relatively large amount in *Sturvea anastomosans*, *Gracilaria crassa*, *Gracilaria salicornia*, *Jania natalensis*, *Padina pavonia*, *Hormophysa triquetra* and *Sargassum polycystum* and (vi) Cadmium is found in the range 1 - 4 ppm.

Cadmium and lead are non-nutritive toxic elements. Seaweed species analysed have low cadmium level (1-4 ppm). However the level of lead is rather high. The statutory limit for Pb in food is 2 ppm.

Sturvea anastomosans, *Jania natalensis* and *Padina pavonia* have relatively large amounts of the toxic elements and these may be avoided as nutrients and fertilizers. Also it is apparent from the Table V that the seaweeds from the Mandaitivu coast are richer in trace elements than those from Nainativu.

TABLE 5. Amounts of Copper, Zinc, Manganous, Nickel, Lead and Cadmium present in seaweeds. All values are expressed as mg per kg (i.e. ppm) of air dried samples of seaweeds. (Date of collection is the same as in the Tables 1 & 2).

Alga	*Locality*	*Cu*	*Zu*	*Mn*	*Ni*	*Pb*	*Cd*
a. Rhodophyta							
1. Gracilaria edulis	Mandaitivu	5.3	9.2	397.3	24.0	8.3	3.3
	Nainativu	6.0	6.4	76.3	12.9	7.0	3.9
2. Gracilaria crassa	Mandaitivu	6.3	6.0	217.2	11.9	10.1	2.5

(*Contd.*)

(*Table 5 Contd.*)

Alga	*Locality*	*Cu*	*Zn*	*Mn*	*Ni*	*Pb*	*Cd*
3. Gracilaria salicornia	Mandaitivu (13.2.83)	3.4	6.6	62.0	15.5	9.9	1.3
4. Laurencia obtusa	Mandaitivu	5.2	6.4	129.7	14.3	8.6	2.2
5. Hypnea musciformis	Mandaitivu	2.7	11.9	149.6	14.5	8.7	1.3
6. Centroceros clavalatum	Mandaitivu	6.7	5.9	48.1	21.8	8.8	2.2
7. Gelidiella acerosa	Mandaitivu	2.7	7.3	102.8	12.3	5.7	2.4
8. Jania natalensis	Mandaitivu	3.0	6.9	87.6	32.2	19.3	3.1
b. Phaeophyta							
9. Padina pavonia	Mandaitivu	40.8	12.4	211.9	21.5	18.4	3.9
10. Stoechospermum marginatum	Mandaitivu	11.6	10.1	21.4	13.6	9.3	1.3
11. Cystophyllum muricatum	Mandaitivu	8.7	8.3	31.6	17.1	8.3	2.1
12. Dictyota sp.	Mandaitivu	7.2	14.5	37.2	16.3	8.1	2.0
13. Hormophysa triquetra	Mandaitivu	5.4	7.4	29.0	22.3	11.0	1.6
14. Sargassum polycystum	Mandaitivu	10.3	8.1	189.1	23.9	10.4	2.8
	Nainativu	5.6	5.4	29.0	6.9	6.9	1.6
15. Sargassum tenerrimum	Mandaitivu	7.9	7.6	138.6	13.6	9.3	2.4
16. Turbinaria ornata	Mandaitivu	4.0	4.5	27.9	9.7	5.4	1.6
17. Pocockiella variegata	Nainativu	5.0	6.9	63.5	16.2	10.1	2.5
18. Turbinaria conoides	Nainativu	3.1	3.0	22.6	7.6	7.4	2.1
c. Chlorophyta							
19. Sturvea anastamosans	Mandaitivu	20.7	20.2	110.2	37.3	18.5	2.4
20. Ulva reticulata	Mandaitivu	3.6	5.9	74.0	10.4	3.9	2.0
21. Chaetomorpha sp.	Nainativu	6.9	8.4	36.1	22.8	10.1	1.7
22. Codium sp.	Nainativu	4.5	10.4	45.1	9.7	9.3	4.3
d. Angiosperm							
23. Thalasia hemprichi	Mandaitivu	10.8	7.4	51.3	25.1	8.5	2.5
	Nainativu	8.4	7.3	70.9	19.8	13.4	2.5

Chloride ion which is a micronutrient and sulphur which is a macronutrient[2] are also found in seaweeds. Table VI gives the values obtained for the amounts of ionic chloride and total sulphur present in some seaweeds.

TABLE 6. Amounts of ionic chloride and total sulphur present in seaweeds. All values are expressed in g/100g of air dried seaweeds.

Alga	*Locality*	*Date of Collection*	*Ionic Chloride*	*Total Sulphur*
a. Rhodophyta				
1. Centroceros clavulatum	Mandaitivu	31.12.82	6.43	2.02
2. Gracilaria edulis	Mandaitivu	10.12.82	3.88	4.13
	Nainativu	01.01.83	1.58	2.79
b. Phaeophyta				
3. Sargassum polycystum	Mandaitivu	31.12.82	7.95	1.03
4. Sargassum tenerrimum	Mandaitivu	10.12.82	7.23	1.71
5. Pocockiella variegata	Nainativu	01.01.83	0.61	0.50
6. Stoechospermum marginatum	Mandaitivu	13.02.83	7.16	1.06
c. Chlorophyta				
7. Codium sp.	Nainativu	01.01.83	5.88	3.65
8. Chaetomorpha sp.	Nainativu	01.01.83	8.07	4.03
d. Angiosperm				
9. Thalasia hemprichi	Mandaitivu	10.12.82	5.34	0.58
	Nainativu	01.01.83	2.67	0.49

Our results show that *Pocockiella variegata* and *Gracilaria edulis* have relatively low amounts of ionic chloride. The species *Thalasia hemprichi*, *Pocockiella variegata*, *Sargassum polycystum* and *Stoechospermum marginatum* have relatively low amounts of sulphur.

4. Conclusion

Some species of seaweeds such as *Centroceros clavulatum, Gracilaria edulis, Gracilaria confervoides, Acanthophora delilei* and *Ulva lactuca* have relatively large amounts of protein and could be used for fortifying food items deficient in protein. Seaweeds such as *Gracilaria edulis, Laurencia obtusa, Padina pavonia, Ulva lactuca, Thalasia hemprichi, Gracilaria crassa, Sargassum polycystum* and *Sargassum tenerrimum* have fairly large amounts of the elements nitrogen, phosphorus and potassium and these could be used as fertilizers. *Gracilaria edulis* and *Gracilaria crassa* also have relatively large amounts of the trace elements. Attempts should be made to cultivate the above species of algae so that they could be profitably used.

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Seasonal and Diurnal Variation in Thermal Comfort in Sri Lanka

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Abstract: The present work reports evidence bearing on the question whether seasonal acclimatization occurs in thermal comfort in a tropical country (Sri Lanka) where the seasonal change of temperature is small. Thermal comfort votes were taken in each of two subjects on nearly a hundred occasions over a period of 10 - 12 consecutive months. One of the subjects also had records which had been taken 12 years previously over a period of six consecutive months. The ambient temperature level which was compatible with a sensation of satisfactory thermal comfort (comfort temperature) rose in the warmer season and fell in the less warm. Evidence is also presented on the question whether there is a seasonal variation in the effect which diurnal temperature change has upon thermal comfort. The change in thermal comfort from morning to afternoon was recorded in one subject on 73 days during a 12-month period. A seasonal acclimatizational effect was detected in which the change in ambient temperature which produced thermal discomfort was found to be larger in the warmer than in the less warm months. The effective temperature scale was noticed to be no better than the dry bulb temperature in demonstrating these seasonal acclimatizational effects.

1. Introduction

The ambient temperature level at which individuals feel thermally comfortable shifts with the seasons of the year. It shifts upwards in the hotter season and downwards in the colder. This seasonal shift of the preferred temperature for thermal comfort has been noticed in all climates which have been studied. In temperate climates the zone of comfort temperature shifts upwards in summer and downwards in winter. In the U.S.A. the winter comfort zone extends over an effective temperature range of 17.2 - 21.7 °C (63 - 71 °F), midpoint 18.9 °C (66 °F), while the corresponding figures for the summer comfort zone are 18.9 - 23.9 °C (66 - 75 °F), midpoint 21.7 °C (71 °F).[12] In the U.K. the midpoint of comfort temperature is 22 °C effective temperature in summer and 17 °C in winter.

Does the phenomenon of a seasonal shift of comfort temperature occur in 'monotonous' climates with only small changes in seasonal temperature? In the equatorial tropics the mean monthly temperature of the warmest month of the year is only about 5 °C (9 °F) higher than that of the coolest month, with a mean annual temperature of about 27.7 °C (80 °F).[6] Tropical marine climates are similar to equatorial climates. In higher latitudes the temperature changes which occur from month to month are more marked and there may be a hot season ('summer') and a cold season ('winter'). The island of Sri Lanka, situated at 5 - 10°N latitude, has a practically equatorial climate. Referring to the absence of seasons in Sri Lanka

by Western standards a British observer over a century ago wrote: "and fruit hangs ripe on the same branches that are garlanded with opening buds"[10]; and a still earlier observer spoke of "the perennial summer which it experiences (I cannot say enjoys)"[2]. The mean annual temperature for its seaside capital, Colombo, is 26.9 °C (80.5 °F); the mean monthly temperature for the hottest month, May, is 27.9 °C (82.3 °F) and that for the coolest month, December, 26.1 °C (79.0 °F), so that the difference between warmest and least warm months is 1.8 °C. In Kandy, which is at an altitude of about 500 m above mean sea level, the corresponding figures are a mean annual temperature of 24.4°C (75.9°F), hottest month, April, 26.0°C (78.8°F), coolest month, January, 23.1°C (73.6°F).[9] The purpose of the present work was to find out whether there was any seasonal shift of comfort temperature in so 'monotonous' a climate as that of Sri Lanka.

The diurnal changes in ambient temperature are, in tropical climates, more marked than the seasonal changes. The nights feel cooler than the daytime; there is a saying that 'night is the winter of the tropics'. The early afternoon usually has the highest temperature over a 24-hour period. In Sri Lanka the annual mean daily temperature range is about 6.1°C (11°F) for Colombo and 8.3°C (15°F) for Kandy. Would the comfort temperature shift with the diurnal change in ambient temperature? The available evidence is small and contradictory. A study in Calcutta collected records of ambient temperature and thermal comfort at 10h, 12h, 14h and 16h during the day twice a week throughout one year but the purpose of the study was to determine the comfort temperature range rather than to detect diurnal and seasonal effects.[7] In the Australian tropics (Welpa, North Queensland) the upper limit of corrected effective temperature for thermal comfort was found to be less by night than day.[13] The comfort temperature for British sailors serving in warships in tropical seas was the same for evening as for midday. Nor was the comfort temperature changed as a result of a sojourn in a cooler region (Japan).[4] In the present study an attempt was made to compare the comfort temperature for morning with that for afternoon.

2. Method

The study was done in a physiology laboratory at Peradeniya, within the Kandy municipal limits.

Recordings were made of ambient temperature and thermal comfort in two subjects as occasion arose over a period of months. The observations fall into two series:- Series A, observations made on one subject (Subject I) during April - September 1967 once a day at c.9.30h for a total of 40 days. The subject was a 41 - year old male. Series B, observations made during October 1978 - September 1979 in the same subject as above (Subject I, 53 years old by then), and during 1978 - August 1979 in a 23-year old female (Subject II), at 9.30h. In series B the ambient temperature at 9.30h was recorded on 170 days while thermal comfort was recorded

on 95 occasions for Subject I and 91 for Subject II. In addition, recordings were also made at 14.30h on 73 out of these 95 occasions for Subject I. All the measurements were made indoors in the laboratory with the subjects in the sedentary state and the clothing was customary light wear (shirt and long trousers for the man and frock for the woman).

Ambient temperature was measured as dry bulb temperature (DBT), wet bulb temperature (WBT) and effective temperature (T_{eff}). DBT and WBT were measured with a whirled pair of thermometers (whirling psychrometer). T_{eff} was read from a nomogram for 'normal effective temperature' using data for air speed obtained with a katathermometer (dry, red spirit, 95-100 °F).

Thermal comfort was recorded verbally on a seven-point scale: comfortable (grade 4), comfortably warm (grade 5), warm (grade 6), hot (7), comfortably cool (3), cool (2), cold (1). This scale closely follows the customary seven-point thermal comfort scales.[1]

In looking for seasonal effects, all the thermal comfort votes taken at 9.30h were analysed month by month, separately for each of the two subjects. For each month all the votes which stated 'comfortable', 'comfortably warm', or 'comfortably cool' (grades 4, 5 and 3 respectively) were regarded as signifying a satisfactory state of thermal comfort. The corresponding ambient temperatures were regarded as 'comfort temperatures'. These 'comfort temperatures' for each month were then summarised as a median value and their range.

Diurnal effects were looked for in the 73 pairs of morning and afternoon readings which were available for Subject I. The analysis was done as follows: The difference in temperature ($\triangle T$) between morning and afternoon was expressed as the afternoon temperature minus the morning temperature. The change in thermal comfort ($\triangle_{com}$) from morning to afternoon was expressed as the afternoon rating minus the morning rating on the seven-point scale. (Thus a morning rating of comfortable, grade 4 on the seven-point scale, and an afternoon rating on the same day of warm, grade 6, was counted as a change of +2 grades, i.e. deterioration in thermal comfort by two grades. A change from comfortably warm, grade 5, in the morning to comfortably cool, grade 3, in the afternoon was counted as -2 grades, i.e. an 'improvement' in the thermal comfort by two grades.) Finally the data for $\triangle_{com}$ were tabulated in relation to $\triangle T$ in order to see whether the two could be related.

A seasonal effect was also looked for in the morning and afternoon pairs by tabulating $\triangle T$ and the number of occasions on which a deterioration in thermal comfort by two or more steps was recorded month by month. There was a total of 40 such occasions during the 73 days on which morning and afternoon readings were taken for Subject I.

3. Results and Conclusions

3.1 Season and comfort

Table 1a and 1b show the relation between comfort temperature (T_{com}) and ambient temperature (T_{amb}). T_{com} denotes the monthly median value for ambient temperature when the subject felt thermally comfortable (comfort temperature). T_{amb} denotes the monthly median value for all readings of ambient temperature irrespective of comfort. Both sets of readings are from the 1978-79 study (Series B). Figure 1 shows the relation between T_{com} and T_{amb} graphically.

TABLE 1a. Season and ambient temperature

Month	No. of days observed	Ambient temperature at 9.30 h (°C) Median temperature Dry bulb	Wet Bulb	Effective
1978				
Oct	21	26.5	24.1	25.1
Nov	14	25.6	22.8	23.9
Dec	12	25.6	22.2	23.9
1979				
Jan	11	25.3	22.6	24.2
Feb	7	25.3	22.5	23.9
Mar	3	26.7	21.9	23.9
Apr	13	27.5	24.2	25.6
May	20	27.2	23.9	25.6
Jun	19	26.1	23.7	24.5
Jul	18	25.4	23.1	24.1
Aug	14	25.6	22.9	23.9
Sep	18	25.0	22.8	23.8

TABLE 1b. Season and comfort temperature

Month	Ambient comfort temperature at 9.30 h (°C) Subject I No. of days	Median temperature Dry bulb	Wet bulb	Effective	Subject II No. of days	Median temperature Dry bulb	Wet bulb	Effective
1978								
Oct	11	26.6	24.0	25.4	16	26.4	24.0	25.1
Nov	8	25.6	22.9	24.1	12	25.7	23.2	23.9
Dec	8	25.6	24.9	24.4	12	25.6	22.5	23.9
1979								
Jan	10	25.4	22.5	24.2	11	25.3	22.6	24.2
Feb	6	25.1	22.6	24.0	7	25.3	22.5	23.9
Mar	3	26.1	21.9	23.9	3	26.1	21.9	23.9
Apr	9	27.2	24.2	25.3	5	27.8	24.4	26.1
May	13	27.5	23.9	25.6	12	27.2	23.7	25.5
Jun	8	27.3	22.9	25.3	6	27.0	23.6	24.9
Jul	3	25.9	22.6	23.9	7	25.7	23.3	24.0
Aug	4	25.6	24.4	24.8	—	—	—	—
Sep	12	25.1	22.8	23.9	—	—	—	—

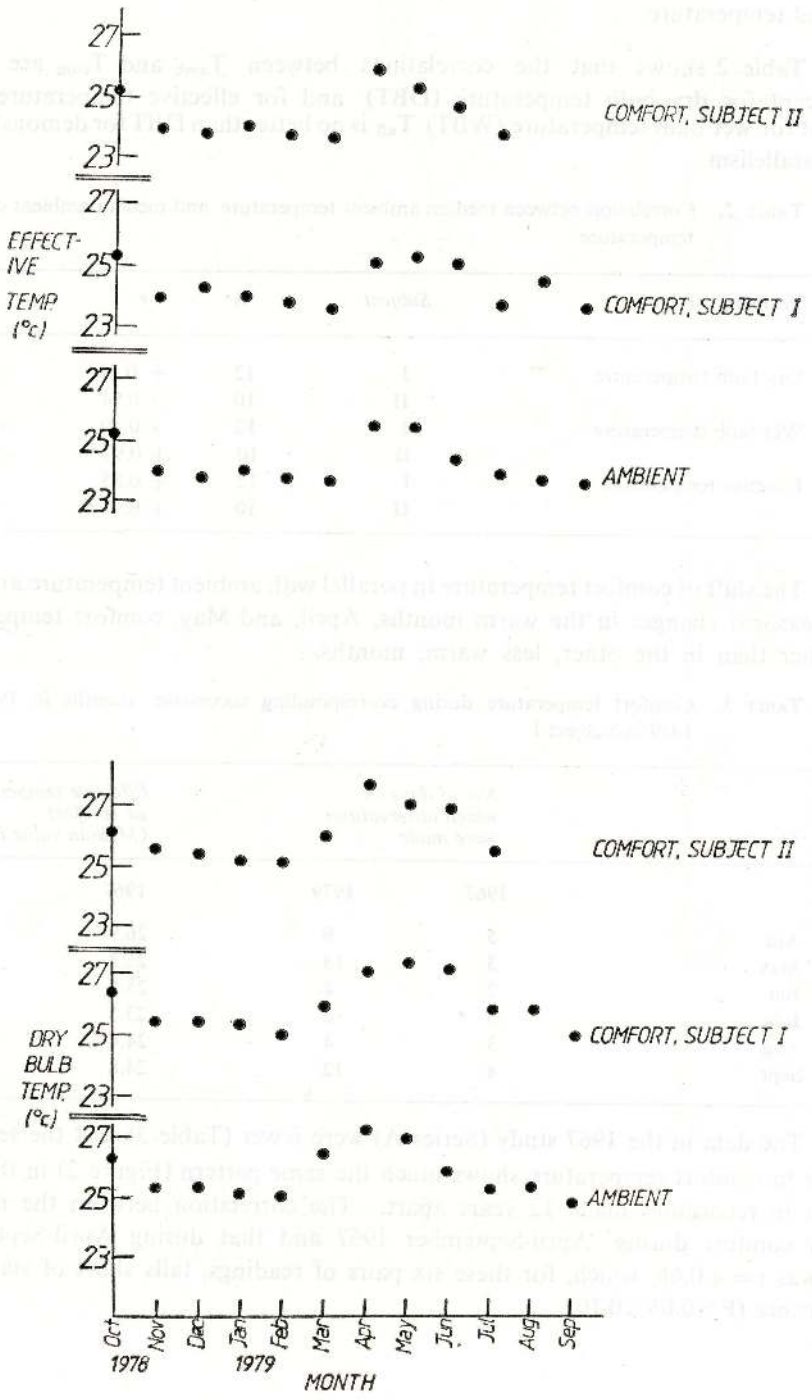

FIGURE 1 — Season and thermal Comfort:
relation between monthly median ambient temperature and monthly median comfort temperature in two individuals.

There is a parallelism between the monthly comfort temperature and the ambient temperature.

Table 2 shows that the correlations between T_{amb} and T_{com} are highly significant for dry bulb temperature (DBT) and for effective temperature (T_{eff}) but not for wet bulb temperature (WBT). T_{eff} is no better than DBT for demonstrating the parallelism.

TABLE 2. Correlation between median ambient temperature and median ambient comfort temperature

Temperature	*Subject*	*n*	*r*	*P*
Dry bulb temperature	I	12	+ 0.87	< 0.001
	II	10	+ 0.91	,,
Wet bulb temperature	I	12	+ 0.40	> 0.1
	II	10	+ 0.97	< 0.001
Effective temperature	I	12	+ 0.85	,,
	II	10	+ 0.97	,,

The shift of comfort temperature in parallel with ambient temperature amounts to a seasonal change: in the warm months, April, and May, comfort temperature is higher than in the other, less warm, months.

TABLE 3. Comfort temperature during corresponding successive months in 1967 and 1979 in Subject I

Month	*No. of days on which observations were made*		*Effective temperature at comfort (Median value in °C)*	
	1967	1979	1967	1979
Apr	5	9	26.9	25.3
May	3	13	25.2	25.6
Jun	2	8	25.3	25.3
July	7	3	23.5	23.9
Aug	3	4	24.4	24.8
Sept	4	12	24.8	23.9

The data in the 1967 study (Series A) were fewer (Table 3), but the seasonal change in comfort temperature shows much the same pattern (Figure 2) in this one subject in recordings made 12 years apart. The correlation between the median T_{eff} at comfort during April-September 1967 and that during April-September 1979 was $r = +0.66$, which, for these six pairs of readings, falls short of statistical significance ($P > 0.05 < 0.10$).

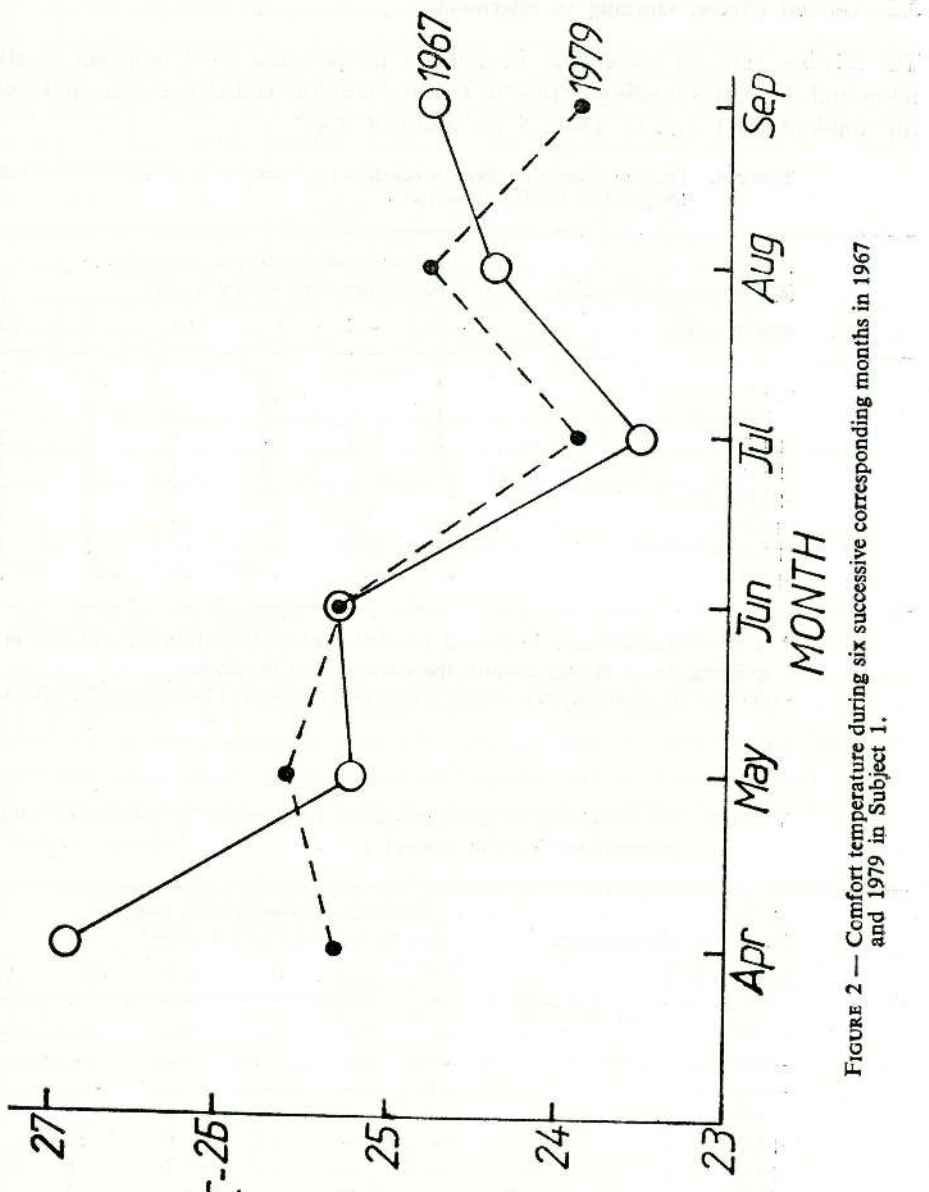

FIGURE 2 — Comfort temperature during six successive corresponding months in 1967 and 1979 in Subject 1.

3.2 Diurnal effects: morning vs afternoon

The relation between the change in ambient temperature from morning to afternoon and the corresponding change in thermal comfort status is shown in Table 4 for ambient DBT and in Table 5 for ambient T_{eff}.

TABLE 4. Diurnal change in thermal comfort (△ comfort) in relation to dry bulb temperature (DBT) in Subject I

△DBT (*afternoon minus morning reading*) (°C)	*Frequency distribution of △ comfort (no. of steps on 7 - point scale)**					
	—2	—1	0	+1	+2	+3
—1.0 —	1	1	1	—	—	—
0.0 —	1	1	4	3	7	—
+1.0 —	2	1	4	6	3	2
+2.0 —	—	—	3	1	8	1
+3.0 —	—	—	—	3	8	2
+4.0 —	—	—	—	—	3	2
+5.0 —	—	—	—	—	2	1
+6.0 —	—	—	—	—	—	2

* + denotes an increase in thermal comfort grade in the afternoon over that in the morning, i.e., a change towards the warm end of the scale.
—denotes the opposite, i.e. a change towards the cool end of the scale in the afternoon

TABLE 5. Diurnal change in thermal comfort (△ comfort) in relation to effective temperature (T_{eff}) in Subject I

△ T_{eff} (*afternoon minus morning reading*) (°C)	*Frequency distribution of △ comfort (no. of steps on 7 - point scale)**					
	—2	—1	0	+1	+2	+3
—3.0	—	1	—	—	—	—
—2.0	—	—	1	—	—	—
—1.0	1	—	—	—	—	—
0.0	3	2	7	6	7	1
+1.0	—	—	2	6	12	3
+2.0	—	—	2	1	8	2
+3.0	—	—	—	—	3	3
+4.0	—	—	—	—	—	1

* + denotes an increase in thermal comfort grade in the afternoon over that in the morning, i.e., a change towards the warm end of the scale.
—denotes the opposite, i.e. a change towards the cool end of the scale in the afternoon.

As the ambient temperature rose in the afternoon the thermal comfort status tended to deteriorate. Variability was considerable: anything could happen to thermal comfort when the rise of ambient temperature was less than 1°C T_{eff} or less than 2°C DBT. It is accordingly difficult to quantify the effect of the afternoon rise of T_{amb} upon thermal comfort. General inspection of Tables 4 and 5 suggests a rough approximation: the deterioration in thermal comfort in the afternoon is likely to be about one grade (e.g. from comfortably warm to warm, or from comfortable to comfortably warm) when the DBT rises by about 1.5°C in the afternoon over that in the morning; the deterioration is likely to be two grades (e.g. from comfortable to warm) for a rise of about 2.5°C; and three grades (e.g. from comfortable to hot) for about 3.5°C. The corresponding figures for T_{eff} are about 1°C, 1-2°C and 2°C or more, respectively.

It can also be seen that when the afternoon temperature fell below the morning temperature, as on a cloudy rainy afternoon, thermal comfort status tended to improve. The data are too few to look for further relationships.

T_{eff} does not appear to give a distinctly cleaner prediction of the change in comfort than does DBT.

3.3 Seasonal-diurnal effects

The change of ambient temperature ($\triangle T$) from morning to afternoon which went with a deterioration in thermal comfort by two or three grades (no greater degree of deterioration was noticed) is shown in Tables 6 and 7. The data suggest that in April and May, which are the warmest months, $\triangle T$ is of the order of 2 - 4°C DBT (Table 6) and 2 - 3°C T_{eff} (Table 7) while it is of the order of 1°C for the other less warm, months.

TABLE 6. Seasonal effect in thermal comfort deterioration in the afternoon, in relation to dry bulb temperature (DBT)

$\triangle$DBT *afternoon minus morning reading* (°C)	*No. of occasions on which deterioration* occurred*											
	1978			*1979*								
	Oct	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*
0.0 —	1	1	1	—	—	—	—	—	1	1	1	—
1.0 —	—	1	1	—	—	—	—	—	1	—	1	1
2.0 —	1	—	—	—	1	—	5	—	2	2	3	—
3.0 —	—	1	—	—	—	—	—	3	1	—	—	—
4.0 —	—	—	—	1	—	—	—	3	—	—	1	—
5.0 —	—	—	—	—	—	—	1	2	—	—	—	—
6.0 —	—	—	—	1	—	—	—	1	—	—	—	—

* Deterioration by 2 or 3 steps in the 7-point comfort scale.

TABLE 7. Seasonal effect in afternoon thermal comfort deterioration, in relation to effective temperature (T_{eff}).

$\triangle T_{eff}$ (*afternoon minus morning reading*) (°C)	*No. of occasions on which deterioration* occurred*											
	1978			*1979*								
	Oct	*Nov.*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*
0.0 —	—	1	2	—	—	—	—	—	2	1	2	—
1.0 —	2	2	—	—	—	—	2	1	2	1	4	1
2.0 —	—	—	—	1	1	—	2	4	1	1	—	—
3.0 —	—	—	—	—	—	—	2	4	—	—	—	—
4.0 —	—	—	—	1	—	—	—	—	—	—	—	—

* by 2 or 3 steps in the 7 - point scale of thermal comfort

T_{eff} showed this in a less clear cut way than DBT did.

4. Discussion

The seasonal variation in temperature recorded during the present study at Peradeniya was fairly typical of that shown by meteorological records for Kandy. The mean monthly DBT for Kandy, calculated as a 30-year average for the period 1931-1960, is as follows:- Jan 23.1°C; Feb 23.8°C; Mar 25.2°C; Apr 26.0°C; May 25.7°C; Jun 24.6°C; Jul 24.1°C; Aug 24.4°C; Sep 23.8°C; Oct 24.8°C; Nov 23.9°C; Dec 23.2°C. The same pattern is shown in the ambient temperature recordings in the present study. The correlation between the 12 median values in Table 1 and the 12 meteorological monthly values given above was $r = + 0.92$. The absolute level of the ambient temperature readings in Table 1 is higher than in the meteorological series because the readings were made at 9.30h while the meteorological values are averages from daily records of maximum and minimum temperature readings taken at 8.30h and 17.30h local time.

The results show that there is a seasonal effect on thermal comfort even in a climate in which the seasonal variation in temperature is relatively small. The comfort temperature in the warmest month, April, was about 27.5°C DBT, while in the least warm months, in and around January, it was about 25.3°C. These figures are practically identical with those for the average ambient DBT. Thus, as the prevailing ambient temperature rises seasonally, the tolerance level for thermal comfort also rises.

The subject is unaware of this seasonal acclimatization. In fact he is aware of the discomfort of the hot season and the comfort of the cool season. In Colombo, in April, "the heat in close apartments becomes extreme and every living

creature flies to the shade from the suffocating glare of mid-day"; in December "the morning and the afternoon are again enjoyable in the open air".[10] Discomfort arises when the ambient temperature increases on hot days and in hot afternoons, or when other factors, such as radiant heat, humidity, stillness of the air, muscular activity, clothing, and psychological factors including expectations, affect the situation.

Skin temperature is known to be a prime determinant of thermal comfort in the sedentary state.[3,12] It is possible that the seasonal acclimatization in thermal comfort is achieved by maintaining the skin temperature at its usual level of about 33°C by compensatory adjustments in skin blood flow and sweat output. Data are not available to prove this hypothesis.

Diurnal changes in thermal comfort in the tropics usually consist of a deterioration of comfort in the afternoon and an improvement in the night and early morning. They are associated with corresponding changes in ambient temperature. The association is, however, not strong enough to enable us to predict the degree of change in thermal comfort with much certainty, especially in climates where the diurnal ambient temperature change is relatively small. In Peradeniya, the median differences in DBT between afternoon and morning, as recorded in 134 pairs of indoor readings at 9.30h and 14.30h in Oct. 1978 - Sep. 1979, were as follows: Oct. 0.83°C; Nov. 0.94°C; Dec. 1.28°C; Jan. 2.22°C; Apr. 3.11°C; May 3.83°C; Jun. 1.50°C; Aug. 1.67°C; Sep. 1.39°C. The largest differences were 6.7°C (on a day in May) and - 1.5°C (i.e. afternoon cooler, on a day in June). With morning - afternoon temperature differences of this order of magnitude during the year, the morning - afternoon thermal comfort differences could only be broadly related to ambient temperature change. An increase of DBT by 1°C could be accompanied by a one-, two-, or three-step deterioration in thermal comfort or a one- or two-step improvement (Table 4). Presumably other factors such as radiant heat, humidity and air movement affect the result, but these could not be evaluated for their separate contributions to thermal comfort. Radiant heat did not seem to be an important variable; globe thermometer readings showed negligible differences from dry bulb thermometer readings, as has been noticed in Singapore too.[11]

The diurnal effect is influenced by season. In the warmer season, April and May, a bigger increase of afternoon temperature than in the less warm months was required to produce a deterioration in thermal comfort. The physiological basis for this effect is not known. It is possible that the same mechanism which produces seasonal acclimatization also produces this seasonal-on-diurnal acclimatization, such as a compensatory increase in vasodilatation and sweat output which preserve the skin temperature at comfort levels over a wider span of increasing ambient temperature.

The question of superiority of the effective temperature (T_{eff}) over dry bulb temperature (DBT) as an indicator of thermal comfort in certain climatic conditions remains controversial. T_{eff} is an index which was devised in 1920s in order to take into account not only DBT but also two other atmospheric factors which affected comfort, viz. humidity and air movement. Furthermore the T_{eff} scale was meant to give due weightage to the influence upon thermal comfort of even small changes of humidity and air movement. Later studies showed that the T_{eff} scale is generally satisfactory for predicting objective physiological strain (judged by sweat output) in ordinary warm atmospheres.[8] But as a predictor of the subjective feeling of thermal comfort in tropical warmth, T_{eff} has failed to show superiority over ordinary DBT. In climatic chamber experiments in which sedentary subjects were exposed to an ambient temperature which rose from an initial level of 70°F to a final level of 120°F in 2.5 h thermal discomfort was found to be better related to DBT than to T_{eff}[3]. In natural outdoor and indoor conditions in Calcutta it has been noticed that T_{eff} is hardly better than DBT for predicting thermal comfort.[7] In Singapore, however, T_{eff} was found to be a better index than DBT for predicting thermal comfort indoors.[5] In the present study T_{eff} was found to be no better than DBT in demonstrating diurnal and seasonal effects upon thermal comfort. Perhaps T_{eff} would outclass DBT in conditions where air movement is considerable. Natural outdoor air movement in equatorial climates is often small, and it is still less indoors during daytime.[11] The mean speed in the 170 readings made at 9.30h was 0.16 m/s SD 0.094 m/s (32 ft/min. SD 18.5 ft/min). As to the influence of humidity, the effective temperature scale assumes that thermal comfort improves when relative humidity falls. It is questionable whether this is so for peoples living in humid climates. It may be worth exploring whether it is the other way around for them, i.e. whether relative humidity may contribute to thermal comfort. When ambient temperature is rising, discomfort sets in slowly in highly humid air and abruptly in moderately humid air.[3] Effective temperature could therefore be a poorer indicator of thermal comfort than is the dry bulb temperature on days when the diurnal swing in relative humidity is large. The average relative humidity in Sri Lanka is about 80 per cent and the daily variation is small, e.g. a relative humidity of 75% by day and 90% by night. But in the warm season the afternoon relative humidity in Peradeniya often falls to 50% or even 40%, and this is accompanied by thermal discomfort which has a 'dry heat' quality. Wet bulb temperature (WBT), which falls below DBT as the humidity falls, was a poor indicator of thermal comfort.

The 'equatorial comfort index 'ECI',[11] which is an adaptation of the effective temperature scale for equatorial climates, could not be systematically used in the present work because its lower limit of 75°F was above the level of many of the readings for ambient temperature, especially wet bulb readings. For such ECI readings as could be taken in the present work, the same patterns of seasonal

acclimatization were visible as with DBT and T_{eff}. There were slight indications that ECI might be a better predictor of afternoon thermal discomfort.

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Photooxidation of Water by Ferric Hexathiocyanate

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Abstract: Ferric hexathiocyanate ion is found to oxidize water on irradiation with visible and near U.V. light (quantum yield $\sim 0.2\%$). Reaction rates are measured and a simple theory is presented to explain the results.

1. Introduction

In recent years the studies on photodissociation of water has received great deal of attention.[1,8] The methods proposed for the achievement of these oxidation reduction processes fall into three main categories - photoelectrochemical cells [2,3] semiconductor powder suspensions[7,10] and redox systems with stable sensitizers.[4,8] Regenerative systems of the third type with stable inorganic sensitizers seems to be one of the most promising methods for conversion and storage of solar energy.[8] In this work we report our observations on oxidation of water by visible and near U.V. light ($\lambda < 360$ nm) in presence of the ferric hexathiocyanate (FH) ion.

2. Experimental

Ferric chloride solution (~ 0.01 mol dm^{-3}) is centrifuged to remove the ferric hydroxide suspension and the Fe^{+} concentration is determined. Aqueous KCNS is mixed with the above until the resulting solution is 1.0×10^{-4} mol dm^{-3} in Fe^{3+} and 0.01 mol dm^{-3} in KCNS. The pH is adjusted by addition of HCl maintaining these concentrations. Photolysis is carried out in a rectangular glass cell (7.5 cm x 6 cm x 3 cm) using a medium pressure mercury lamp (100W). Experiments are also carried out in direct sunlight. In all cases U.V light is $\lambda \lesssim 360$ nm filtered off with pyrex glass sheets and the intensity is estimated using a calibrated thermopile. The time variation of the concentration of FH under constant irradiation is determined by colorimetry. To remove photogenerated O_2, the solution is kept purged with oxygen free N_2. The oxygen entry from the atmosphere is completely prevented. Absorption spectra and molar extinction coefficients are measured using the Unicamp Sp 500 Series II spectrophotometer.

3. Results

A plot of C/C_o (C_o, C = concentrations of FH at time t = 0,t) is indicated in Figure 1. There is no evidence for an equilibrium, the reaction proceeds in the forward direction until all ferric ions are reduced. Again it is found that the plots of

ln (C/C_o) vs t are linear (Figure 2) with slopes independent of temperature and the concentration of KCNS but directly proportional to[OH^-] and the irradiation intensity. The reaction occurs when $\lambda \lesssim 550$ nm, this corresponds to absorption region of the FH ion (Figure 3). At a given intensity of illumination (λ, 360 - 550 nm) there is a tendency for the slopes to decrease with the increase of wave length. Unfortunately we did not have facilities to investigate the wave length dependence of the reaction rate.

4. Theory and Discussion

Experimental results indicate that the reaction obeys simple apparently unimolecular kinetics. It is possible to give a simple theory to explain these observations. The photoactive species in the solution is FH ion generated via,

$$Fe^{3+} + 6CNS^- \rightleftharpoons Fe(CNS)_6^{3-} \qquad (1)$$

We assume that the primary photochemical act is the formation of excited ions

$$Fe(CNS)_6^{3-} \overset{h\nu}{\rightleftharpoons} Fe^*(CNS)_6^{3-} \qquad (2)$$

and these participate in the oxidation process

$$Fe(CNS)_6^{3-} + OH^- \rightarrow Fe^{2+} + 6CNS^- + \underset{\downarrow O_2}{OH} \qquad (3)$$

The step (3) can be written in other equivalent ways (CNS^- does not complex with Fe^{2+}). Since the rate of (3) is proportional to (FH*)(OH^-) and (FH*) in turn is proportional [FH] via (2) have,

$$dC/dt = -kcC \qquad (4)$$

$$\text{ie } C = C_o e^{-t/\tau},$$

where $c = [OH^-]$, which remains nearly constant and $\tau = (ke)^{-1}$. The rate constant k is proportional to the number of photons absorbed per ion and if the reaction is carried out in a cell of volume V, cross sectional area A and length l

$$k = \frac{IA\eta}{CV} \qquad (5)$$

where I = einsteins absorbed per sec from light passing through unit area of the cell and η = a constant which is a measure of the quantum yield (quantum yield per unit concentration of OH^-). From Beer-Lambert law,

$$I = I_o(1 - e^{-x}) \simeq I_o x, \qquad x = \varepsilon c l \qquad (6)$$

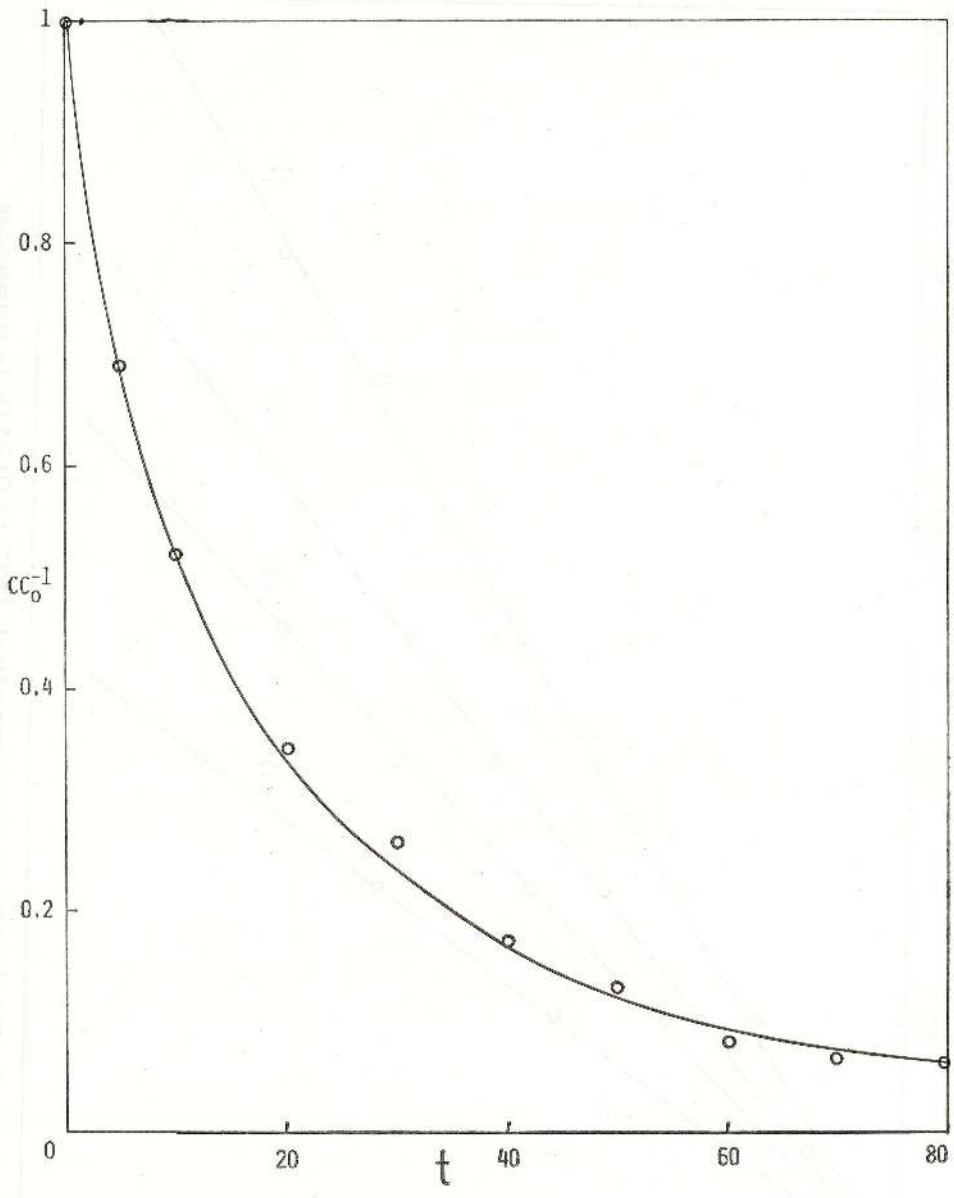

FIGURE 1 — Plot of C/C_0 vs t (pH = 1.2, irradiation intensity = 1.5×10^{-7} einsteins $cm^{-2}sec^{-1}$ from a 100 W mercury lamp, $\lambda < 360$ nm filtered off)

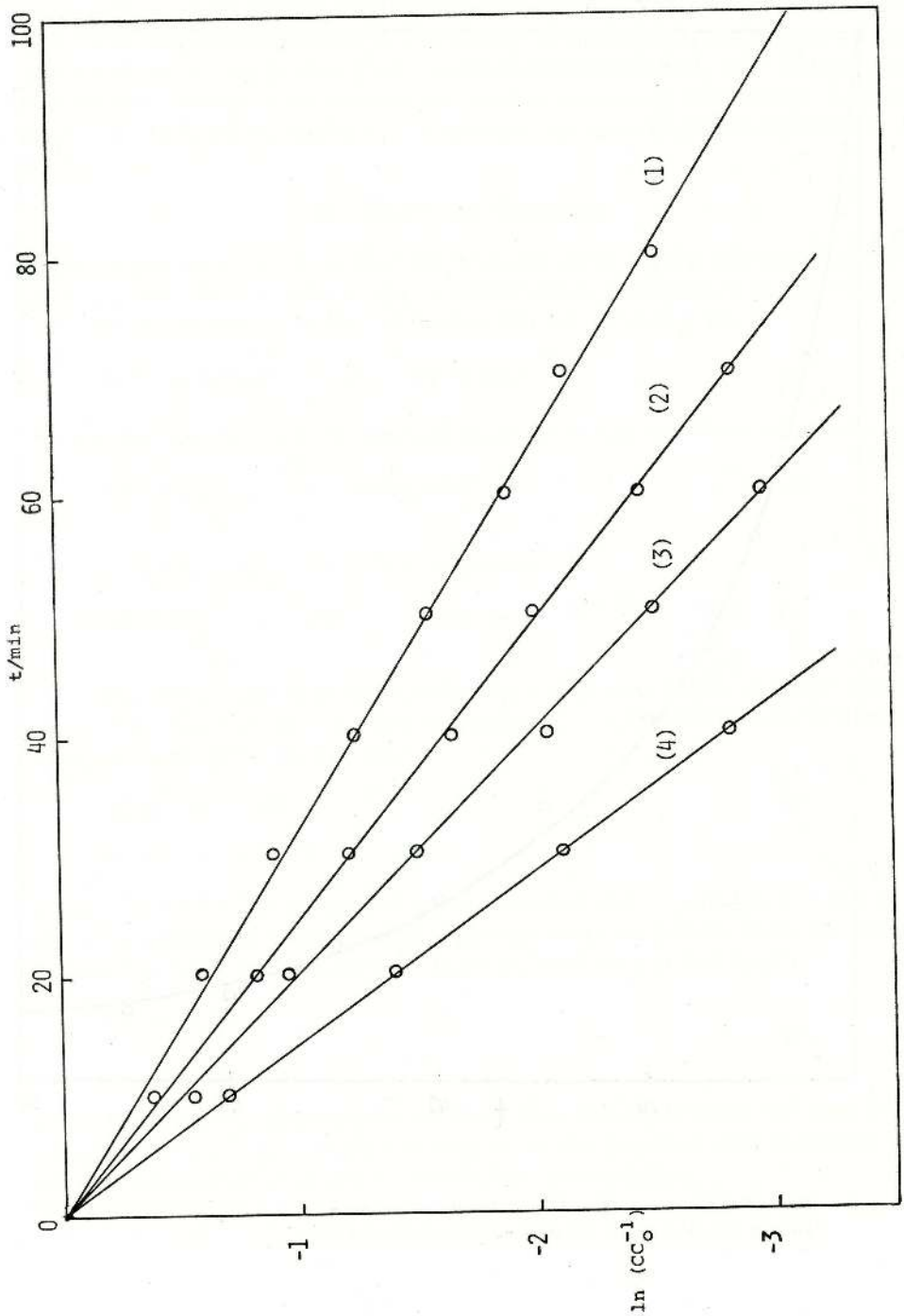

FIGURE 2 — Plot of ln (CC_o^{-1}) vs t at different p Hs (1) 0.6 (2) 1.2 (3) 2.5 (4) 3.8 corresponding value τ are 32, 25, 20 and 14 mins respectively.

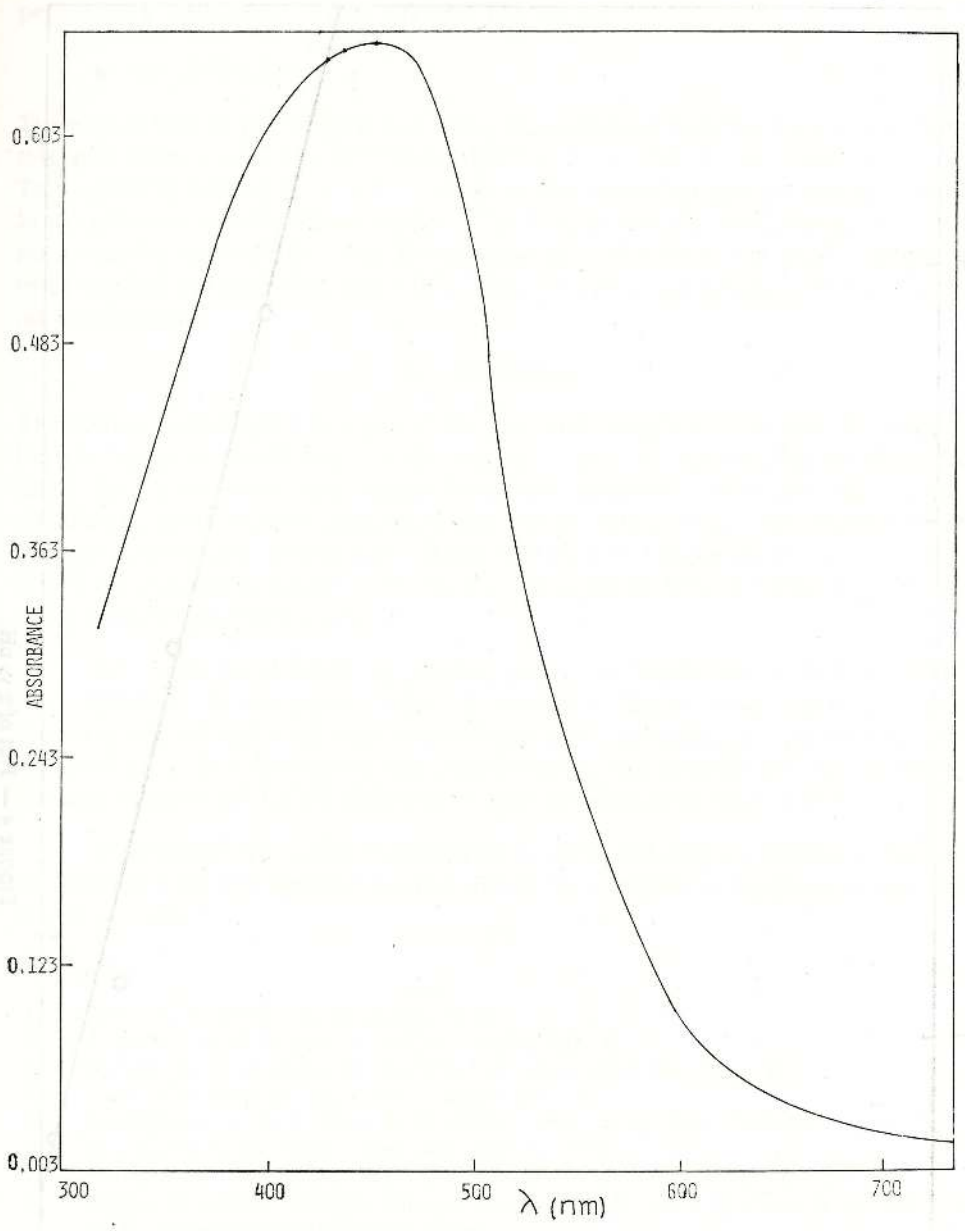

FIGURE 3 — Absorption spectrum of Ferric hexathiocyanate solution (1 cm cell, concentration ~ 1×10^{-4} mol dm^{-3}).

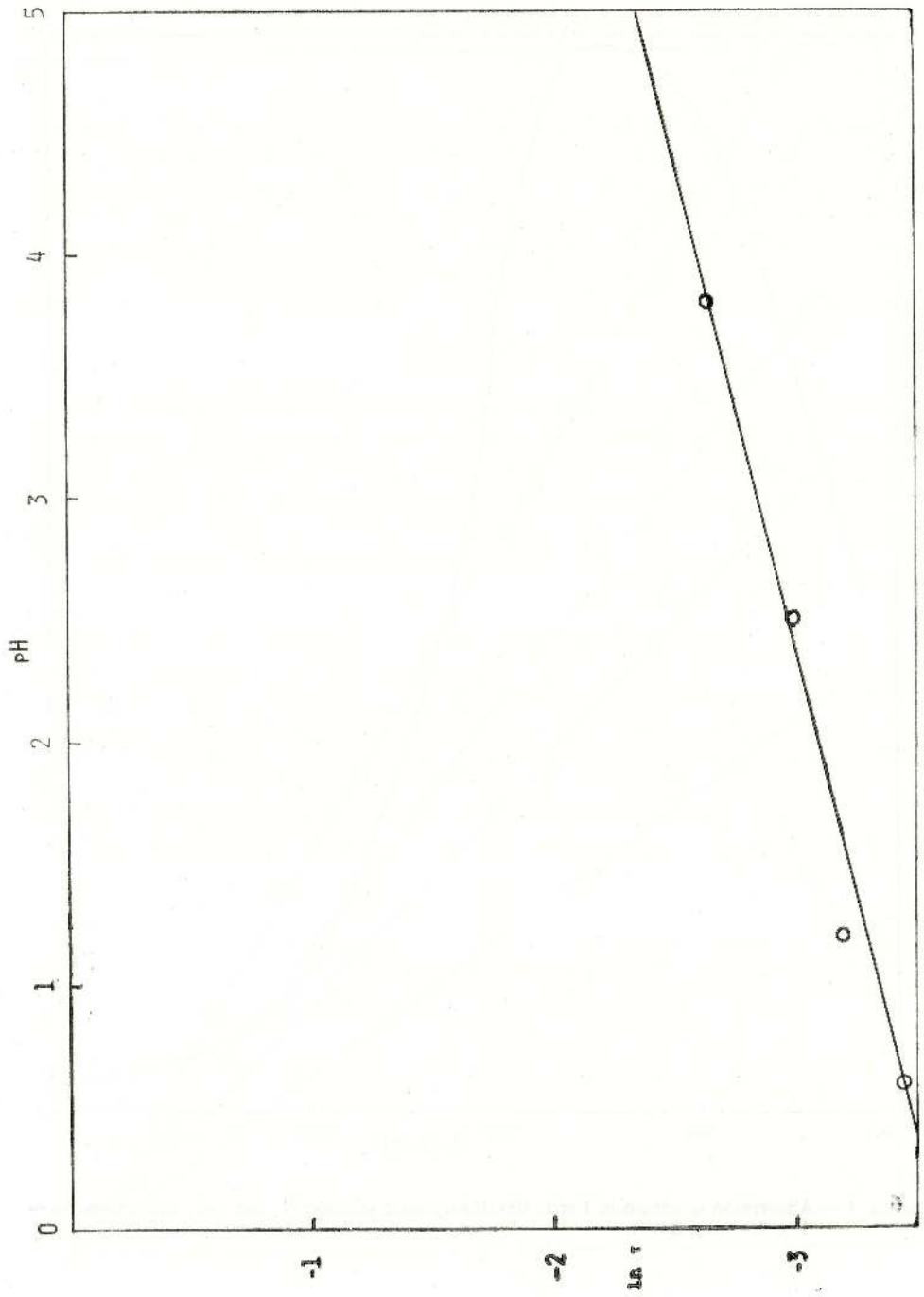

FIGURE 4 — Plot of τ vs pH.

where ϵ = extinction coefficient, I_0 = einsteins incident on front face of the cell per sec per unit area. From (5) and (6) we get

$$k = 2.303\ I_0\ \epsilon\eta \qquad (7)$$

The plot of ln τ va pH (Figure 4) is linear in agreement with the theory, the slope this plot gives $\eta = 2.1 \times 10^{10}$ mol^{-1} dm^3 for $I_0 \simeq 1.5 \times 10^{-7}$ einsteins cm^{-2} sec^{-1}. Thus $\eta[OH^-]$ (pH = 3) $\simeq$ 0.23% which is the maximum possible quantum yield as the pH cannot be increased further. The reason why τ is independent of temperature can be understood. The de-excitation time of FH* is very small compared to its thermal collision time with OH^-. Thus the rate of the reaction cannot depend on temperature.

5. Conclusion

The system is interesting because of the extremely simple kinetics and the adaptability to accurate measurement of the reaction rates. As the quantum yield is quite small, the O_2 evolution rate cannot be directly measured. However, the analysis of outgoing gases used for purging reveals the presence of O_2. The analysis of the residual solution also proves that oxygen evolution had taken place. The molarity of KCNS remains constant while ferric is reduced to ferrous, showing that any other material had not oxidized.

Fe^{3+} ions are known to oxidize water on irradiation with U.V light[10] ($\lambda < 300$ nm). In our process which is sensitive to higher wave lengths the active species is FH ion and there is no evidence that Fe^{3+} participate in the primary photochemical act. The shifting of the equilibrium in (1) towards left by decreasing the concentration of KCNS does not change the quantum yield of Fe^{2+}.

In principle the system is regenerative, when atmospheric oxygen is allowed to combine with the reduced product the ferric complex is regenerated with the release of energy.

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Studies on the Repellency of some Plant Distillates to Adult *Sitophilus* sp.

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Abstract: The volatile distillates of leaves of *Ocimum sanctum, Vitex negundo, Azadirachta indica* and *Citrus aurantifolia* were investigated for repellency to *Sitophilus* sp. in the laboratory using a Y-shaped olfactometer. Of the plant distillates tested *O. sanctum* was found to be the most effective repellent to *Sitophilus* sp. The other plant distillates tested showed repellency of a significantly lesser degree than *O. sanctum.* The repellency of the synergistic combination of volatile distillates of *O. sanctum* and *A. indica* was found to be as effective as that of *O. sanctum* alone. With regard to the duration of the repellent effect of the steam distillates (crude water extracts) of the plants tested, it was found that the freshly prepared and 10 day old preparation of *O. sanctum* had the same effect. The 20 and 30 day old preparation of *O. sanctum* showed significantly lesser repellency than the freshly prepared or 10 day old preparation of *O. sanctum.*

1. Introduction

The rice weevil (*Sitophilus* sp.) is an important pest of rice in some parts of Sri Lanka.[2,3] Juriansz[5] made a preliminary study on the efficacy of essential oils such as Lime leaf oil as a repellent to *Sitophilus.* Krishnarajah and Ganesalingam[6] have shown that the steam distillates of certain plants repelled *Sitotroga cerealella.* The present study was carried out to evaluate the repellency of the extracts of certain plants to adult *Sitophilus* sp.

2. Materials and Methods

Sitophilus culture was maintained on rice in the laboratory. The culture contained *Sitophilus oryzae* (L.) and *Sitophilus zeamais* Mostch. which usually occur together in storage.[3,4]

The leaf samples were steam distilled and the distillate was extracted with ether. The water from the ether extract was removed by anhydrous sodium sulphate and the ether was removed under reduced pressure. This volatile extract was used in Experiments 1 and 2. In Experiment 3 the volatile matter used was direct steam distillate after separation in a separating funnel (crude water extract). The leaves of the following plants were used in this study:

a. *Ocimum sanctum* L. — Madura-tala (S); Tulasi (T)

b. *Vitex negundo* (L.) — Nikka (S); Nochchi (T)

c. *Azadirachta indica* (A. Juss.) — Kohomba (S); Vembu (T)

d. *Citrus aurantifolia* (Christan) Swingle — Dehi (S); Elumichai (T)

The repellency of the extract was determined using a Y-shaped olfactometer (Figure 1). A filter paper (1.0 cm x 0.3 cm) moistened with 3 μl of the extract, was placed in one arm; a filter paper of the same size moistened with 3 μl of distilled water was placed in the other arm as a control. The opening of the arms of the Y tube was plugged with cotton wool. Ten adult insects of the same age were introduced into the main arm. The insects moved forwards and subsequently moved *either* into the arm containing the repellent *or* into the other arm. The number of insects recorded in the arm containing distilled water represented the number repelled by the extract. This was repeated keeping the extract in the other arm. Fifteen replicates were taken in each experiment. However some beetles did not show any response in the experiment while some of them died during the experimental period, and their numbers were not taken into account. The olfactometer was washed with distilled water and dried and the position of the arms were changed at every replicate. The whole experiment was carried out in a dark room with ten watts light kept 60 cm away from the front part of the olfactometer. Preliminary experiments were conducted in order to confirm that the movement of the beetles towards either arm was random by introducing the beetles into the main stem of the olfactometer without test materials in it. Nearly equal number of beetles moved to either arm when 50 beetles were introduced into the main stem in five replicates.

The experiments were conducted at room temperature 30°C $\pm$ 2, and R.H 80% $\pm$ 2.

3. Results

When the number of *Sitophilus* sp.. moving towards the various volatile distillates such as *O. sanctum*, *V. negundo*, *A. indica* and *C. aurantifolia* was compared with that moving towards distilled water by x^2 test, it was found that the repellency of the extracts of these plants differ from one another ($P > 5\%$ for each extract). Anova test applied to the results showed that *O. sanctum* had a repellency that was significantly higher than that of other plants tested and the repellency of the distillates of the other plants did not show any significant difference among themselves.

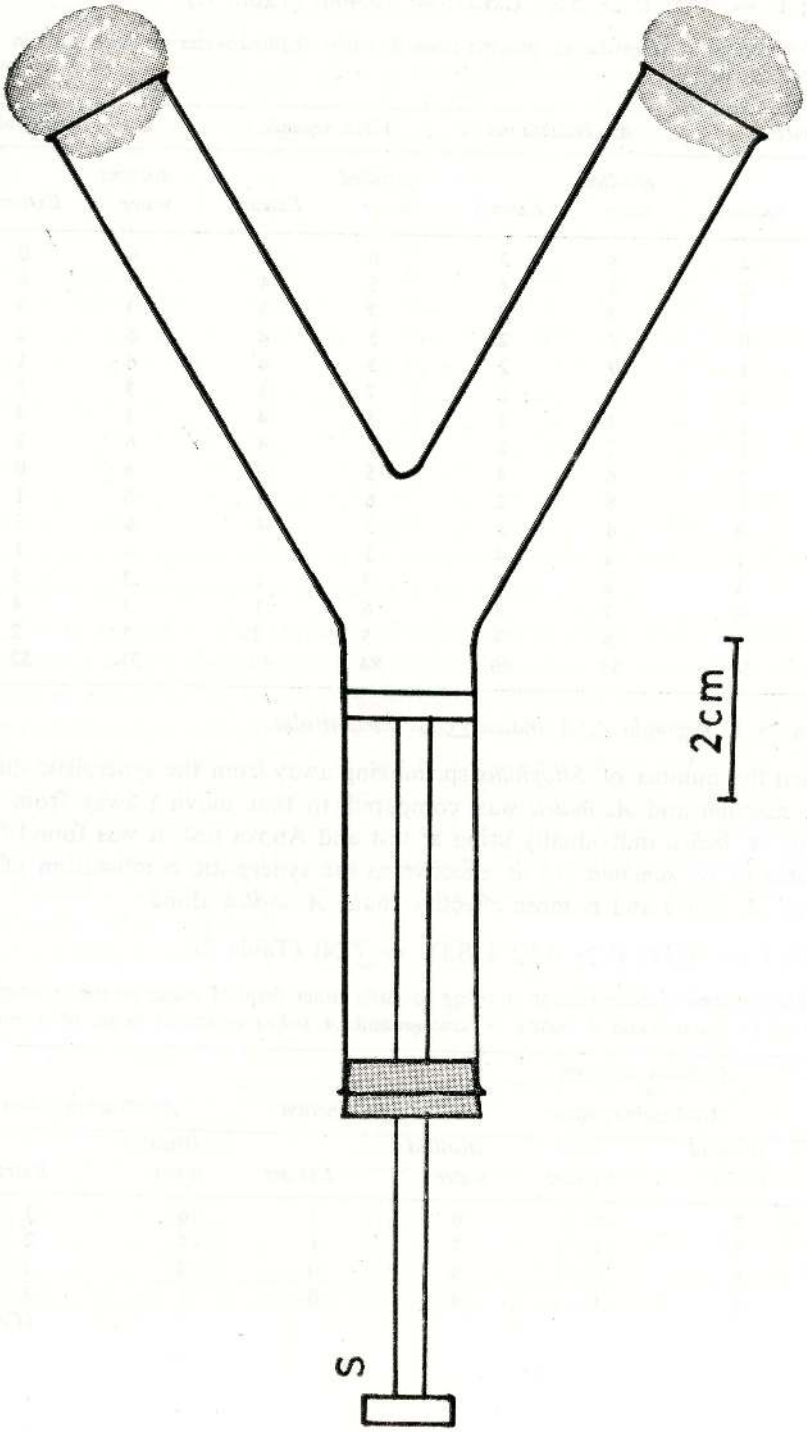

FIGURE 1. — Y - shaped olfactometer and Syringe (S)

($F = 3.56$; $F = 7.45$; $P > 5\%$; L.S.D. = 10.460) (Table 1.)

TABLE 1. The number of *Sitophilus* sp. moving towards *either* distilled water or the extract in olfactometer

Ocimum sanctum		*Azadirachta indica*		*Vitex negundo*		*Citrus aurantifolia*	
distilled water	*Extract*	*distilled water*	*Extract*	*distilled water*	*Extract*	*distilled water*	*Extract*
8	2	8	2	6	1	6	0
7	0	6	4	5	4	3	4
6	1	4	3	7	1	3	3
7	0	8	2	5	4	6	2
9	1	7	2	5	4	6	1
8	2	8	2	7	1	3	3
7	1	4	3	5	4	3	4
8	1	7	2	5	4	6	2
8	2	6	4	5	3	6	0
6	1	8	2	6	1	6	1
7	0	4	3	5	4	6	2
7	1	6	4	5	3	6	1
9	1	8	2	7	1	3	3
7	0	7	2	6	1	3	4
6	1	6	3	5	4	5	2
Total 110	14	97	40	84	40	71	32

O. sanctum > *V. negundo* △ *A. indica* △ *C. aurantifolia.*

When the number of *Sitophilus* sp. moving away from the synergistic distillate of *O. sanctum* and *A. indica* was compared to that moving away from *O. sanctum* and *A. indica* individually using x^2 test and Anova test, it was found that the distillates of *O. sanctum* are as effective as the synergistic combination of *O. sanctum* and *A. indica* and is more effective than *A. indica* alone.

($F = 2.42$; $f = 36.49$; $P > 5\%$; L.S.D. = 7.24) (Table 2).

TABLE 2. The number of *Sitophilus* sp. moving towards *either* distilled water *or* the synergistic combination of *O. sanctum* and *A. indica*, *O. sanctum* and *A. indica* separately in an olfactometer

Ocimum sanctum + *Azadirachta indica*		*Ocimum sanctum*		*Azadirachta indica*	
Distilled Water	*Extract*	*Distilled water*	*Extract*	*Distilled water*	*Extract*
7	0	6	3	6	3
7	1	7	1	4	2
8	1	9	0	4	3
5	1	8	0	6	3

(*Contd.*)

(Table 2 Continued)

	Ocimum sanctum + *Azadirachta indica*		*Ocimum sanctum*		*Azadirachta indica*	
	Distilled Water	*Extract*	*Distilled water*	*Extract*	*Distilled water*	*Extract*
	6	1	7	2	6	2
	8	1	8	1	4	5
	6	1	6	1	6	1
	5	1	6	0	5	4
	6	1	6	3	4	5
	7	1	6	0	4	3
	5	1	6	1	4	2
	8	1	7	2	5	4
	7	1	6	0	4	2
	8	1	7	2	4	3
	7	1	8	1	4	5
Total	100	14	103	17	70	47

O. sanctum △ *O. sanctum* + *A. indica* > *A. indica*

With regard to the duration of the repelling effect of the distillates of the plant extract (crude water extract) of plants tested, when the mean percentages of the number of *Sitophilus sp.* moving away from the distillate was compared in respect to age of the plant extracts by Anova test, it was found that the freshly prepared and ten day old extracts of *O. sanctum* had the same effect. However, 20 and 30 day old distillates of the *O. sanctum* showed significantly less repellency than the freshly prepared or ten day extracts of *O. sanctum*. Similarly the freshly prepared, 10, 20 and 30 day old extracts of the other plants used in the experiment also showed a significantly lower repellency than the freshly prepared or ten day old extracts of *O. sanctum*.

($F = 15.239$; $F = 11.92$; $P > 5\%$; L.S.D. $= 9.118$) (Table 3).

TABLE 3. Effect of time on the repelling effect of the plant extracts (Crude water extracts) to *Sitophilus* sp.

Time	*Mean percentage of Sitophilus sp. moving away from the extracts*			
	Ocimum sanctum	*Vitex negundo*	*Azadirachta indica*	*Citrus aurantifolia*
0 day	91.705	68.819	71.094	64.920
10 days	74.954	60.928	63.906	52.687
20 days	67.873	54.0	67.620	55.716
30 days	67.150	58.453	52.381	52.064

O. sanctum (fresh) △ *O. sanctum* (10 day) > *O. sanctum* (20 - 30 day).

4. Discussion

Juriansz[5] observed repulsion of *Sitophilus* to lime leaf oil. A comparative study of repulsion of *Sitophilus* to various plant extracts was made in this investigation, and it was found that the extract of *O. sanctum* was the most effective repellent used to the rice weevil. It has been recorded however, that *Vitex negundo* is the most effective repellent to *Sitotroga cerealella*.[6] The plant extract of *Azadirachta indica* was reported to be an effective repellent to *Sitotroga cerealella*.[1] The products of some plants, treated or untreated, are useful as insect repellents. However, it appears that the repellent for one pest species may not be effective for another. The extraction of plant products without loss of their essential oils will be of great value in selecting the appropriate repellent to each pest.

It has been recorded that the effect of two repellents was greater than the repellency of the individual plant extracts.[7,8] However, in this study the synergistic mixture of *O. sanctum* and *A. indica* seems to be as effective as *O. sanctum* when used singly, and is more effective than *A. indica*.

In this study it was found that in the case of all plants used the freshly prepared extract was as effective as the 10 day old, while preparations which were older became progressively less effective with increasing age.

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Mercuric Iodide - Photocorrosion Resistant Semiconductor

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(*Date of acceptance: 27 November 1984*)

Abstract: n - Mercuric Iodide with layer crystal structure is found to resist photocorrosion when used as the anode in photoelectrochemical cells.

1. Introduction

In recent literature, a great deal of attention is given to photoelectrochemical cells as promising devices for conversion and/or storage of solar energy.[4,9] The advantages of these systems is that the insensitivity of the photoresponse to defects and impurities in the semiconductor - polycrystalline and amorphous materials give results comparable to single crystal slices.[8,11] However, they are plagued with photocorrosion. Most semiconductors show a noticeable rate of photocorrosion even if best possible redox electrolytes are used.[6,7] Recently it has been found that semiconducting materials with layered crystal structure (e.g. MoS_2, WSe_2) strongly resist photocorrosion.[12] In this note we report our observations on photocorrosion resistance of red mercuric iodide which is known to have a layered crystal structure.[14]

2. Experimental

Red HgI_2 (α) has a layer structure with HgI^{2-}_4 tetrahedra linked the vertices.[14] The α- phase is stable up to 400° K.[14] Above this temperature, the yellow HgI_2 (β) is more stable. Red HgI_2 behaves as a n - type semiconductor of band gap 2.37 eV.[2,10] In all experiments analytical grade (BDH brand) HgI_2 is used. HgI_2 made by double decomposition of mercuric chloride with potassium iodide gives identical results.

The photoanode is made by depositing HgI_2 on a platinum foil by vacuum sublimation at ~ 423°K. The yellow form which is deposited reverts to the red α-phase few minutes after cooling to the room temperature. The counterelectrode used is a Pt foil and the electrolyte is O.1 mol dm^{-3} solution of sodium sulphate. The time development (cathode illuminated at ~ 40 Wm^{-2} from a mercury lamp) of the open circuit voltage V_{oc} and the short circuit current density (J_{sc}) is given in Figure 1. V_{oc} and J_{sc} remain practically constant demonstrating the photostability of HgI_2.

3. Results

Oxygen evolution can be seen at the photoanode. In the presence of atmospheric oxygen the cell operates in the photogalvanic mode where O_2 reduction instead of H_2 evolution takes place at the cathode. When the electrolyte is purged with

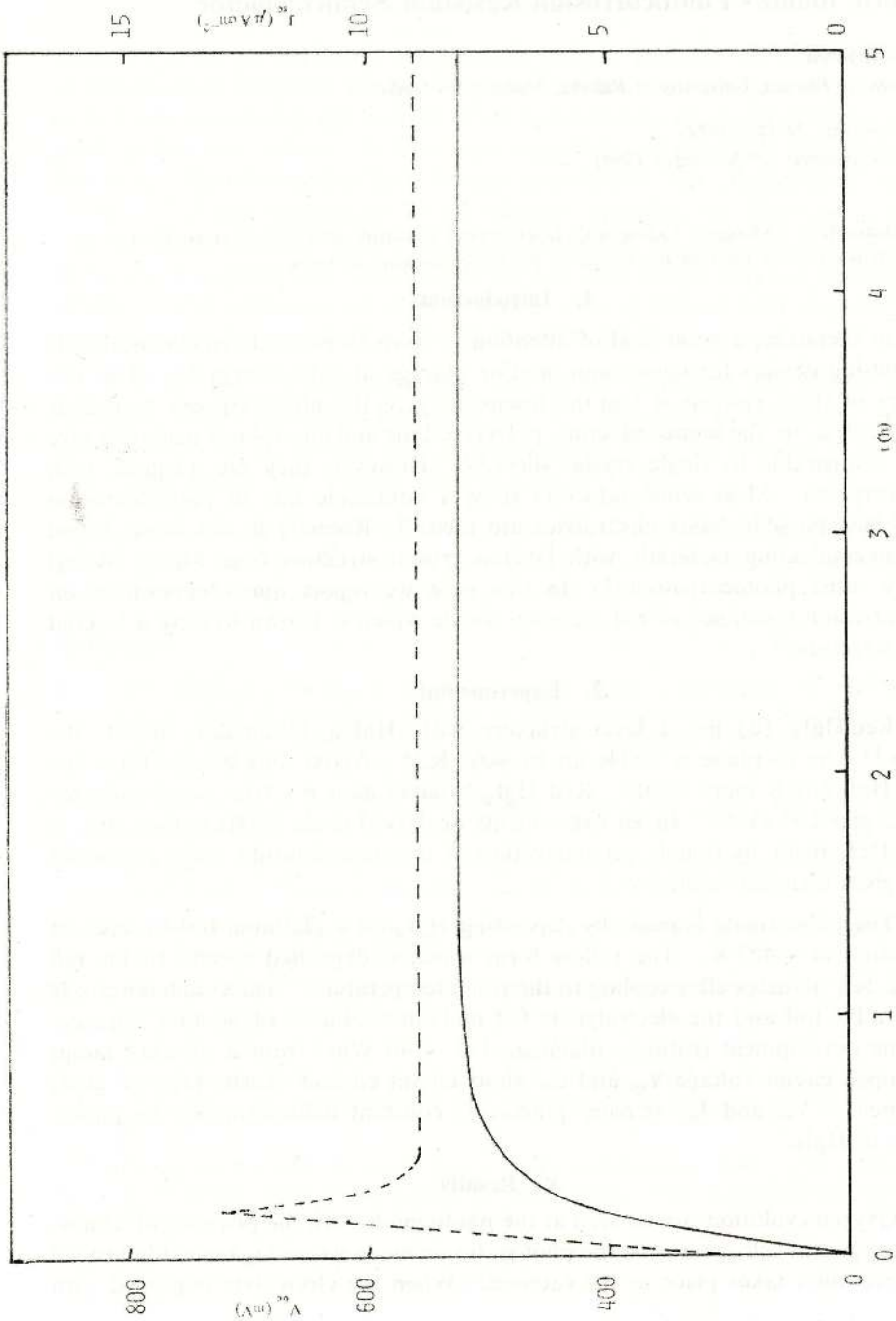

FIGURE 1. — The plots of V_{oc} vs t (continuous line) and J_{sc} vs t (broken line) when the cathode is illuminated at 40 Wm^{-2} from a mercury lamp.

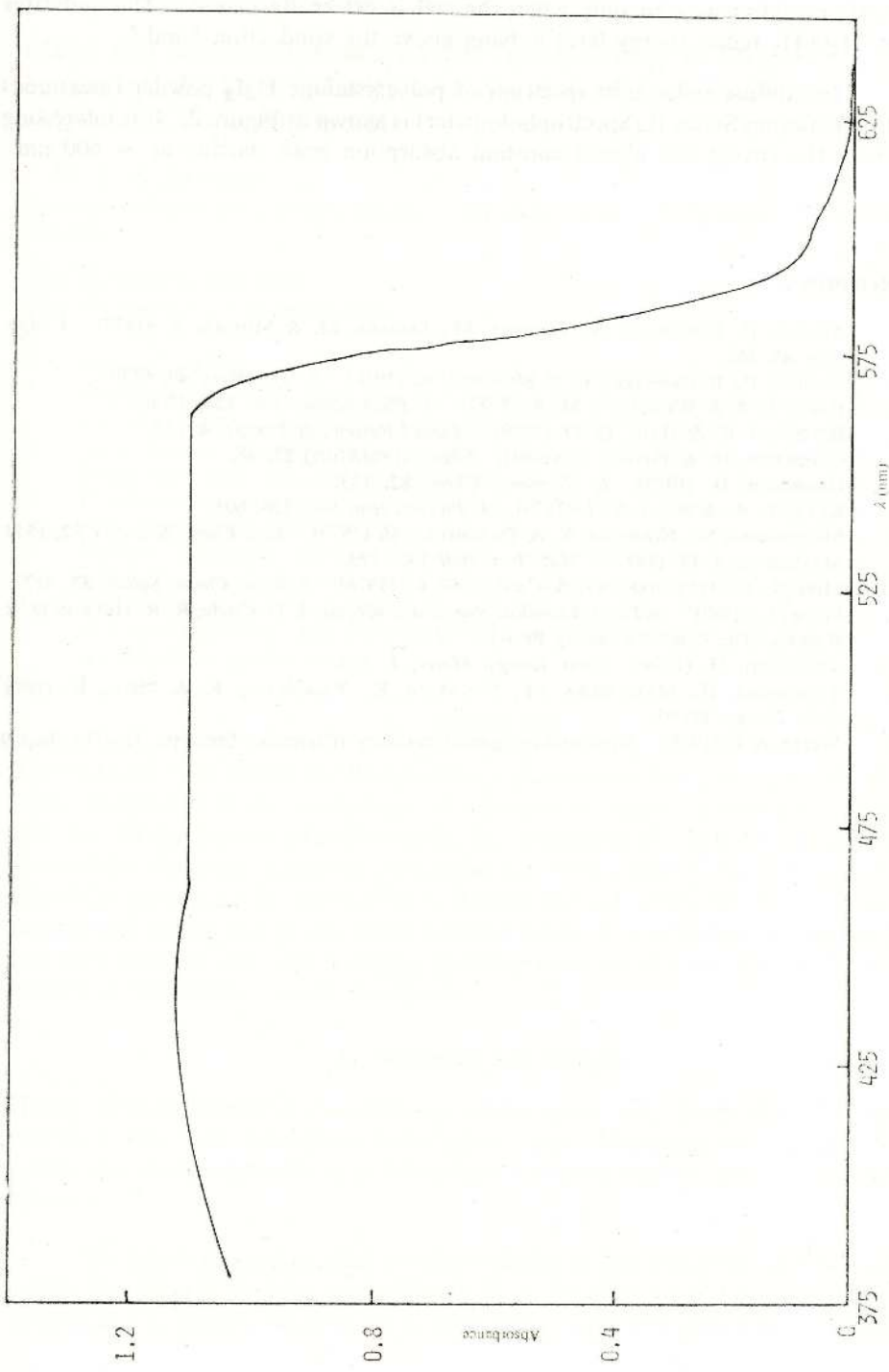

FIGURE 2 — Diffuse reflectance spectrum of HgI_2.

N_2, H_2 evolution is seen only when the cell is externally biased. This indicates that H_2O/H_2 redox energy level is lying above the conduction band.[5]

The diffuse reflectance spectrum of polycrystalline HgI_2 powder (measured) with a Unicamp Series II (Spectrophotometer) is shown in Figure 2. It is interesting to note the strong and almost constant absorption peak starting at ~ 600 nm.

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Effect of Chemical Treatments and Incorporation of Organic Matter on the Pathogenicity and Survival of *Pseudomonas solanacearum* (Smith) in Soil

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Abstract: All solanaceous crops cultivated in Sri Lanka except chilli cv. MI 1 were found to be susceptible to biotype 3 of *Pseudomonas solanacearum*. Bacterium was also proven pathogenic to some of the improved cultivars of AVRDC tomato selections. Organic manure (chicken manure, cowdung, and *Gliricidia* leaves) when incorporated into inoculated soil significant increase in number of propagules of *P. solanacearum* and severity of wilt disease in subsequent tomato cv. marglobe were observed in contrast to chemical treatments (lime, acetic acid, Benomyl and Captan). Significant reduction of bacterial population and disease severity was seen in Captan and Benomyl treated soil only. Organic manure treatments stimulated growth of both *P. solanacearum* and other saprophytic bacteria. The ratio of *P. solanacearum* to other bacteria showed a direct relationship to percentage wilt in a subsequent tomato crop.

1. Introduction

The bacterial wilt caused by *Pseudomonas solanacearum* E.F. Smith is one of the major constraints in the production of solanaceous crops. Bacterium survives in soils for varying periods of time even in the absence of the host.[10] The ability of the primary inoculum to survive during the non-crop period is therefore one of the important aspects to be considered in disease control. Survival of the pathogen may depend on the genetic and environmental factors it is subjected to. An attempt has been made to simulate a control practice based on the survival of *P. solanacearum* in soil under control conditions.

2. Materials and Methods

Highly virulent isolate of *Pseudomonas solanacearum* E.F. Smith biotype 3 sensu Hayward was used throughout these experiments. Pathogen was isolated from potato and its pathogenicity to potato plants was confirmed by stem and soil inoculation.

The nutrient medium used for the isolation of the bacterium and its routine culture was glucose peptone agar (Glucose 5.0 g, Peptone 5.0 g, Yeast extract 2.0 g, $KHPO_4$ 0.2 g, $MgSO_4.7H_2O$ 0.2 g, $CaCO_3$ 0.1 g, Agar 18.0 g in 1 litre of distilled

water). Virulence of the isolates were maintained by passing the cultures at least once in 6 weeks through tomato (*Lycopersicon esculentum* Mill) cv. marglobe. Cultures in agar or as suspensions in sterile distilled water were maintained at 21 ± 1°C in Precision low temperature incubators.

2.1 Pathogenicity tests

Pathogenicity of the bacterial isolates were confirmed by re-inoculating tomato plants. Five weeks old tomato cv. Marglobe plants raised in sterile soil were stem inoculated with the bacterial suspension containing 10^6 cells/ml. Bacterial suspension was prepared with 48 h cultures grown in glucose peptone agar. Three, 10μl drops of the suspension were placed on the axil of the third leaf from the top and the stem was then pricked with a syringe needle (gauge 25) through the inoculum drop.

Inoculated plants were placed in a green house (24°C night 28 - 33°C day). Plants were observed for the wilt and yellowing after three days from inoculation.

2.2 Evaluation of control measures

Cultivars of popular solanaceous crops were screened for resistance to *P. solanacearum* infection. Plants were inoculated either directly by stem inoculation or by transplanting into soil inoculated with *P. solanacearum*. In the latter to each plastic pot (diameter 15.5 cm) filled with 1.3 kg of sand loam soil (about 550 ml), 25 ml of *P. solanacearum* suspension 10^8 cells/ml was added. Soils were mixed thoroughly and left in the green house for three days before transplanting the test plants. Host plants used were tomato (*Lycopersicon esculentum* Mill.) cv. Marglobe, Katugastota selection and cvs. AVRDC selection No. CL 141.0.10.3, CL 113.2.4, CL 1561.6.0. 22.4, CL 1591.5.0.1.6, CL 1591.5.0.1.7, CL 1094, F_4-57, CL 11d.0.12.1, L1 and L 387. Egg plant (*Solanum melongenae*) cv. SM 164, Chilli (*Capsicum annuum*). cv. MI 1, (*Capsicum annuum* var. *grossum*) cv. CA 8, Potato (*Solanum tuberosum*).

2.3 Chemical and cultural methods

A sand loam soil collected from virgin land under a thick cover of grass near Meewatura research station of the Faculty of Agriculture was used. The physical analysis of soil reveals the following mechanical composition. Sand 75.40%, silt 10.32%, clay 14.32% and C = 3.05%. The soil was passed through a 2 mm sieve (End Cott. Ltd., London) prior to inoculation with *P. solanacearum*. Soil was inoculated as described above.

Inoculated pots were left in the green house for five days before transplanting five tomato cv. Marglobe seedlings raised in moist heat sterilized soil. One month after transplanting dead plant material was incorporated back into soil to develop "sick" soil. Pots were later emptied and the soil was mixed thoroughly before refilling the pots with "sick soil" for experimentation.

The pot trial consists of eight treatments. Each treatment was replicated five times. To each plastic pot (diameter 15.5 cm) 1.3 kg of "sick" soil was added.

In organic manure treatments 26 g of either sun-dried cattle manure, poultry manure or leaves of *Gliricidia maculata* was added to each pot. Two fungicides Captan and Benlate were used in addition to lime and acetic acid as chemical treatments. To each pot either 0.5 g in 100 ml of Captan (a.i. N-trichloro methyl thio tetrahydrophthalimide), 0.3 g in 100 ml water of Benlate (Dupont, Methyl (1-butylcarbamoyl) benzimidazol -2-ylcarbamate or Benomyl), 15 g of $CaCO_3$ or 25 ml of 10% acetic acid was added. Inoculated and uninoculated controls were used. Five weeks old tomato cv. Marglobe was transplanted as a test plant. Each treatment was replicated five times and pots were kept in the green house in completely randomized design.

2.4 Quantitative assessment of microflora

Population levels of *Aspergillus* sp., *Penicillium*, sp., *Pythium*, *Trichoderma* and *P. solanacearum* were estimated.

Five soil samples were taken from each pot at two weeks interval for 2 months using a No. 5 cork borer. Samples from all the pots were bulked together to form a composite sample. These samples were collected in polypropylene wide neck bottles and mixed by agitating on a Vortex Genie mixer before taking sub samples for the preparation of soil suspensions. Five sub samples were taken from each composite sample using No. 1 cork borer. This soil was used to make soil dilution 10^4 (w/v) in sterile distilled water.

Population of *Aspergillus* spp., *Trichoderma* spp., and other fungi were estimated by the dilution plate technique using Martin's medium.[11] One ml aliquots from the soil dilution (1:10^4) were pipetted into sterile petri dishes followed by 10 ml autoclaved Martin's medium to each plate and the soil suspension was mixed thoroughly with melted agar by swirling the freshly poured plates. Plates were incubated at 25°C in Precision low temperature incubator for 5-7 days and number of colonies of *Aspergillus* spp., *Penicillium* spp., *Trichoderma* spp. and other fungi were counted. Different species were identified by the characters described by Barnett[3] and Gilman.[7]

Population of actinomycetes were estimated by procedure adopted by William and Cross.[18] Inoculated plates were incubated for 8 - 10 days at 25°C before counting the number of actinomycital colonies per plate.

The survival of *P. solanacearum* in soils under different treatments was studied by monitoring the population levels at 3 weeks intervals. Selective medium proposed by Karganilla and Buddenhagen[9] was used for the estimation of the bacterial

populations. Colony counts as an average of five replicates at 10^{-4} dilution were recorded. Number of tomato cv. Marglobe plants wilted as percentage was recorded as estimates of pathogenicity.

3. Results and Discussion

Results of the pathogenicity tests showed that all cultivated varieties of *Solanacea* except chilli (pepper) cv. MI 1 are susceptible to *P. solanacearum* infection. Although initial symptoms of wilt appeared on the 3rd day after axil inoculation in most susceptible cultivars of the crops tested 100% wilt was recorded at a very early stage in commonly cultivated potato variety Arka 1 (Figure 1).

All the improved cultivars of tomato supplied by AVRDC and almost all other solanaceous crops tested were found to be susceptible to biotype 3 of *P. solanacearum*. It was found that 100% of the plants were wilted on the 13th day after axil inoculation. Since biotype 3 has an island-wide distribution and especially in tomato growing areas[2] any attempt to introduce new cultivars without proper soil sterilization or control measures will not be desirable.

Bacterial wilt thus remains potentially the most serious bacterial disease in solanaceous crops.

Effect of incorporation of organic manures and chemicals on the final disease severity in tomato plants are summarized in Table 1. There was a significant reduction in disease severity in Poultry manure treatment in comparison to control, although it remained at a high % of 40. However all organic manure additions have increased the disease severity.

TABLE 1. Effect of various soil treatments on the population of *Pseudomonas solanacearum*, other bacteria and bacterial wilt of Tomato (Marglobe) plants

Treatment	*pH*	*P. solanacearum*[a] *x* 10^3/*g soil*	*Other bacteria*[a]	*OB/PS ratio*	*%wilt*
Poultry manure	7.5	11.3	99.6	10	40
Cowdung	7.9	20.0	98.0	5	85
Glyricidia	7.2	42.3	166.0	4	75
Lime	7.4	7.0	126.0	18	5
Benlate	7.3	3.6	60.3	15	10
Captan	6.5	3.0	35.0	12	0
Acetic acid	5.0	3.0	22.3	7	0
Control	6.6	9.8	74.6	8	65
LSD at P = 0.01		8.02	22.6		5.84
0.05		6.05	18.7		5.10

a. Mean of 5 replicates after 9 weeks from treatments.

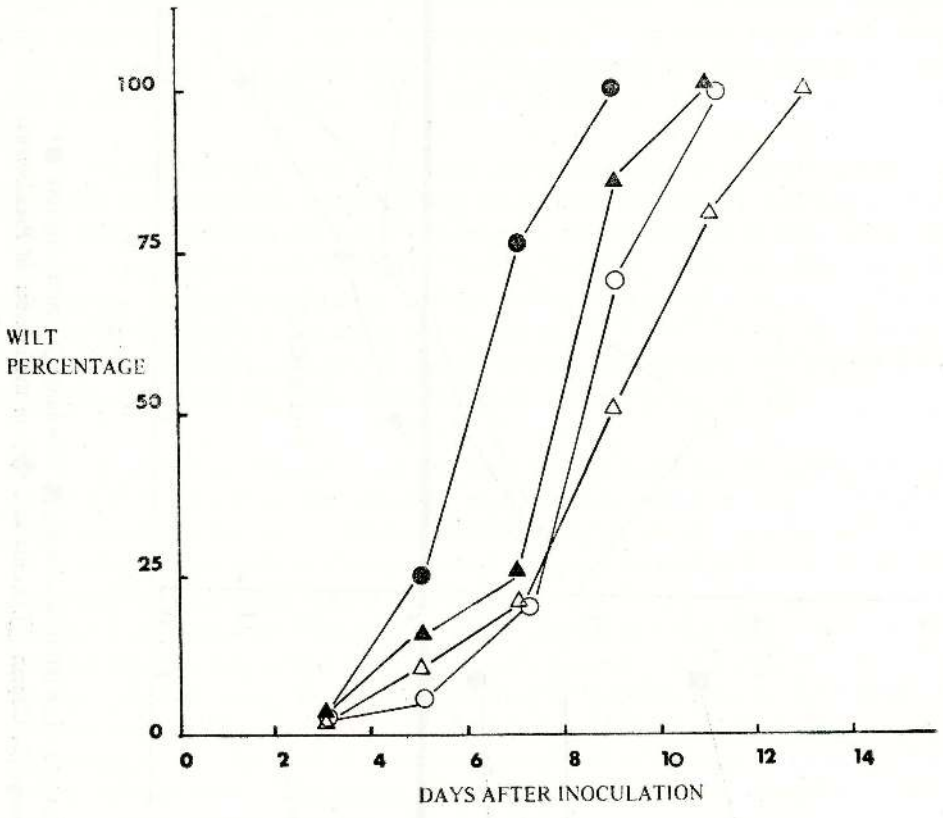

FIGURE 1 — Rate of wilting of few selected solanaceous crops artificial inoculation with *Pseudomonas solanacearum* (Smith) biotype III.

△ Tomato — Marglobe
▲ Brinjal — SM 164
○ Capsicum — CA 8
● Potato — Arka

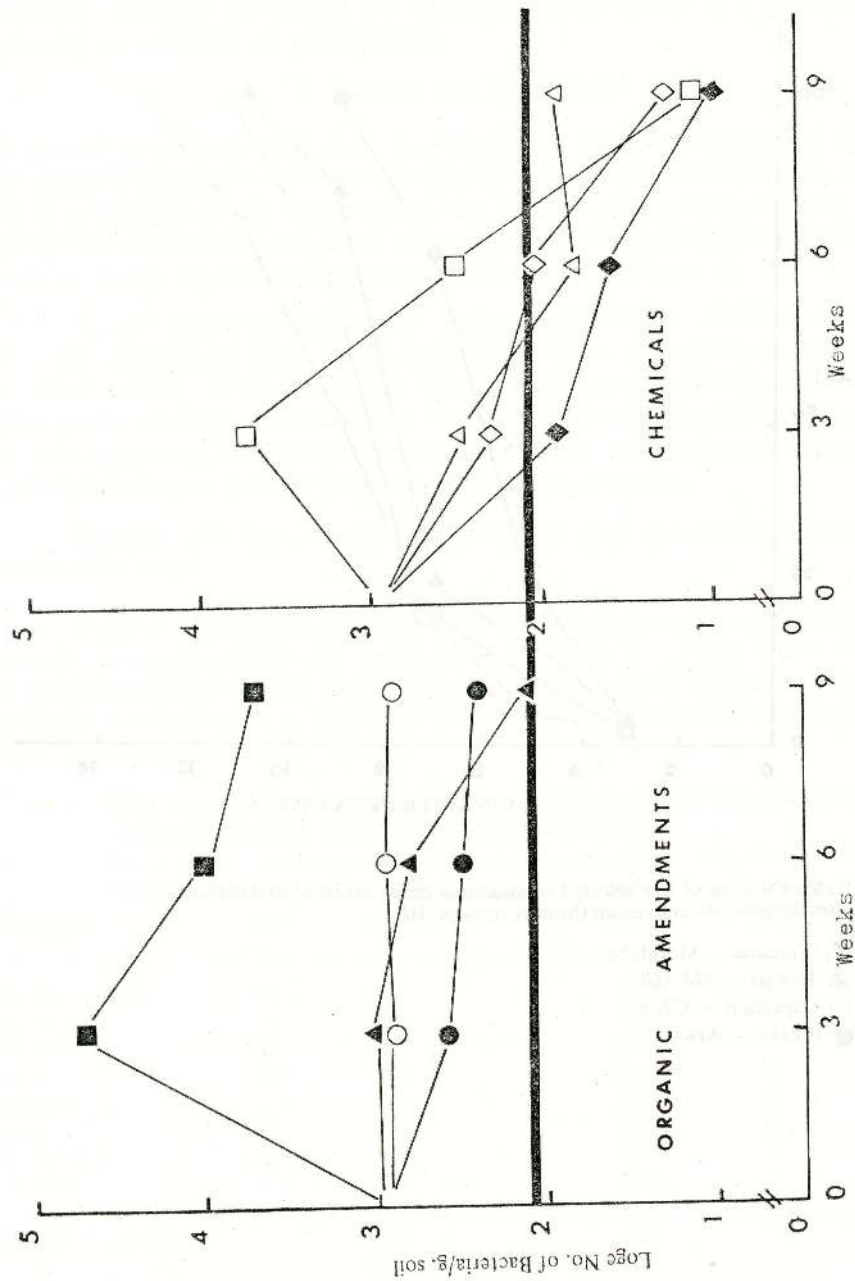

FIGURE 2 — Effect of incorporation of organic matter (Gliricidia leaves ■, Cowdung ○ Poultry manure ●) and chemicals (Lime △, Benomyl ◇, Captan □, Acetic acid ◈) on the number of *Pseudomonas solanacearum* in soil. Control ▲

Benomyl, Captan and Acetic acid applications to soil have significantly (P=0.05) reduced the disease level in subsequent tomato crops. It is evident from Table 1 that pH had little effect in disease development. The literature concerning the importance of pH however is contradictory.[10] In some respects it appears that the disease is more severe in soils with moderate to acid pH values (pH 5.0-5.5) but it also may be severe in alkaline soil with pH 7.0 - 7.5.[14]

Okabe[13] reported that *P. solanacearum* reproduces in soils with a pH of 5.0 but that the population decreased with an increase in soil pH. Untreated, inoculated control soil with pH 6.6 produced 65% wilt compared to Benomyl treated or lime incorporated soils with pH 7.3 - 7.4 (Table 1). However pH changes due to organic matter incorporation had no direct relationship with percentage wilt. Okabe[13] attributed low bacterial population at pH 7.1 - 7.7 to greater activity of microflora. The pH changes in organic matter incorporated soils are temporary changes and could be easily reversed to its original pH with time.

Since the solanaceous crops are short age irrigated and are commonly cultivated it is vital to know the behaviour of *P. solanacearum* in a short period of non crop seasons in the field. Further examinations of treated soil for the survival of *P. solanacearum* and the biology of other common microorganisms in soil revealed that addition of organic matter to soil was favourable for the multiplication and survival *P. solanacearum* (Figure 2). Table 1 shows that the change in population of other bacteria was similar to that of *P. solanacearum*. This indicates that various organic manure used in tomato-vegetable cultivation provide favourable soil environment for the multiplication of bacteria and their survival. However, it is interesting to note the ratio of *P. solanacearum* to other bacteria was directly related to the disease level. This could be due to the saprophytic competition offered by the non-pathogenic bacteria.

When the microflora was studied it was found that percentage wilt was not directly related to *P. solanacearum* in soil but its relative density in soil with respect to saprophytic bacteria (Table 1). Percentage wilt showed direct relation to other bacteria/*P. solanacearum* ratio (OB/PS) in all treatments except in acetic acid treated soil (Figure 3). This was probably due to extremely low pH 5.0 toxic effect of acid treatment that completely inhibited bacterial multiplication. Poultry manure in soil at pH 7.5 gave a OB/PS ratio 10. All soils with a OB/PS ratio higher than 10 were suppressive for wilt production.

Gliricidia leaves when incorporated into soil had a boosting effect on the *P. solanacearum* population. In almost all organic manure treatments it remains significantly higher than control even after 9 weeks. Although *P. solanacearum*

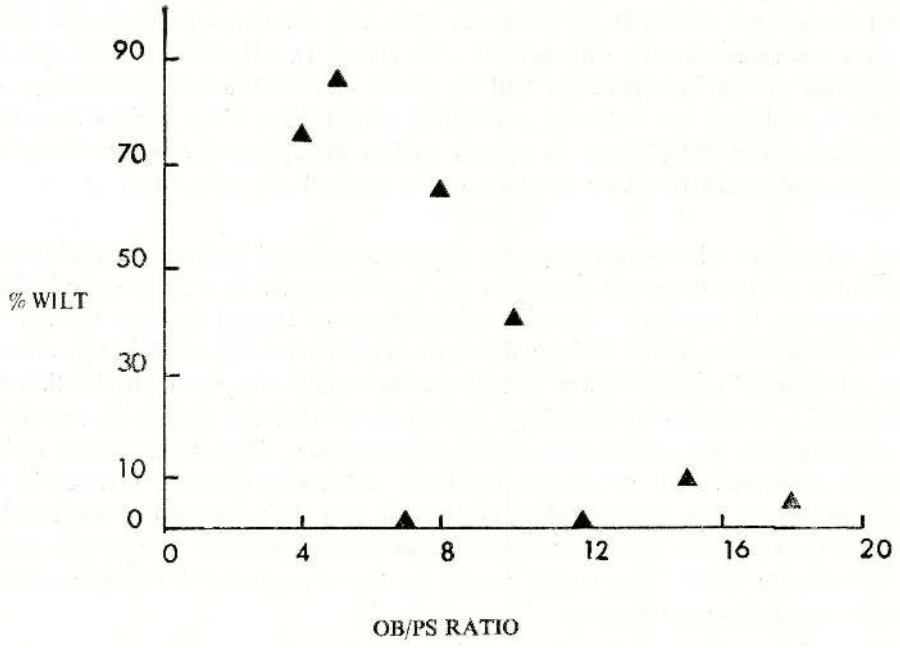

FIGURE 3 — Relationship between (No. of other bacteria/No. of *Pseudomonas solanacearum* OB/PS ratio and percentage wilt increased in tomato cv. Marglobe.

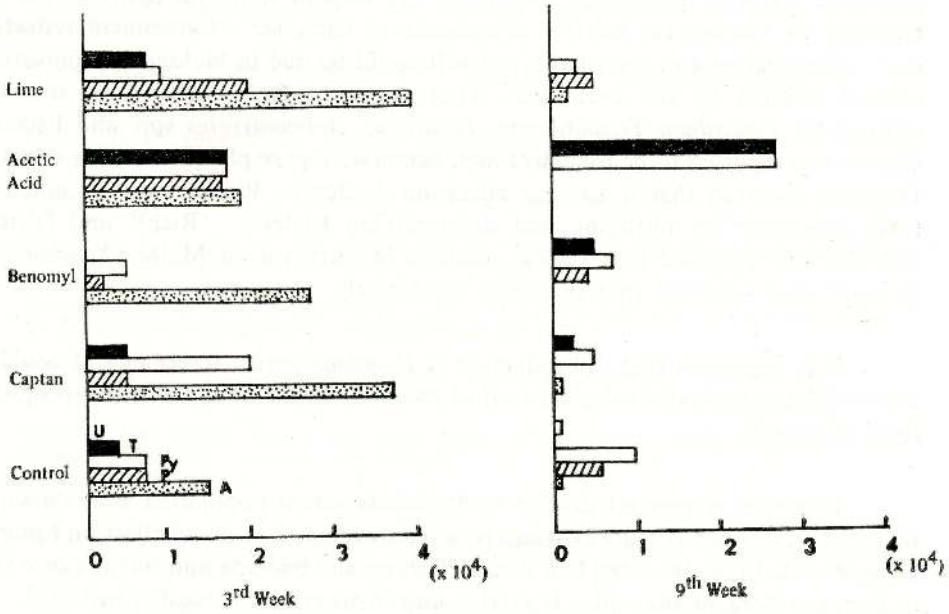

FIGURE 4 — Distribution of saprophytic fungi in soils treated with chemicals on the 3rd and 9th week after treatment.

A — Aspergillus spp.
P — Penicillium spp.
Py — Pythium spp.
T — Trichoderma spp.
U — Unidentified fungi

numbers in chemical amended soils were reduced, a significant reduction (at P=0.05) was obtained only in Captan, Acetic acid and Benomyl treatments (Figure 2). Effect of acetic acid could probably be due to its low pH and toxicity and therefore not desirable as a control practice.

The behaviour of *P. solanacearum* population in Captan and Benomyl treatments needs further discussion. Initial increase in bacterial population in Captan treatment was very prominent (Figure 2). A Captan spray on apple leaves was reported to increase the relative abundance of bacteria.[8] Subsequent reduction in *P. solanacearum* and severity (%) of wilt could be due to biological suppression/control initiated by the chemical.[1] They suggested that Captan may stimulate saprophytic *Penicillium Trichorderma, Fusarium, Actinomycetes* spp and bacteria. Captan was reported to be toxic to fungi, bacteria, higher plants and even insects.[17] Domsch[5] observed that it has no effect on bacteria. Picci[15] however noted its toxic properties on nitrifying and ammonifying bacteria. Rich[16] and Dienner and Carlton[4] reported that Captan controls Stewarts wilt in Maize (*Xanthomonas stewarti*) and bacterial spot of peach respectively.

It is suggested that the reduction in *P. solanacearum* levels in soil could be due to Captan initiated biological control probably by actinomycetes or saprophytic fungi (Figure 4).

However, a gradual decline in *P. solanacearum* population was shown in Benomyl treated soil (Figure 2), which is probably due to to a direct effect on bacteria. Fassan[6] stated that Benomyl had direct effect on soil bacteria and might cause shift in bacterial flora of the soil. It is also known to reduce Rhizobia in soil.[12]

The numerous materials and the microbial habitats available in soil to serve as energy sources provide a range of niches for plant pathogenic bacteria. Most pathogenic bacteria however could be easily displaced by more efficient nutrient utilizing saprophytes. Therefore the control of *P. solanacearum* may be achieved by selective stimulation of saprophytic population by the use of Captan or Benomyl rather than incorporation of organic matter.

Acknowledgements

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Studies on the Extraction of Cerium Ions into Systems Containing Saponified Coconut Oil and some of the Acylates Present in Coconut Oil

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Abstract: Among the rare earths, Cerium (Ce) and several of its compounds find a wide range of industrial applications. Cerium is also that most abundant of the rare-earth elements, being found in several minerals (e.g. monazite) in high proportions. It is generally extracted from fractions obtained in the processing of these minerals. Potassium stearate has been used as one of the extracting agents for Ce (IV). In this study, the feasibility of extracting cerium both as Ce (IV) and Ce (III), by precipitation with sodium and potassium salts for stearic, lauric, palmitic, capric, oleic acids; mixture of these acids and saponified coconut oil was investigated. The main objective was to study the extractibility of Ce (III) and Ce (IV) in coconut oil saponified by sodium hydroxide (NaOH); because both coconut oil and sodium hydroxide are available in Sri Lanka, and the method if successful could be economically used on a large scale. The extractibilities of Ce (III) and Ce (IV) ions were determined on a quantitative basis, by their conversion into acylates in each of the above systems over a range of pH values. The results showed that (a) the extent of extraction of Ce (III) and Ce (IV) are reasonably high in the saponified coconut oil, (b) Ce (IV) is best extracted with sodium salts and Ce (III) with potassium salts at a pH value around 5, (c) more than 65% of Ce (III) can be extracted by sodium salts in the pH range of 3.5-6.8 under carefully controlled conditions. Therefore coconut oil saponified by sodium hydroxide can be considered as a promising extracting medium for Ce (IV) ions especially, while the oil saponified by hydroxides of both sodium and potassium is promising for the extraction of Ce (III) ions.

1. Introduction

Triacylates of lanthanum (III) and cerium (III) have been quantitatively precipitated by the reaction of their nitrates or chlorides with an excess of sodium soap in aqueous solution.[1,3] A similar study of lanthanum (III) and cerium (III) chloride using palmitic acid at different molar ratios in benzene, where mono-, di- and tri-palmitates have been isolated, have been reported.[4] Stearic acid has also been used as an extracting reagent[5], for the separation of metallic ions. This extracting reagent has been used to separate cerium from a mixture of rare-earth oxides.[6]

In view of these results and also considering the importance of cerium and its compounds in the context of their industrial application it was considered rele

vant to study the extractibility of cerium ions by the above-mentioned pure acid soaps and coconut oil soap, at different pH values. A preliminary study using pure fatty acids was necessary in order to understand, by means of the metal complexes formed, the extent of cerium precipitated in the coconut oil soap system, since coconut oil consists of a mixture of fatty acid glycerides and has the following approximate composition.[6]

1.1 Studies on the extraction of Cerium ions

The w/w percentages are given within brackets

1.1.1. Saturated fatty acids

caprylic	$C_7H_{15}COOH$ (9.5%)	capric	$C_9H_{19}COOH$ (7.2%)
lauric	$C_{11}H_{23}COOH$ (47.3%)	nyristic	$C_{13}H_{27}COOH$ (16.6%)
palmitic	$C_{15}H_{31}COOH$ (7.8%)	stearic	$C_{17}H_{35}COOH$ (4.2%)

1.1.2. Unsaturated fatty acids

oleic	$C_{17}H_{33}COOH$ (4.7%)	linoleic	$C_{17}H_{31}COOH$ (2.1%)

Each extracting reagent was in the form of its potassium or sodium salt and the cerium was in the form Ce (III) or Ce (IV) as sulphate.

Extraction of cerium into a coconut oil system is of special significance since this method could be utilized to extract cerium from monazite at an intermediate state in the chemical processing of monazite sand.[2]

2. Experimental

2.1 General

Aqueous solutions of potassium and sodium soaps were prepared separately and solutions of cerium ions were added separately to these solutions. The pH values of the mixtures were adjusted using a pH meter (Corning Model 5) to be in the range 1 to 10. These mixtures were kept overnight and the resulting precipitates were separated. The whole of cerium extracted by the soap was regenerated as sulphate from the precipitate by heating with dilute sulphuric acid, and separating the free fatty acid. A similar procedure was followed in the case of saponified coconut oil, it was observed that the amount of cerium extracted was highly dependent on the pH of the solution.

Several quantitative methods are available for the determination of cerium as Ce (IV). Therefore in order to determine Ce (III) by the above-mentioned procedure; it was oxidised to Ce (IV) using sodium bismuthate ($NaBiO_3$), Ce (III) ions in solution tested for various stages by adding H_2O_2 and ammonium hydrate which

gave a yellowish brown cerium perhydroxy precipitate. Cerium was quantitatively determined as Ce (IV) by titrating with ferrous ammonium sulphate, according to the equation:

$$Ce^{4+} + Fe^{2+} \rightarrow Ce^{3+} + Fe^{3+}$$

Three indicators were tried out separately in the determination of Ce (IV) and these were (1) ferroin (2) benzidine/acetic acid (3) N-phenyl anthranilic acid. The most satisfactory one was found to be ferroin which therefore was used for all the determinations.

2.2 Extraction of cerium with free acid soap solution

(*i*) *Preparation of soap solution*

Pure acid (8 g) in water (100 ml) was heated to above the melting point (i.e. below 373°K) of the acid and the base MOH (3 g) in water was added to it. The mixture was heated to 373°K; and maintained at this temperature for 2-3 hours, cooled and diluted to make up one litre.

(*ii*) *Preparation of the acetylates of cerium*

0.01 M Ce (III) (5 ml) and 0.01 M Ce (IV) (5 ml) were added separately to carboxylate solution (100 ml) of sodium or potassium (0.028 M - 0.040 M). This was the amount of carboxylate solution required for the complete removal of the yellow colour of Ce (IV) ions in the solution. Further 10 ml of the carboxylate solution was then added to ensure an excess. Except in the case of lauric, capric and oleic acid systems in others a white precipitate was obtained. The pH of each solution was adjusted to have specified values in the range 1 to 10 using dilute H_2SO_4. The mixture was shaken thoroughly and left overnight. The precipitate was filtered and washed several times with water and dried. The cerium ions remaining in the aqueous filtrate were determined using ferroin as indicator.

(*iii*) *Extraction of Ce (III) and Ce (IV) from the complex*

The precipitate obtained in (ii) was decomposed by heating with dilute H_2SO_4 (50 ml) to just above the melting point of the free acid. When allowed to cool, most fatty acids separated as solids. In cases where the fatty acid was a liquid at room temperature, ice-salt mixtures were used to freeze the fatty acid leaving the Ce (III) and Ce (IV) ions in the dilute H_2SO_4 solution. The solid fatty acids were separated by filtration, and were washed with two 10 ml portions of hot dilute H_2SO_4. All these filtrates were combined and these contained Ce (III) or Ce (IV) ions.

(iv) The determinaton of the Ce (III) and Ce (IV) in the filtrate from (iii) above

The filtrate was directly titrated with 0.0025 M ferrous ammonium sulphate. In the case of cerium in Ce (III) filtrates were estimated after oxidising with sodium bismuthates in dilute H_2SO_4 in the presence of a small quantity of ammonium sulphate. The resulting solution was filtered and the Ce (IV) ions present were determined using ferroin as the indicator.

This procedure was repeated by varying the pH values in the range 1 to 10 for the following component groups:

The equation for the reaction is

$$RCOOH + MOH = RCOOM + H_2O \ (M = Na \text{ or } K)$$

2.3 Extraction of cerium with coconut oil soap solutions

(i) Saponification of coconut oil

MOH (M = Na or K) (15 g) in water (100 ml) was added slowly with continuous stirring (magnetic stirrer was used) to coconut oil (100 ml = 92 g approximately) heated to 373°K. This mixture was heated for a further 3 hours in the case of M = Na, and one hour in the case of M=K, and allowed to cool. Salt water (500 ml) was added to precipitate the soap from glycerol. The solid soap obtained was dissolved in water and made up to one litre.

(ii) Preparation of the cerium complex with the soap solution

0.01 M cerium (III) and cerium (IV) sulphate solutions (5 ml) were added separately into the soap solution (125 ml) prepared as in 2.3 (i). The solutions were cooled in a freezing mixture to a temperature below 278°K, and the pH adjusted as required to lie between 1 and 10. The mixture was left overnight and cooled rapidly in a freezing mixture, then the precipitates were filtered and washed in pre-chilled water. The filtrates were tested for Ce (IV) ions using ferroin indicator. These were found to contain only very small amounts of cerium. Cerium contained in the precipitate was extracted into dilute H_2SO_4 (50 ml). The free oil was re-extracted twice with 10 ml portions of hot dilute H_2SO_4, (10 ml). In each case the oil was removed by solidifying it in a freezing mixture. The amount of cerium present in the total extract was determined by the method as described in 2.1.

3. Results and Discussion

3.1 Stearic acid system — Figures 1 (i) and 1 (ii)

From the results obtained it can be seen that both potassium and sodium soaps have comparable extractibilities with maximum values of 84% at pH 4.5 and 91% at pH 4.0 respectively for Ce (III).

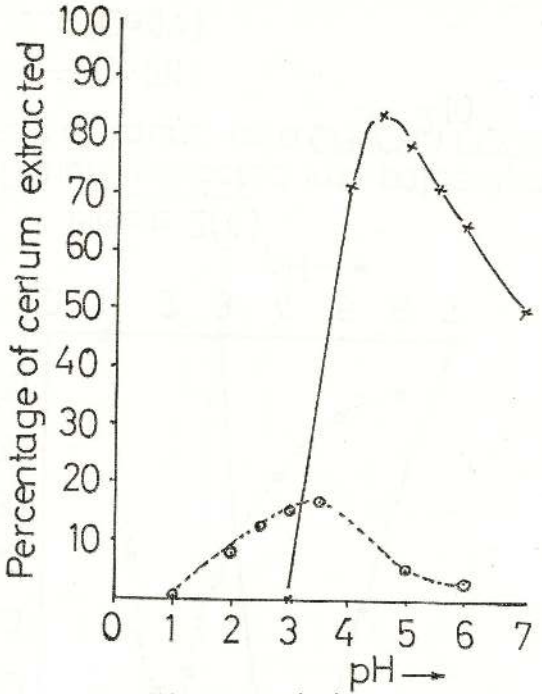

Figure 1 (1)

Cerium extracted into potassium salt of stearic acid $CH_3(CH_2)_{16}COOH$

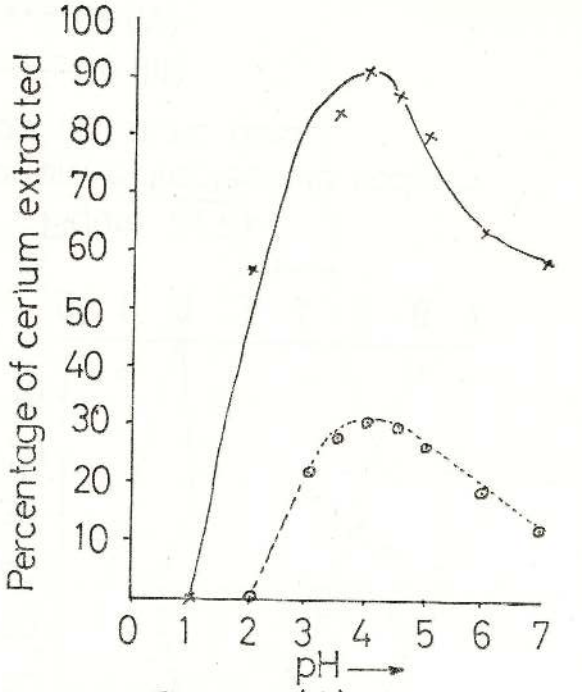

Figure 1 (2)

Cerium extracted into sodium salt of stearic acid

Figure 2(1)
Cerium extracted into potassium salt of Lauric acid $CH_3(CH_2)_{10}COOH$

Figure 2(2)
Cerium extracted into sodium salt of Lauric acid

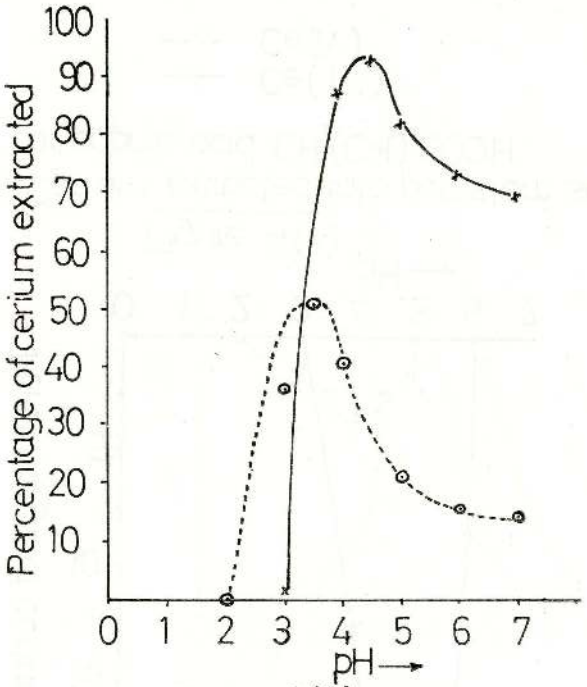

Figure 3(1)

Cerium extracted into potassium salt of Palmitic acid $CH_3(CH_2)_{14}COOH$

—— Ce(111)

----Ce(1V)

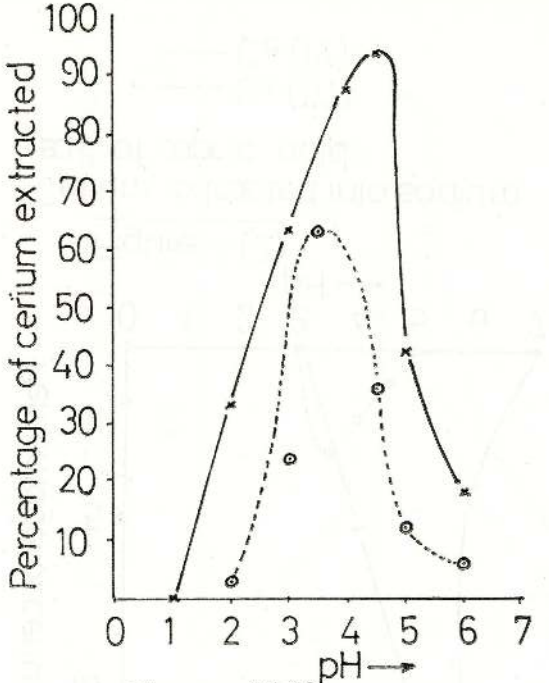

Figure 3(2)

Cerium extracted into sodium salt of Palmitic acid

—— Ce(111)

-----Ce(1V)

Figure 4(1)
Cerium extracted into potasium salt or capric acid $CH_3(CH_2)_8COOH$

Figure 4(2)
Cerium extracted into sodium salt of capric acid

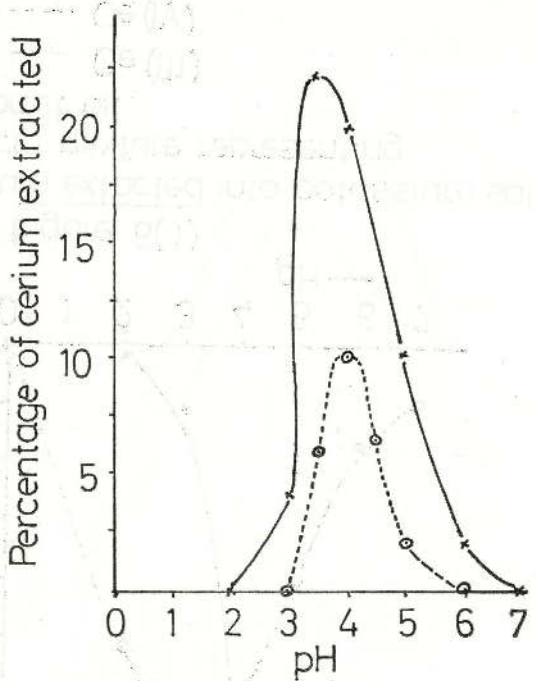

Figure 5 (1)

Cerium extracted into potassium salt of Oleic acid $CH_3(CH_2)_7CH=CH(CH_2)_7COOH$

——Ce (III)

----Ce (IV)

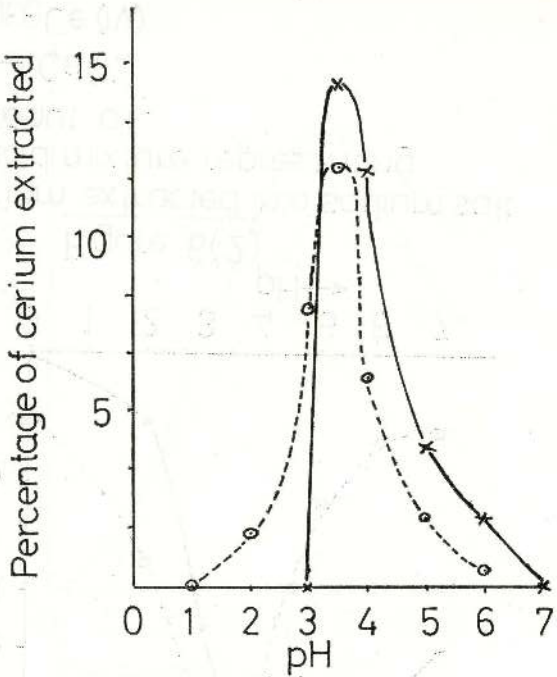

Figure 5(2)

Cerium extracted into sodium salt of Oleic acid

——Ce (IV)

----Ce (IV)

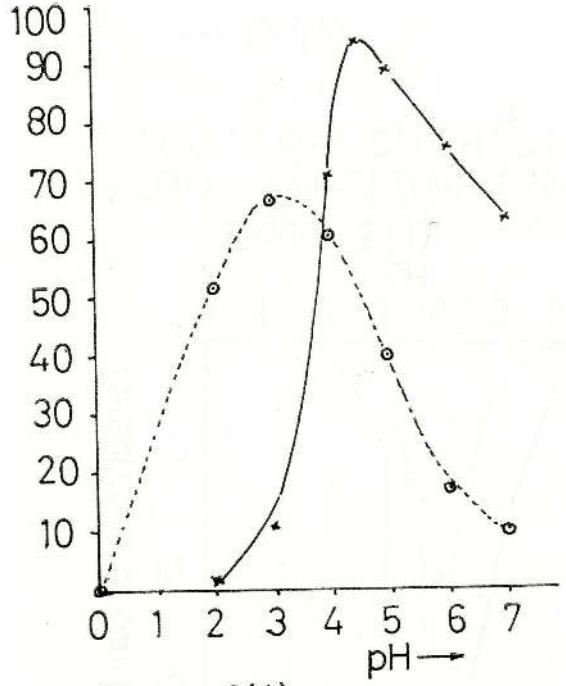

Figure 6(1)
Cerium extacted into potassium salt of acid mixture representing coconut oil.
—— Ce (III)
---- Ce (IV)

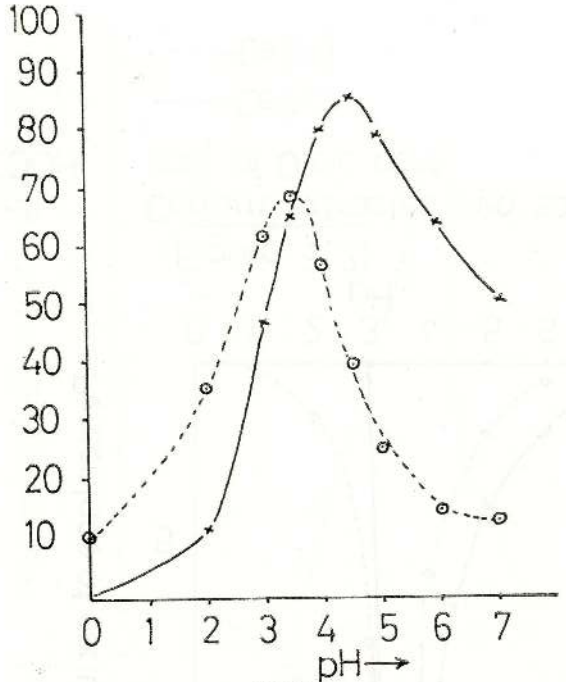

Figure 6(2)
Cerium extracted into sodium salt of acid mixture representing coconut oil.
—— Ce (III)
----- Ce (IV)

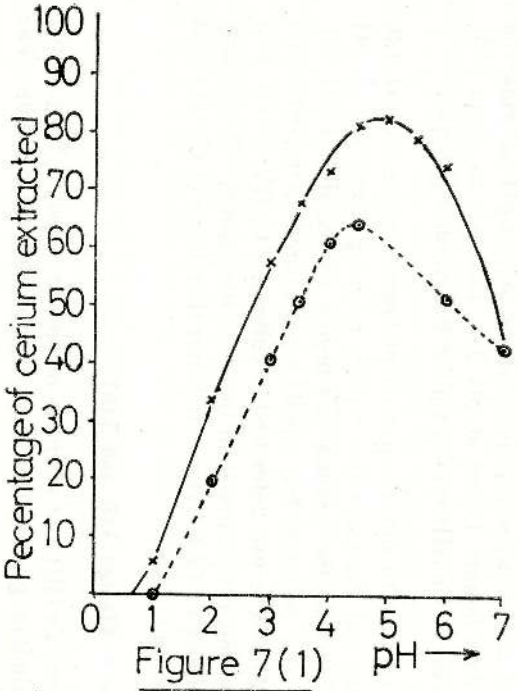

Figure 7(1)

Cerium extracted into potasium salt of coconut oil.

—— Ce(III)

-- --- Ce(IV)

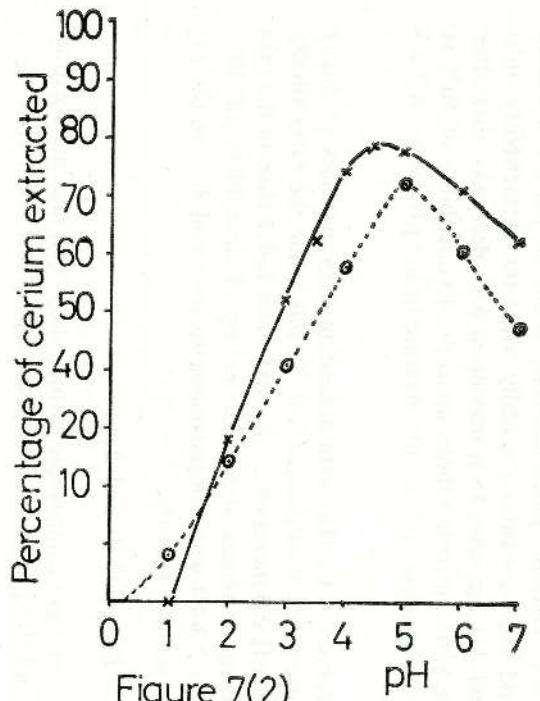

Figure 7(2)

Cerium extacted into sodium salt of coconut oil.

—— Ce(III)

------ Ce(IV)

The extractibility of Ce (IV) is much less, the maximum values in this case being 17% at pH 3.6 and 30% at pH 40 by potassium and sodium soaps respectively.

The extractibility of Ce (III) into potassium soap begins at pH 3.0 increases sharply to a maximum and then decreases gradually while the extractibility into sodium soap begins at pH 1.0 increases to a maximum and decreases thereafter throughout the range, the variation being more uniform. Extractibility of 60% is obtained for both potassium stearate and sodium stearate in the pH ranges 4.0-6.3 and 2.1-6.5 respectively.

The extractibility curve for Ce (IV) with potassium soap increases gradually from pH 1.0 to the maximum and then decreases uniformly while the extractibility into sodium soap begins at pH 2.0 increases to the maximum faster than in the case of potassium salt and then decreases slowly thereafter. Extractibility of 10% is observed in the pH range 2.3-4.4 with the potassium stearate and 20% in the pH range of 2.2-6.0 with the sodium stearate.

3.2 Lauric acid system — Figures 2 (i) and 2 (ii)

Potassium and sodium soaps have comparable extractibility with maximum extraction of 86% at pH 4.5 and 91% at pH 4.0 respectively for the Ce (III).

The extractibilities for Ce (IV) are relatively lower; the maximum values being 65% at pH 2.2 and 74% at pH 3.0 for the potassium laurate and sodium laurate respectively.

The extractibility of Ce (III) into the potassium salt begins at pH 3.0, increases rapidly to a maximum and decreases less rapidly to about 28% at pH 6.0 while the extractibility into the sodium laurate begins at pH 2.0, increases to about 50% at pH 6.0. The two curves for Ce (III) exhibit similar behavioural patterns.

The extractibility of Ce (IV) into the potassium laurate begins at pH 1.0, increases to the maximum and decreases less rapidly reaching about 9% at pH 6.0, while the extractibility into the sodium salt begins around 6% at pH 1.0, increases to a maximum and decreases less rapidly as compared to the potassium salt reaching 6% at pH 6.0. The two extractibility curves for Ce (IV) of the two salts show appreciable dissimilarities notably in the decreasing range. It is clearly evident that the extractibilities of Ce (III) ions are better than those of Ce (IV) ions by both potassium and sodium salts.

3.3 Palmitic acid system — Figures 3 (i) and 3 (ii)

Potassium palmitic extracts Ce (III) ions giving a maximum value of 92% (at pH 4.5) while the sodium palmitate gives only a maximum of 30% (at pH 4.0). The

maximum extractibilities of Ce (IV) were much lower by both salts, being 51% (at pH 3.5) for potassium salt and 24% (at pH 4.0) for the sodium salt.

The extractibility curves for Ce (III) ions for the two salts show some similarities although their ranges of values differ. The potassium palmitate begins to extract Ce (III) ions at pH 3.0, increases rapidly to the maximum and decreases very slowly reaching about 73% at pH 6.0, and the sodium palmitate begins the extraction at pH 1.0, rises slowly to the maximum and decreases rapidly thereafter to a value of 6% at pH 6.0.

The extractibility curves of Ce (IV) ions for the two salts have much less in common unlike in the case of Ce (III) except that both show a maximum. The potassium palmitate begins to extract Ce (IV) ions at pH 2.0, the extraction reaches the maximum at pH 3.5 and decreases thereafter less rapidly to reach 16% at pH 6.0, while the sodium palmitate also begins to extract Ce (IV) at pH 2.0. The latter reaches the maximum at a higher pH of 4.0 and then decreases nearly at the same rate as in the case of the potassium salt to about 2% extraction at pH 6.0.

For both Ce (III) and Ce (IV) ions the potassium soap has a better extractibility than the sodium soap. When Ce (IV) acylate is decomposed Ce (III) ions are regenerated and not Ce (IV) ions. These in turn have to be oxidized to Ce (IV) in order to be estimated. The change in the oxidation state of cerium ions provides a valuable insight as to why Ce (III) ions are extracted better than Ce (IV) ions into two salts. The conversion of Ce (IV) into Ce (III) probably occurs during the formation of the acylate.

3.4 Capric acid system — Figures 4 (i) and 4 (ii)

The extractibility of Ce (III) ions by the capriates is lower than for the acylates given in 3.1 to 3.3. The maximum values for potassium salts is 26% at pH 5.0 and for sodium salt is 12% at pH 5.5.

The extractibilities of Ce (IV) ions have maxima of 4% at pH 4.0 for the potassium salt and 3% at pH 3.5 for the sodium salt. The curves for Ce (III) show similarities in that the values are ascending more rapidly than descending with respect to the change of pH values. The extractibility for potassium capriate lies entirely in the pH range 3.0-6.0 and that for sodium capriate lies entirely in the pH range 3.0-7.0 with the zero value at the extremities in both cases.

In the case of Ce (IV) the sodium and potassium salts give extractibility curves which have almost opposite forms with respect to each other. The curve for potassium salt lies in the range pH 2.0-5.0 and shows a rapid descent while that for sodium salt lies in the range pH 3.0-5.0 and shows a rapid ascent and a slow descent.

3.5 Oleic acid system — Figures 5 (i) and 5 (ii)

Since this was the only unsaturated acylate found in coconut oil in appreciable amounts this was the only system studied. The extractibilities are generally low for Ce (III); the maximum value is 24% at pH 3.5 for potassium oleate and 15% at pH 3.5 for sodium oleate. Ce (IV) has a maximum value of 10% at pH 2.0 for the potassium salt and 12% at pH 3.5 for the sodium salt.

The forms of the extractibility curves of Ce (III) for the two acylates are similar showing a steep ascent up to the maximum and then a gentle descent. The curve for potassium oleate lies in the pH range 2.0-7.0 while that for the sodium salt lies in the pH range 3.0-7.0. The curve of Ce (IV) for the potassium salt lies in the pH range 3.0-6.0 and that for sodium salt lies in the pH range 1.0-6.0. Both curves have similar shapes with comparable ascending and descending parts. The low melting point of oleic acid causes difficulties in handling this system.

3.6 Mixture of acids representing coconut oil — Figures 6 (i) and 6 (ii)

A synthetic mixture of the acids containing capric, lauric, palmitic, stearic and oleic acids approximately in the ratio as found in coconut oil (3.1: 20.8: 3.9: 1.0: 2.8 by weight) was used. Myristic acid could not be used because of its non-availability.

Potassium acylate showed a greater extractibility of both Ce (III) and Ce (IV) than the sodium acylate. For Ce (III) the maximum value with the potassium soap is 94% at pH 4.5 and that with sodium soap is 87% at pH 4.5. The corresponding maxima for Ce (IV) are 72% at pH 3.5 and 69% at pH 3.5 respectively.

The curves for Ce (III) acylates are similar with a much steeper ascent than descent, whereas in the case of Ce (IV) the ascent and the descent are comparable for the mixture of acylates.

It is seen that for a given oxidation state of cerium and for a known mixture of acylates, the variation of the extractibility with pH is almost independent of the nature of the alkali ion.

The extractibilities in these two acylate mixtures are high and are similar to those in the pure lauric, stearic and to a small extent palmitic acid systems, although the percentages of the components differ widely. The effect of the other two low extractibility components is very small.

3.7 Saponified coconut oil — Figures 7 (i) and 7 (ii)

Saponified coconut oil shows high extractibilities for both Ce (III) and Ce (IV). The maximum value for Ce (III) by potassium soap is 83% at pH 5.0 and by sodium

soap is 80% at pH 4.5. The corresponding extractibilities for Ce(IV) are 64% at pH 4.5 and 72% at pH 5.0 respectively.

The curve shows that more than 50% of Ce (III) can be extracted by potassium soap in the pH range 2.6-6.8 and more than 65% by sodium soap in the pH range 3.5-6.8. Similarly over 50% extraction of Ce (IV) can be affected by the potassium and sodium soaps in the pH ranges of 3.5-6.2 and 3.5-6.8 respectively.

4. Conclusion

The results show that (a) the extents of extraction of Ce (III) and Ce (IV) are reasonably high in the saponified coconut oil, (b) Ce (IV) is best extracted with sodium salts and Ce (III) with potassium salts at a pH value around 5, (c) more than 65% of Ce (III) can be extracted by sodium salts in the pH range of 3.5-6.8 under carefully controlled conditions. Therefore coconut oil saponified by sodium hydroxide can be considered as a promising extracting medium for Ce (IV) ions especially, while the oil saponified by hydroxides of both sodium and potassium is promising for the extraction of Ce (III) ions. Since the sodium soaps are cheaper than the potassium soaps; especially in Sri Lanka, the use of the former is economically feasible.

There were some experimental difficulties encountered in using coconut oil as compared to the use of pure fatty acid soaps as indicated below:

(i) Due to low efficiency of re-saponificated, coconut oil is difficult to recycle where as pure fatty acid soaps can be recycled with very little loss (5%). This is probably due to the strong nature of the combination of cerium-ions with saponified coconut oil.

(ii) pH measurements are somewhat difficult due to the fatty acid being deposited on the electrodes.

(iii) The acylate is very difficult to filter even at the best extracting pH.

We strongly feel with a further amount of extensive and effective research, these experimental difficulties could be greatly minimized.

The dissimilarity observed in the Figures 6 and 7 may be partly due to the acylates of myristic, caprylic and linoleic acids were not studied due to their non-availability at the time of study.

Even with the above-mentioned experimental difficulties, it could be stated that a reasonably high extractibility of cerium (III) and cerium (IV) can be achieved in coconut oil saponified with sodium hydroxide under carefully controlled

conditions. After the above difficulties are overcome with further research, the process has to be carried out on a pilot scale and the details of its economics have to be worked out.

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The Evidence for a Linkage Isomerism in Solid Cupric Ferricyanide

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Abstract: Experimental evidence is presented to show that solid cupric ferricyanide undergoes a structural transition when bonded interstitial water is removed. It is suggested that this transition is caused by a linkage isomerism where the co-ordination of C to Fe^{2+} and N to Cu^{++} in CN^- is reversed.

1. Introduction

Prussian blue type compounds, i.e. the ferrocyanides and ferricyanides of heavy metals form a class of crystalline solids with fascinating structure.[5,16] They have face-centred cubic arrangements of metal cations at the corners of unit cubes linked by cyanide ions placed along the edges.[5,16] In ferrocyanides the carbon atom of CN^- is co-ordinated to Fe^{2+} and the nitrogen atom is co-ordinated to the other metal ion. Ferricyanides have the same type of bondings[5,16] with Fe^{2+} replaced by Fe^{3+}. A remarkable property arising from this structure, is that the unit cells are unusually large[5,16] ($\sim$10Å). Consequently, the crystal can accommodate foreign molecules generally water as interstitial impurities.[1,3,6,16] It has been claimed[4] that prussian blue (ferric ferrocyanide, because C is linked to Fe^{2+} as in the ferrocyanide ion) undergoes a linkage isomeric transition at 400°C to ferrous ferricyanide where Fe^{3+} ions are co-ordinated to C and Fe^{2+} ions are co-ordinated to N. In this paper we present evidence for the existence of a similar but even more peculiar transition in cupric ferricyanide.

2. Experimental

Cupric ferricyanide prepared by double decomposition of a cupric salt with potassium ferrocyanide is a greenish yellow powder of stoichometric composition $Cu_3[Fe(CN)_6]_2.xH_2O$ (presence of excess Cu^{++} ions ensure that double salts are not formed).

Thermal gravimetric analysis (Figure 1) indicate that x the maximum number of bonded water molecules is 12 (Figure 1). Cupric ferricyanide and other prussian blue type compounds harbour two kinds of water molecules within the interstices of those co-ordinated to the metal ion (Cu^{++} in this case) as well as molecules hydrogen bonded to the co-ordinated ones[1,8]. X-ray structural analysis indicate that generally water molecules do not get bonded to ferro - or ferri - cyanide ions.[1,8]

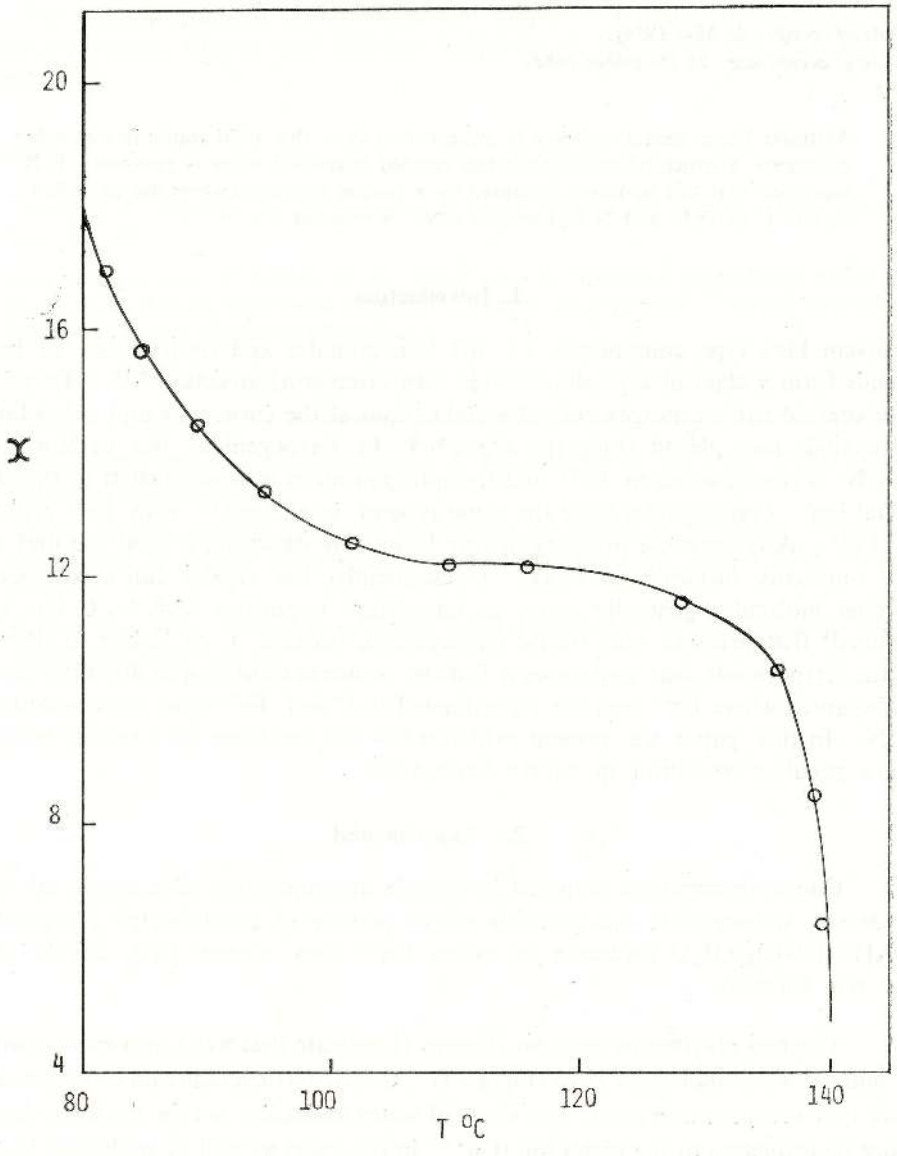

FIGURE 1 — Thermal gravimetric analysis of $Cu_3[Fe(CN)_6].xH_2O$. The plot of x vs T when heated at constant rate 2°C min^{-1}.

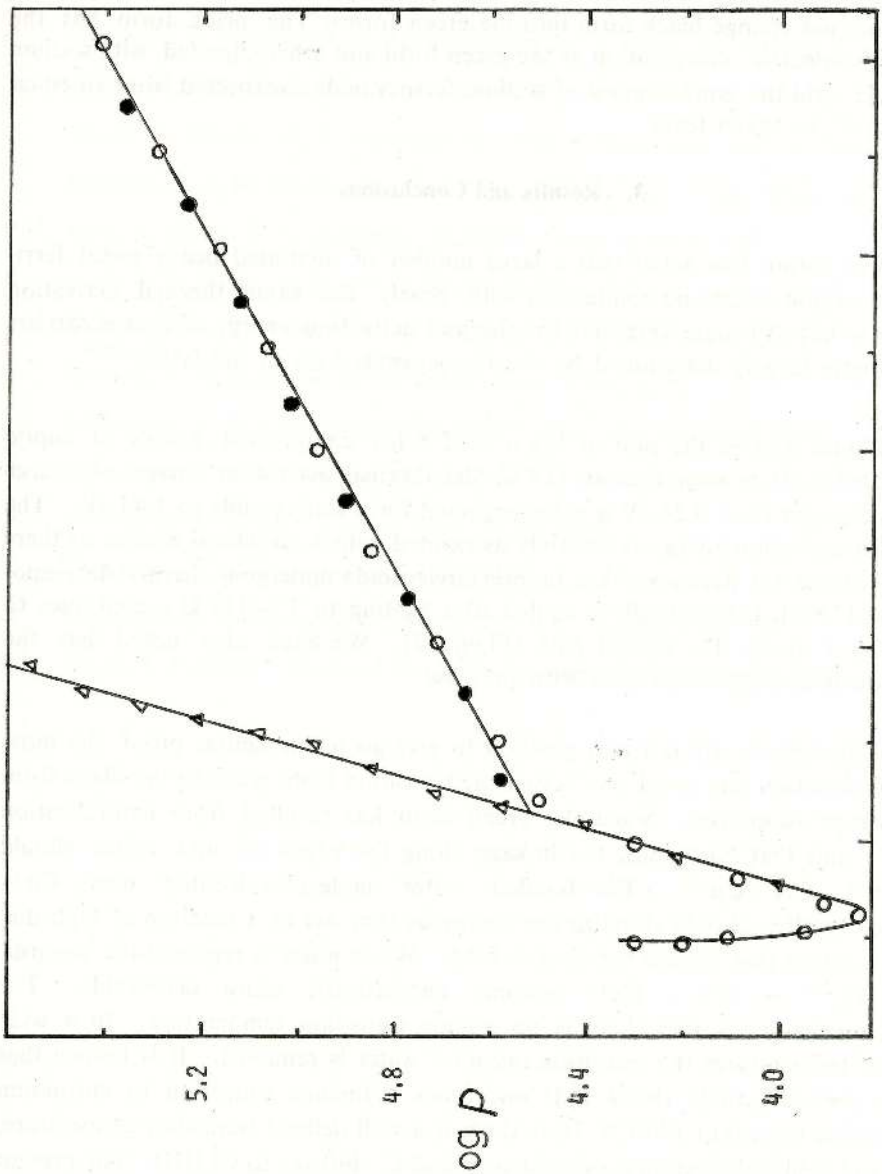

FIGURE 2 — Plot of log p (p in Ω cm) vs T-1, O — heating, ● — cooling after heating to T < 118°C, △ — cooling after heating to T > 118°C. The rapid increase in p at 138°C is due to thermal decomposition.

If the interstitial water in cupric ferricyanide is removed by heating the substance up to 118°C at atmospheric pressure (Figure 1) or prolonged evacuation of an enclosure containing the material at an elevated temperature below 118°C, it changes irreversibly into a different form which is black in colour (addition of water does not change black form into the green form). The black form has the same stoichometric composition as the green form and when digested with sodium hydroxide yield the same amount of sodium ferrocyanide as expected from an equal quantity of the green form.

3. Results and Conclusions

The author has noted that a large number of hydrated heavy metal ferricyanides exhibit electronic conduction with nearly the same thermal activation energy ($\sim$0.25 eV) suggesting that the thermal activation energy of charge carriers is a property largely determined by the ferrocyanide ions in the lattice.[11,14]

Figure 2 gives the plot of log ρ vs T^{-1} for compressed pellets of cupric ferrocyanide. It is seen that at 118°C, the thermal activation energy of charge carriers changes from 0.24 eV a value expected for a ferricyanide to 1.43 eV. The change in activation energy is certainly associated with a structural change as there is no evidence for decomposition, (cupric ferricyanide undergoes thermal decomposition at 139°C). If the sample is cooled after heating to $T \lesssim 118$°C ρ continues to vary with T along the second path (Figure 2). We have also noted that the transition temperature increases with pressure.

Although we are not in a position to give an unambiguous proof, the most likely explanation one could give is that the transition from green to the black form is a linkage isomerism. Since the green form has resulted from neutralization of Cu^{++} and $Fe(CN)_6^{3-}$ ions, the linkage along the edges of unit cubes should be Fe^{+++} - CN - Cu^{++}. The bonded water molecules located near Cu^{++} influence the ligand field stabilization energy as they act as a medium of high dielectric constant that screens the electric field. When water is removed the co-ordination Fe^{+++} - CN - Cu^{++} become energetically more favourable. The interesting feature is that there is no unique transition temperature. In a wide range of temperatures the transition occurs if water is removed. It is known that ferrous chromocyanide (brick red) undergoes a linkage transition to chromium ferrocyanide (green) at 100°C.[9] Here there is a well defined transition temperature, the ligand field stabilization favours strong field C - linkage to Cr (III). The present example clearly shows the influence of bonded water on ligand field stabilization.

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Geology and Occurrence of Gems in Sri Lanka*

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Abstract: The gemstones of Sri Lanka with the exception of moonstones, some tourmaline, and garnets which have been found *in situ*, are all obtained from old alluvial deposits. Although the occurrence of gems in their rock-matrix is rare, there is no doubt that they are associated with some form of intrusive material and most probably originated in material of pegmatitic nature. The succession of formations observed in alluvial gem fields varies much in character according to the materials and the circumstances under which they are deposited. Perhaps nowhere in the world are so many minerals of the gem variety (common and rare) concentrated in such a comparatively restricted area of mountainous country as in the Sabaragamuwa Province of Sri Lanka in which Ratnapura is the main gem trading centre.

1. Introduction

Sri Lanka has long been renowned for its gems. In the Chronicles, reference is made to gems being brought from Ceylon to the Court of Solomon. The 'Mahawansa' the great historical record of the Island, refers to the singular reputation of the Island for its gems. Several Greek writers of the first and second centuries refer to the reputation of Sri Lanka for its precious stones. From about the fourth century to the eleventh century the Arabs and the Persians exercised a great influence over the trade of the Island. The Venetian traveller, Marco Polo in the thirteenth century visited Sri Lanka on his homeward journey from China and in his book he mentions the gems of the Island. He also records that he found the Moors, the descendants of the Arabs, in undisputed possession of the gem trade of Sri Lanka. It is also believed that Sinbad's Valley of Gems in the Arabian Nights is probably the Ratnapura gem fields. Sri Lanka has therefore been famous for its gems since early historic times.

Sri Lanka is a tropical Island and lies 32 km to the east of the southernmost extremity of Peninsular India. It has an area of 65,600 sq. km and is 432 km long and 224 km at its greatest breadth. The Island may be divided into two main physiographic divisions:

1. The low lying coastal plain with little relief is traversed by rivers which have reached their base level of erosion.

2. The central highlands with immature drainage pattern and marked relief abounds in numerous strike ridges, hills and mountains.

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The coastal plain is narrow in the western and southern parts of the Island. The general level varies from sea level to about 150 m where some erosion remnants rise to 300m or more above sea level. The central highlands rise steeply from the coastal plain and the highest mountain (Pidurutalagala) attains an elevation of 2528 m above sea level.

Sri Lanka lies in the monsoon region of south-east Asia and it has a humid tropical climate. The division into a West Zone and Dry Zone which merge in an Intermediate Zone is one of the most conspicuous geographical features of the Island. In Figure 1 the rainfall pattern is shown clearly demarcating the Wet and Dry Zone. The average rainfall varies from below 50 inches (1270 mm) in the north-west and south-east parts of the lowland zone to over 200 inches (5080 mm) in the south-west slopes of the central hill country. The mean rainfall for the Island is 80 inches (2032 mm). In the Wet Zone area the average mean temperature varies between 21° and 29°C and in the Dry Zone it may be nearer 32°C. In the highlands the mean temperature ranges between 15° C and 26°C according to elevation.

The rivers are for the most part radial. The upper reaches are mainly confined to the hill country. The radial pattern is the dominant element in the drainage pattern in Sri Lanka. A great problem in the Wet Zone is flood control. In the Dry Zone a seasonal shortage of water is a problem. Very few rivers rise in the Wet Zone and flow into the Dry Zone. The main population concentration is in the Wet Zone. In the Dry Zone the population is sparse. The population of Sri Lanka is around 15 million.

The present paper attempts to give a broad picture of the geology, occurrence, origin and mining of gems in Sri Lanka. During the course of geological mapping of the Ratnapura, Rakwana and Balangoda areas (the main gem bearing areas of Sri Lanka), the author has had the opportunity of examining a large number of gem pits and was closely associated with the work of many gem-miners in the region. During this period of 2 to 3 years a considerable amount of useful information was gathered on the occurrence of gems. Although this paper is not an exhaustive treatment of the subject it provides in a convenient form a useful summary for those interested in the gems of the Island.

2. General Geology

Over 90 per cent of the surface area of the Island is underlain by Precambrian rocks consisting of a complex series of high-grade metamorphic rocks, most of which have been derived from sediments and altered by one or more metamorphisms. Associated with these metamorphic rocks are granites and granitoid rocks of igneous origin. Figure 2 shows the outcrops of the main geological formations in the Island and Table I is presented to show the general succession of geological formations and the important mineral deposits of Sri Lanka.

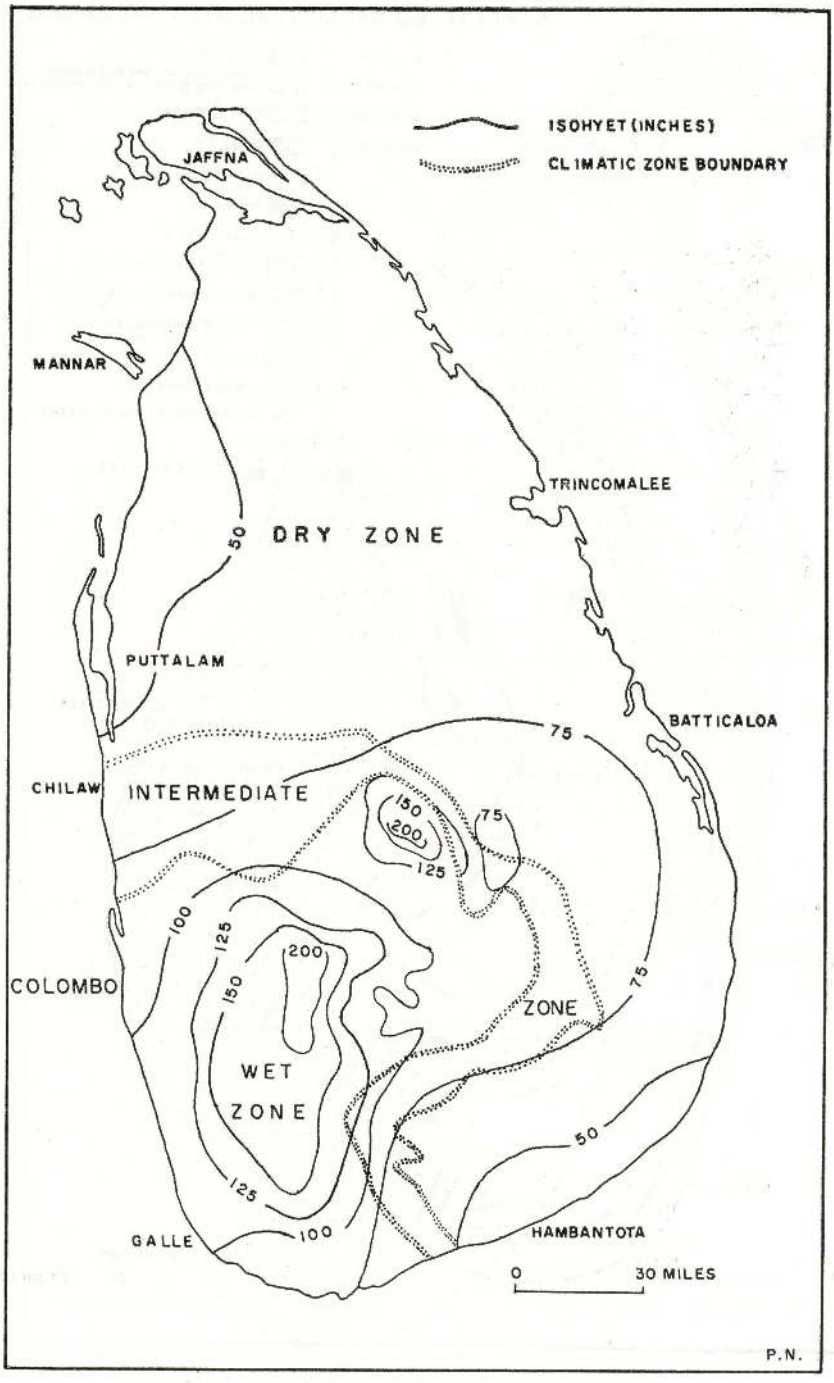

FIGURE 1 — Rainfall Pattern — Sri Lanka

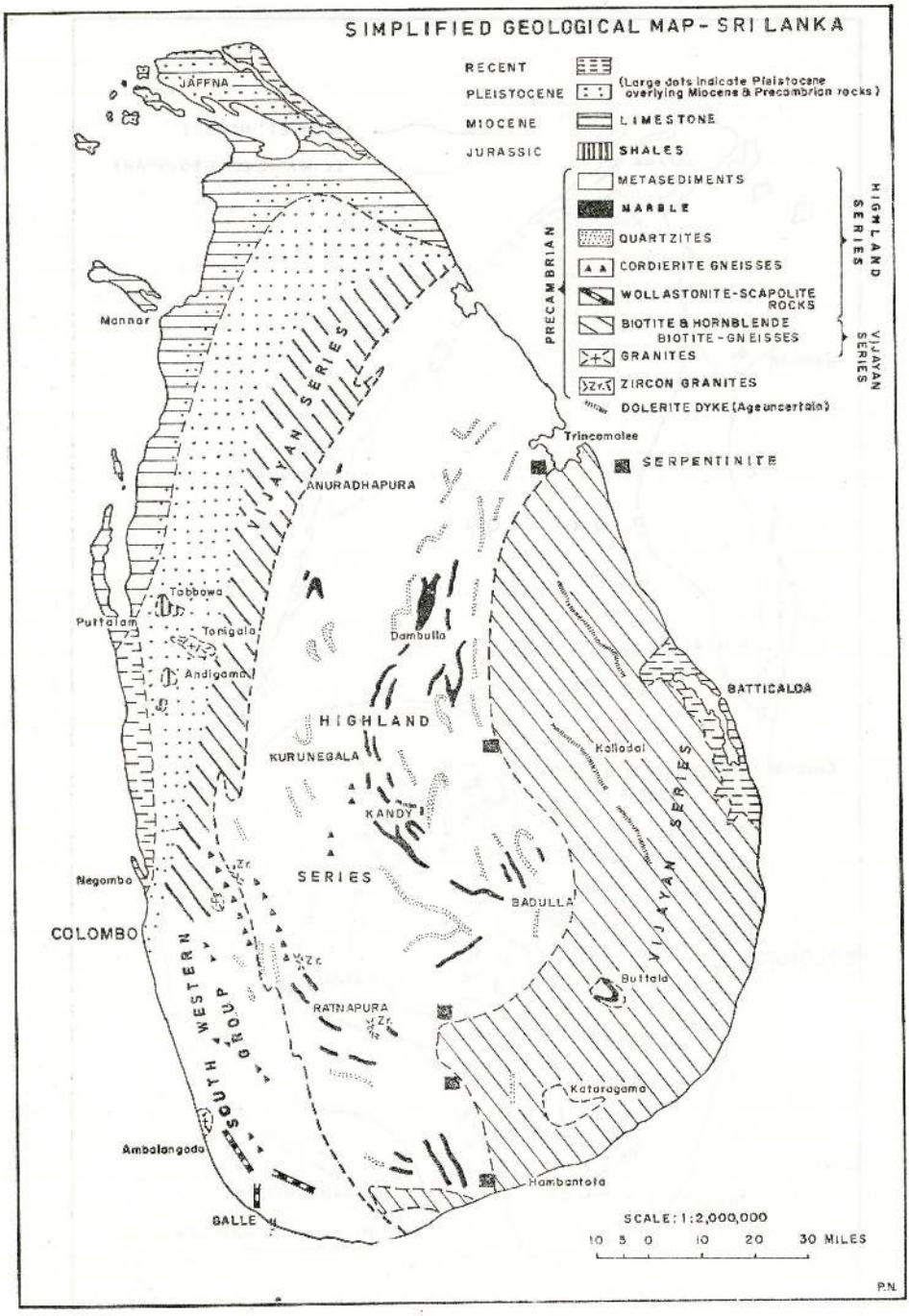

FIGURE 2 — Simplified Geological Map — Sri Lanka

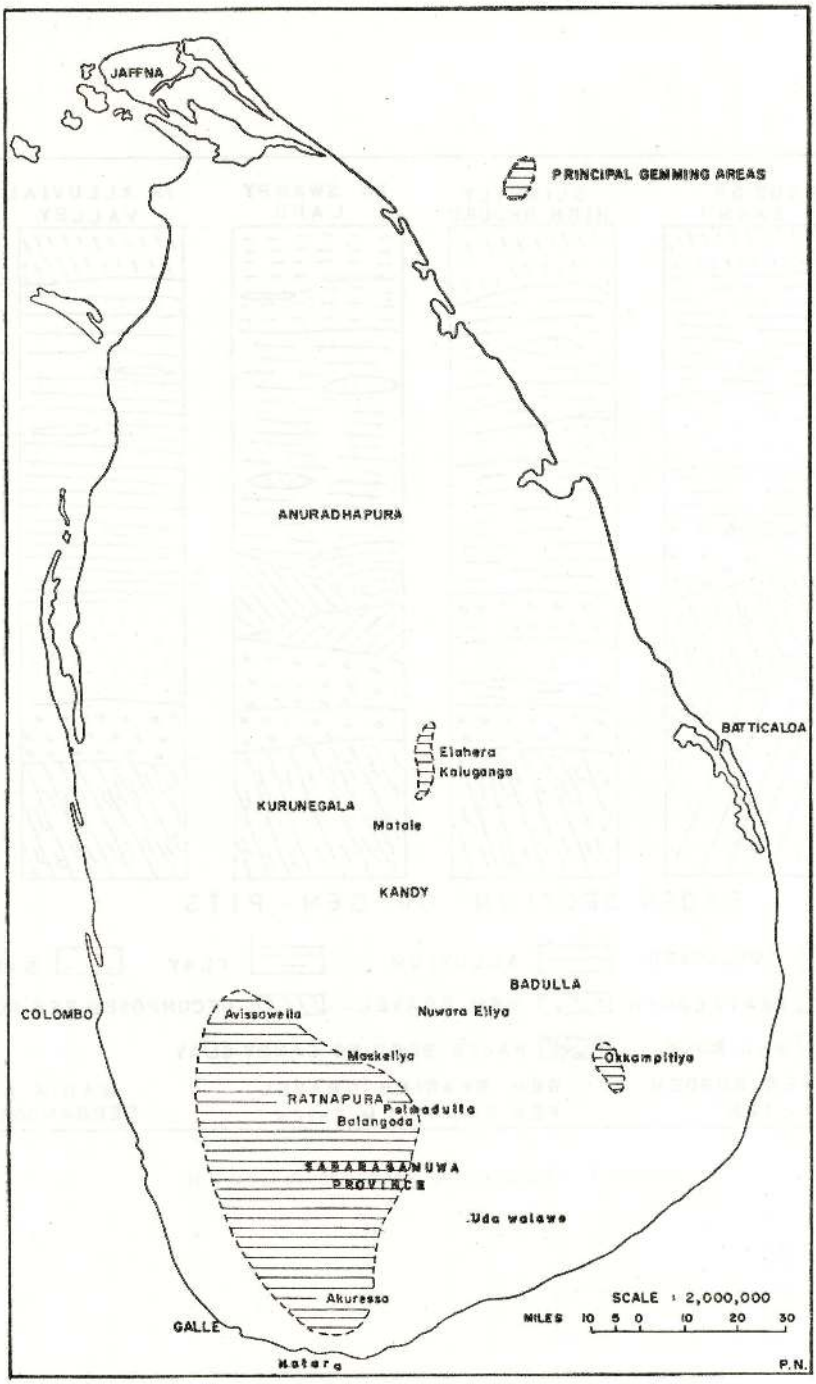

FIGURE 3 — Distribution of Gem bearing Gravel — Sri Lanka

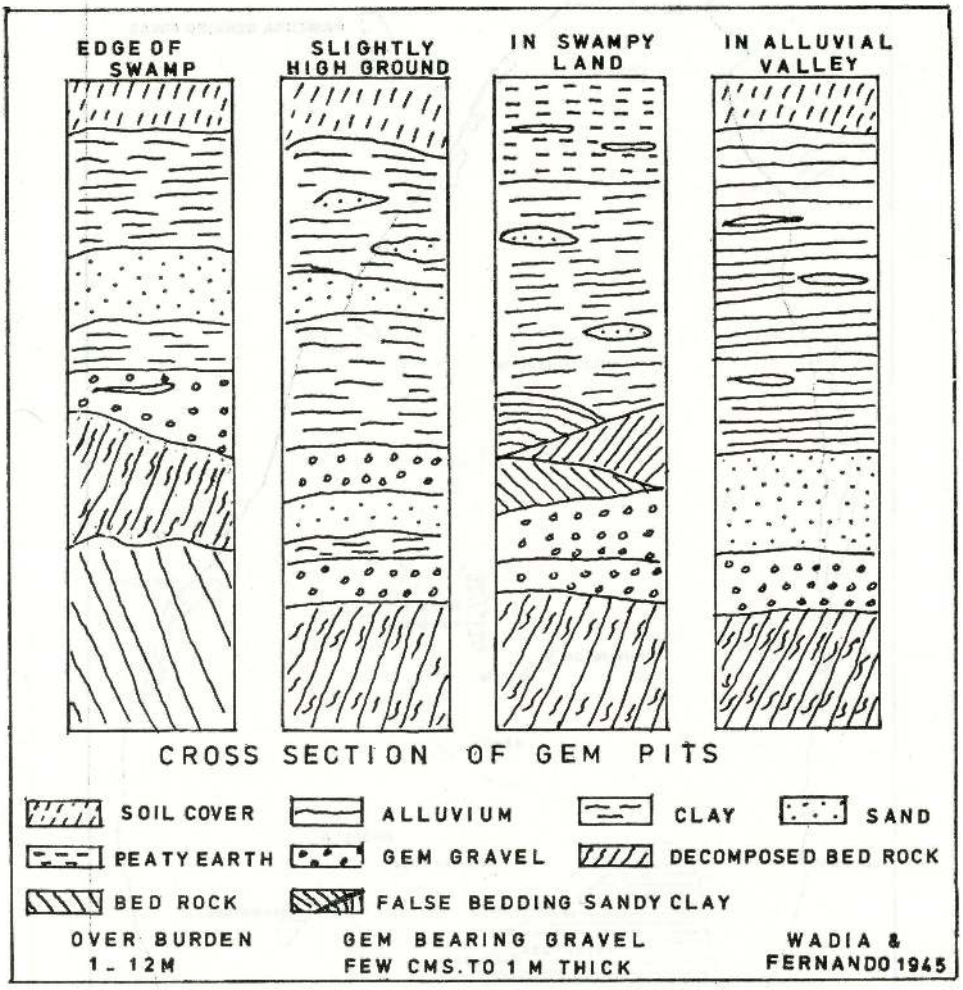

FIGURE 4 — Succession of Formations in Gem Pits

TABLE 1. General succession of Geological Formations and Principal Mineral Deposits in Sri Lanka

Principal Geological Divisions		*Principal Formations*	*Important Mineral Deposits*	*Others*
Era	*Period*			
ANTHROPOZOIC	HOLOCENE (RECENT)	Recent residual and alluvial deposits, blown sand, coastal sandstone, coral and shell formations, beach mineral sands, gem gravels, peat, lagoonal and estuarine deposits	Kaolin, ball clay, refractory bond clay, residual and alluvial clay, silica sand, ilmenite, rutile, zircon, monazite, garnet, gem, coral, shell, *sillimanite*, clay ochers	Thorianite, thorite, baddeleyite.
CENOZOIC	QUATERNARY (PLEISTOCENE)	Laterites (may extend from Recent to Tertiary Periods), gravels, red earths,	Laterites, limonitic iron ore, red earths (sands), gem,	—
	TERTIARY (MICCENE)	Limestone	Limestone	—
MESOZOIC	JURASSIC	Shales, carbonaceous shales and arkosic sandstone	Shales	—
PALAEOZOIC	—	Absent	—	—
ARCHAEOZOIC	PRECAMBRIAN	Highland Series (metasediments) Vijayan Series (gneissic complex) Southwestern Group (gneisses and metasediments) Innusives (granites) dolorite dykespegmatites)	Marble, quartz, felspar, graphite, mica, apatite, magnetite	Magnesite, allanite, cordierite, chert, wollastonite, sillimanite, copper, serpentinite.

Modified after Herath 1980

The precambrian crystalline rocks consist essentially of (1) a Highland Series (2) Vijayan Series and (3) the South - Western Group. The Highland Series is characterised by metamorphosed sediments and charnockitic rocks. The main rock types exposed are quartzites, marble (mainly dolomitic limestones), garnet - sillimanite - graphite schists, granulites and gneisses of various types including a variety of charnockitic rocks. The Vijayan Series is mainly composed of granites, gneisses of various types and migmatites. Athough the South - Western Group is fairly similar to the Highland Series there are differences between the two units in terms of both lithology and metamorphic character. Rock types in this group include thin quartzites, wollastonite bearing rocks, cordierite bearing gneisses, coarse charnockitic rocks and appreciable amounts of chert.

These rocks have been folded into a series of synforms and antiforms, generally trending in a north-west south-east direction. A good deal of controversy still remains about the subdivision of the Sri Lanka Precambrian, what can be generally agreed however, is that the structures are everywhere complex. In recent years the boundary between the Highland Series and the eastern Vijayan has been recognized as a mineralized zone. A number of serpentinite rocks have been located on this boundary (Figure 2) and the Seruwila copper-magnetite deposit in the Trincomalee area is also confined to this zone.

The largest development of sedimentary rocks occur in the north-western coastal belt extending from the Jaffna Peninsula in the north to the south of Puttalam on the west coast. This formation is of Miocene age and the rock type is a massive limestone of marine origin which is fossiliferous. Jurassic rocks are limited in extent and they are exposed in the Tabbowa, Andigama and Pallama areas north of Chilaw. These sedimentary rocks are composed of sandstone, grits, arkoses and shales. Similar Jurassic (Gondwana) rocks occur below the Miocene limestone of the Mannar area (Petroleum surveys-drill cores).

Recent formations include a variety of unconsolidated materials (beach sands and extensive deposits of alluvial clays), coastal sandstone, coral and shell formations. The Pleistocene deposits include the gem gravels of the Island, red earths and ordinary gravel beds in the western and north-western parts of the Island and the laterite deposits in the south-western parts of the Island (residual deposits).

3. Distribution and Geological Occurrence of Gems

The main gem bearing area of Sri Lanka which has been known for centuries comprises a series of parallel hill ranges separated by longitudinal valleys and situated in the Sabaragamuwa Province.

To date, the main gemming fields in the Island are confined to this area which covers nearly 1500 sq. km. The neighbourhood of Avissawella, Ratnapura, Rakwana and Balangoda has undoubtedly supported the most actively worked gem pits in the Island for a number of decades. This region has supplied to the market some high-priced blue sapphires, star sapphires and cat's eyes. Ratnapura (city of gems) is the main centre for the gem industry. Outside this area there are isolated gemming grounds of which Okkampitiya and Elahera are noteworthy. Other areas, include Nuwara Eliya, Horton Plains, Hatton, Kandy, Matara, Hambantota, Uda Walawe and many other localities underlain by Precambrian rocks.

The precious stones of Sri Lanka with the exception of moonstone (Meetiyagoda) corundum, and some tourmalines and a few garnets which have been found *in situ* are all obtained from old alluvial deposits. They represent the indestructible residual debris brought down from the high ground as products of degradation of the rocks and are found embedded in gravel layers and sand in beds of ancient rivers, in valley bottoms, beds of abandoned tributaries, alluvial terraces and in talus accumulations at the foot of hills. All gem minerals are undoubtedly from the rocks of the country in the vicinity of which they are found provided they have not been transported for great distances. Figure 3 is presented to show the distribution of gem bearing gravels in the Island. These are the better known areas but it is believed that gems have been found in many other parts of the Island in Precambrian terrain.

The succession of formations observed in the gem fields differ according to the circumstances and the type of material deposited in flood plains, wide flat bottomed valleys, residual gravel on hill slopes, fan type gravel occurrences at foot hills and gravel stretches on abandoned hill streams. Gravel formations with gem material have also been observed in decomposed material overlying concealed pegmatite dykes. The succession of formations in a typical gem pit may be classified into three categories: (Figure 4).

(i) Superficial layers of soil either lateritic or peaty overlying sandy and clayey material. The clayey material is in parts kaolinized. The thickness of this formation which is virtually the overburden varies considerably and is in general from 1 metre to 12 metres thick.

(ii) A layer or layers of pay-gravel usually of lenticular shape. This is the gem bearing gravel. The miner refers to it as the 'illam'. The illam layer is from a few cms to about a metre in thickness and may be encountered at shallow depths (< 3 metres) or at depths up to 12 metres.

(iii) The next formation is the decomposed rock which is normally kaolinized and micaceous. The decomposed material is termed the 'Malawa'

by miners. In pits where more than one 'illam' or pay-gravel is struck, it is the lower ones which are more prolific in gems. All gem pits should theoretically end work on striking the 'malawa' layer or decomposed rock.

Apart from their economic value as the carrier of the principal gems the 'illam' gravels are highly interesting from a petrological and mineralogical point of view. Once the gems are recovered after washing, the gravels are discarded. This discarded material is termed 'Nambuwa' by the miners and up to recent years very light coloured corundum (semi transparent) has been discarded. Corundum of this nature termed 'Geuda' is now heat treated to enhance its blue colour. The most abundant constituent of gem gravel is quartz in well rounded pebbles. The gem miner has come to regard these quartz pebbles as an infallible companion of gemstones in the field and is guided in his search for pay-gravel by this criterion. Besides quartz and the ornamental stones including a variety of rare gem minerals the gem gravel may also contain grains and crystals of the rare earth minerals - compounds of thorium, uranium, cerium, yttrium, niobium, titanium, beryllium, zirconium and others. In regard to gems in the pay-gravel there is a notorious uncertainty and variation in the content of gems. Some pay-gravel may draw blanks while pits dug a few metres away may yield very high priced gems.

4. Origin of Gems

No detailed work has been attempted on the origin of gems in Sri Lanka. Adams[1] considered that they are the constituents of the associated crystalline rocks. Katz[6] states that the Ratnapura-type gem deposits are derived from cordierite gneisses and associated rocks. Wadia and Fernando[7] and Coates[2] advocated a pegmatitic origin for some of the gem varieties. Dahanayake[3] considered that most of the gem varieties in the Ratnapura and Elehara areas are found associated with garnetiferous gneisses and skarn-type marble deposits and this confirms the author's findings when geological field mapping was carried out in the Ratnapura and Rakwana areas in the mid 1960s.

Zircon from Sri Lanka gem gravel has been dated (560 m. y.). This does not mean that the gem gravel formed during this period. Deraniyagala[4] studied a number of fossils embedded in the gem-gravels of the Ratnapura area and his work indicates a Pleistocene age for the majority of the Ratnapura gem gravels. Wadia and Fernando[7] however, mentions that the gem gravels do not all belong to any one particular age as erosion of the particular rocks of the surrounding area proceeded continuously through each succeeding geological age. Although a few instances are known of raw gem-stones occurring in rocks, there is however, no doubt regarding the pegmatitic habitat of topaz, tourmaline, beryl, chrysoberyl, amethyst, sphene and zircon, but only a few gems have been extracted from this

source. In several Ratnapura fields, gems are found under conditions which point to their being not far removed from the source of origin, but the deep mantle of decomposed material in which the rocks are buried precludes their being examined by pits or trenches. The majority of the rare-earth minerals that are known have likewise come to light from their association with gem gravels. Their habitats are also unknown. It is therefore logical to assume that weathering has exposed deeper parts of the mountain folds of the Island where mineralization has taken place. This is the result of millions of years of subaerial weathering of the highly folded landmass which must have been very different in appearance from what we see now. This weathering process in previous geological ages have exposed pegmatite veins and rocks containing a number of minerals of gem quality. These outcrops of rock and pegmatite material have been subjected to renewed process of weathering through countless ages of time and the gradual sorting action of the water has resulted in the deposition in favourable sites of gem gravel and sands which have subsequently been sealed by a covering of alluvial deposits as in the Ratnapura valleys.

5. Gem Mining in Sri Lanka

The mining methods employed although primitive using only manual labour, are time honoured methods of ancient Sinhalese tradition. They involve little capital outlay and are quick and efficient. Three methods are used to recover the gems:

1. Placer mining
2. Gemming by pits
3. Gemming of river beds by dredging.

1. When the pay-gravel is in superficial soil deposits within about 2 metres of the ground surface, the land is worked by open cast mining after clearing the surface. The material obtained is sorted out and washed in the usual manner in running water or in improvised sluices.

2. When the overburden is of considerable depth the most common method is to sink pits. The size of the pit is normally 3 to 5 metres square, divided into 2 chambers by a partition, one for working and excavating the gravel and the other for de-watering the sump. Lateral drifts are also driven in all directions from the bottom of the shaft in some of the deeper pits. The gravel is washed in shallow baskets made of rattan or wicker.

   Very few pits use mechanised contrivances, however, in recent years a high degree of mechanisation has been introduced at the various mines.

This is the most popular method of gem mining in the Sabaragamuwa mining area.

3. Gemming in beds of rivers is less common and require the assistance of experienced dredgers. An obstruction is put up across a stream to increase the flow of water at a selected spot over its bed. Long handled showels up to 40 feet or more in length are employed by six to eight men to drag the river bed at a point upstream of the dam till the illam layer is exposed after some weeks work. The overburden is carried away by the agitated water and the coarse sand and gravel (illam) is raked up and allowed to collect in a low ridge. This partly sorted illam is then removed from the water in baskets to the bank of the stream and the usual process of gem washing completed.

The gemming season normally extends from December to May, the drier part of the year. Under the existing mining law a licence to mine must be obtained from the State. No prospecting licences are issued for the search for gems. Applications for lease of gemming rights are on approval granted permits to mine for gems at an annual fee. Sometimes gemming rights are given after calling for tenders from applicants, a reserve price or upset premium is fixed beforehand. Seldom are gemming rights in Sri Lanka leased on a royalty or rent basis. The actual work of mining in the property is carried out on a remarkable system of co-operative sharing, of labour, expenses and profits. The output of the gem pit is distributed as follows:

Ground rent of owner	20 per cent
Lease or Licence-holder's share	10 per cent
Financier's share	35 per cent
Diggers share	35 per cent

Suppliers of the pump and timber may also be given a percentage share. This system of sharing is unique in a highly uncertain business. It has maintained the gem-cutting industry in a healthy state for centuries and has checked over production. The system of tenure under which land is held in Sri Lanka makes mechanical large scale operations unworkable in practice.

All mineral deposits that support mining are a constantly diminishing asset. This is true of the gem gravels of Sri Lanka. Exhaustion of gravels at a number of points is an indication that the Ratnapura gem beds will not be everlasting and that their extinction is only a question of time. New areas have however been found. In fact the entire Precambrian of Sri Lanka could be searched for gem gravel. Table 2 is presented to show the main gem varieties in the gem gravels of Sri Lanka and Table 3 is a list of the rare gem minerals of the Island as listed by Zoysa.[8]

TABLE 2. Sri Lanka Gem Varieties

Mineral	*Gem Varieties*
Corundum	Star Sapphire, ruby and star ruby, yellow, Blue, Green, Orange, Pink and White Sapphire.
Chrysoberyl	Alexandrite and Cat's Eye.
Beryl	Aquamarine - Colourless, Pink, Yellow
Topaz	Colourless Yellow topaz. Blue green and rarely red topaz (pale tints)
Tourmaline	Black, pink, rose-red, blue, brown, green, varieties.
GARNET Pyrope Almandine Grossularite	Pyrope - deep red to black Almandine - deep crimson, red to violet Grosularite - honey yellow to brownish yellow, also known as Hessonite or cinnamon stone
Spinel	Spinel - deep red, green, violet
Zircon	Brown, Green, Blue, red, orange, and yellow varieties
Quartz	Rock crystal, amethyst, rose, quartz, smoky quartz, Citrine (yellow) cat's eye quartz and star quartz
Feldspar	Moonstone and amazon stone.

(After Herath 1980)

TABLE 3. Occurrence of rare Gem varieties in Sri Lanka

Mineral	*Star Varieties*	*Cat's Eye types*	*Colour change types*
Garnet	X	—	X
Corundum	X	—	X
Spinel	X	—	X
Zircon	X	X	X
Andalusite	—	X	—
Apatite	—	X	—
Diopside	X	X	—
Enstatite	X	X	—
Euclase	—	X	—
Fibrolite	—	X	—
Ekanite	—	—	X
Kornerupine	—	X	—
Scapolite	—	X	—

Other rare minerals present include morganite, Axinite, Danburite, Epidot, Iolite, Peridot Sinhalite, Sphene, Taaffeite.

(After Zoysa 1983) X occurs in Sri Lanka

Gem cutting in Sri Lanka up to recent years was by machines of primitive construction operated by hand. No mechanical or electrical appliances were employed. During the past 5 to 7 years modern and up-to-date machinery has been introduced to the gem cutting industry and today machine cut gems of a very high quality could be obtained in the Island.

With a view to develop the gem industry of Sri Lanka, the State Gem Corporation was established in November, 1971. The Corporation now handles issue of permits for gemming, buys cut and uncut gems and all exports of gems from the Island have to be channelled through the Corporation. A modern gem testing laboratory with training facilities has been established and the Corporation has already made a significant contribution towards setting up a sound gem industry in the Island. In 1971 exports of gems from the Island were valued at Rupees 3,446,293 and in 1977 the export figures were in the region of Rupees 500 million and in 1982 exports were around Rupees 600 million. These figures indicate the increasing confidence owners of gems are beginning to have in the Corporation.

6. Summary and Conclusions

With the possible exception of Brazil no other country in the world produces such an abundance and variety of precious and semi-precious stones as Sri Lanka. The gemstones of the island are mainly obtained from old alluvial deposits and the main gem-bearing area is confined to the Sabaragamuwa Province of which Ratnapura is the Gem Trading Centre. Gems have however been found throughout the Precambrian of the Island. The co-operative system of working gem pits is unique in mining economics. In recent years mechanisation has been introduced in a number of gem mines and the gem cutting industry has also undergone changes. Machine cut gems of high quality are now freely available. Figures given for exports of gems cannot be considered as accurate as large quantities of gems are taken out of the country by illicit methods. Illicit mining is also prevalent in most parts of the Island. This activity has become so common that unconsidered action could result in a serious environmental problem.

Large scale gem mining operations using modern equipment cannot be undertaken in Sri Lanka and the present system of mining operations has maintained the industry in a healthy state for centuries, and has also checked over production. The possibility of expanding the jewellery industry has great promise. Regional Jewellery Centres could be established with adequate training facilities and such Centres could be operated by a State agency.

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Some Aquatic Hyphomycetes from Sri Lanka

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Abstract: Eighteen types of aquatic Hyphomycete conidia were found in foam samples collected from rivers and streams. Of these 11 were identified to species level and 4 to generic level; three were not identified at all. The number and types of conidia were greater in Sinharaja Forest streams than in rivers and streams flowing through urbanized and agricultural areas.

1. Introduction

The aquatic Hyphomycetes are a relatively small group of water-inhabiting fungi. Some of these fungi complete their entire life cycle including growth, sporulation, spore liberation and dispersal below the surface of water, but some are amphibious and may have telomorphs on substrata exposed to air. Very little was known about these fungi until Ingold[7] published his now famous paper on aquatic Hyphomycetes of decaying alder leaves. Aquatic Hyphomycetes often grow on submerged, partially decayed leaves and twigs present in fast flowing streams in wooded areas.[21]

About 200 species of aquatic Hyphomycetes have already been described. These have been assigned to 60 form genera. A guide to the identification of the commonly encountered forms is now available.[11] Basically, two spore shapes can be seen: the tetraradiate form with four long arms and the sigmoid form with curvature in more than one plane.[11] These spores are concentrated in a remarkable way by air bubbles which under certain conditions collect as persistent foam and scum often captured behind barriers of twigs and rocks in rivers and streams. This foam and scum provide an excellent source for collecting aquatic Hyphomycetes, although it is recognised that the spore content of foam may not actually reflect the spore content of water.[14]

Aquatic Hyphomycetes were first recorded in Europe. They are now known to have a worldwide distribution with the possible exception of North and South poles. Many species are world-wide in distribution, but some are more characteristic of either the warmer regions or the colder regions of the globe. Some species such as *Lunulospora curvula* and *Triscelophorus monosporus* although occurring in temperate colder regions are much more abundant in warmer tropical parts of the world.[11]

Most fresh water biologists would regard these fungi as insignificant and unimportant members of the fresh water biota; but it is now known that in many fresh water habitats they are very abundant.

No organism with a spore concentration of 10,000/l in stream water[14] can be considered as insignificant. The vital role they play as a link in the food chain between the detritus derived from the dead leaves and many invertebrates that feed on aquatic Hyphomycetes has become clear mainly as a result of the studies of Kaushik and Hynes, [15,16] Bärlocher and Kendric[1,2,3] and Berrie.[4]

Aquatic Hyphomycetes have not been hitherto recorded from Sri Lanka. This is a preliminary report of some of the observations made in the rivers and streams mainly in the south-western part of Sri Lanka.

2. Materials and Methods

Samples of foam, scum and decaying submerged tree leaves were collected from 12 streams in the island. Four samples were collected from the stream at Sinharaja Forest and one sample each from the other sites enlarging the total sampling sites to 15. These sampling sites are shown in Figure 1.

Foam and scum samples were scooped into clean screw capped bottles. Within a few minutes foam breaks down and the resulting liquid is fixed by adding 3 - 6 drops of 40% formalin. It is necessary to fix at once, for otherwise conidia will germinate when they settle at the bottom. The bottles were brought to the laboratory, the contents allowed to settle and a drop of the bottom deposit pipetted onto a slide for microscopic examination.

In addition, decaying submerged leaves (which are dark brown, soft and beginning to skeletonise) were collected in polythene bags and brought to the laboratory. They were washed in tap water to remove surface and other debris. Each was then placed in a Petri-dish and covered with distilled water and left for 1 - 2 days at room temperature (30 $\pm$ 2°C) in the dark. The leaf was then scanned under a binocular microscope for aquatic Hyphomycete conidia and mycelia.

3. Results

Eighteen types of aquatic Hyphomycete conidia were encountered in the rivers and streams sampled. Of these 11 were identified to species level and 4 to generic level. Three types were not identified. The occurrence and the distribution of different species appear in Table 1. The results show that these aquatic Hyphomycetes are particularly abundant in streams flowing through the broad-leaved natural vegetation of the Sinharaja Forest.

TABLE 1. Occurrence and distribution of conidia of aquatic Hyphomycete species at 15 sampling sites. (+ present; — absent)

Species \ Sampling site	*Minuwangoda*	*Sinharaja Forest Streams Sub-sites* A	B	C	D	*Mee-Oya*	*Kala-Oya*	*Elpitiya stream*	*Aperakka stream*	*Uduwara-Oya*	*Attanagalu-Oya*	*Ma-Oya*	*Mawanella stream*	*Ambanapitiya stream*	*Habarana stream*
Lunulospora curvula	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Triscelophorus monosporus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Flagellospora sp.	+	+	+	+	+	—	+	—	+	+	+	+	—	+	+
Anguillospora sp.	+	+	+	+	+	+	+	+	—	+	+	—	—	+	—
Anguillospora crassa	—	+	+	+	+	—	—	+	—	—	+	—	+	—	—
Centrospora aquatica	—	+	+	+	+	—	—	—	—	+	+	—	+	—	—
Filosporella sp.	—	+	+	+	+	—	—	—	—	—	+	—	+	—	—
Lunulospora cymbiformis	—	+	+	+	+	+	—	—	—	—	—	—	—	—	—
Dactylella submersa	—	+	+	+	+	—	—	—	—	—	—	—	—	—	—
Lemonniera aquatica	—	—	—	+	+	+	+	—	—	—	—	—	—	—	—
Tricladium sp.	—	+	—	+	+	—	—	—	—	—	+	—	—	—	—
Alatospora accuminata	—	+	—	+	+	—	—	—	—	—	—	—	—	—	—
Tricladium angulatum	—	—	—	—	—	—	—	—	+	+	—	—	—	—	—
Wayaangam cornuta	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tetracladium setigerum	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—
Unidentified sp.	—	+	+	+	+	—	—	—	—	—	+	—	—	—	—

3.1 Genera with unbranched elongated conidia

Lunulospora curvula Ingold

Conidia were found in all streams and rivers examined in fairly large numbers. They are crescent shaped with a conspicuous notch at the point of attachment (Figure 2A). Conidial development was observed on decaying mango (*Mangifera* sp.) and jak (*Artocarpus integrefolia*) leaves under laboratory conditions. The species was reported to be worldwide in distribution.[11]

Flagellospora sp.

Conidia were found in foam from nine streams including four sites at the Sinharaja Forest. Conidia are sigmoid in shape and resemble an open S with curvature in more than one plane (Figure 2B). Conidia were not observed on incubating decaying leaves. Although the conidia resemble those of *Flagellospora curvula* Ingold, no definite identification could be made to species level from detached conidia without observing phialides which bear these conidia.

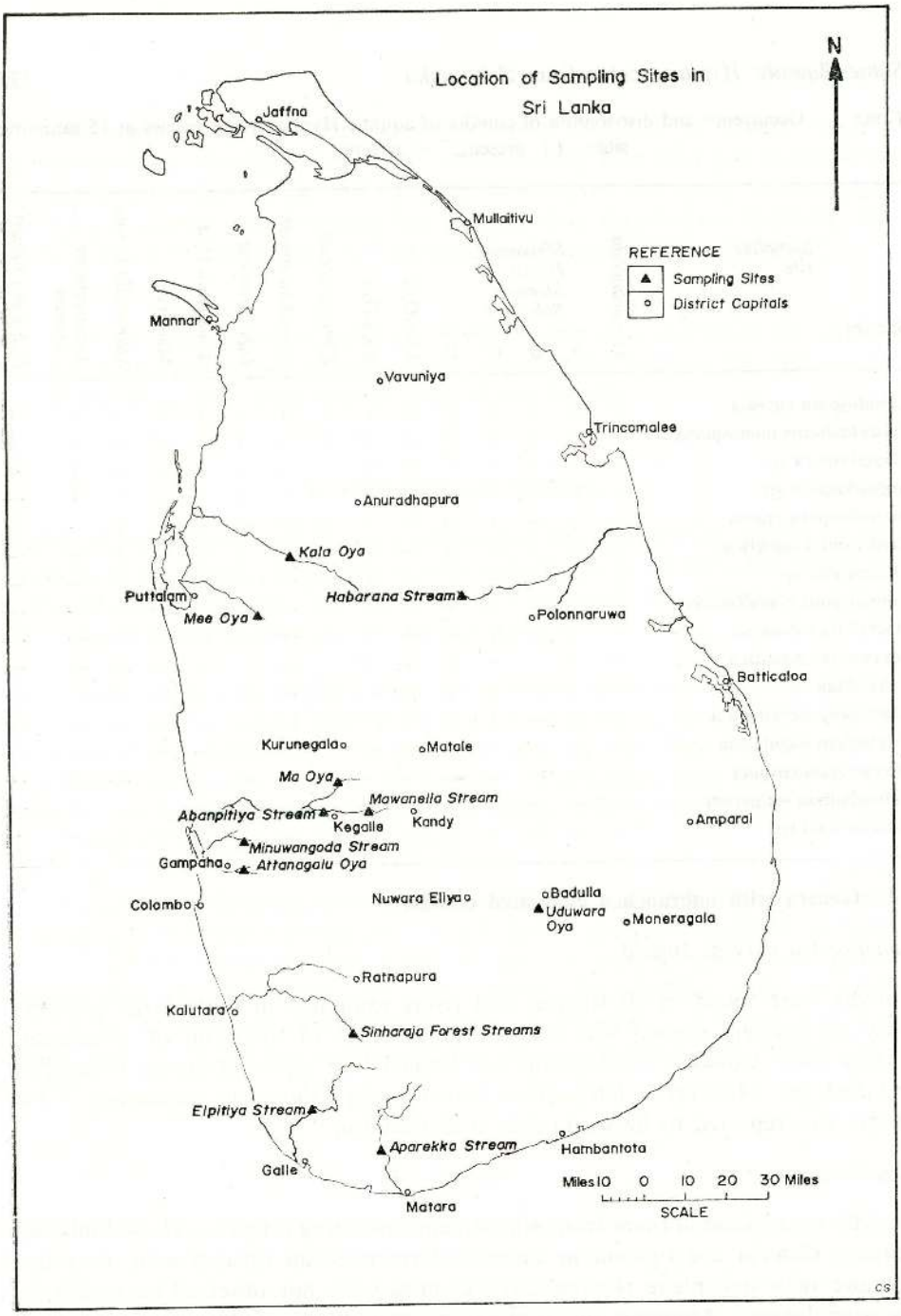

FIGURE 1 — Location of sampling sites.

Note — Four sampling sites in the streams at Sinharaja Forest.

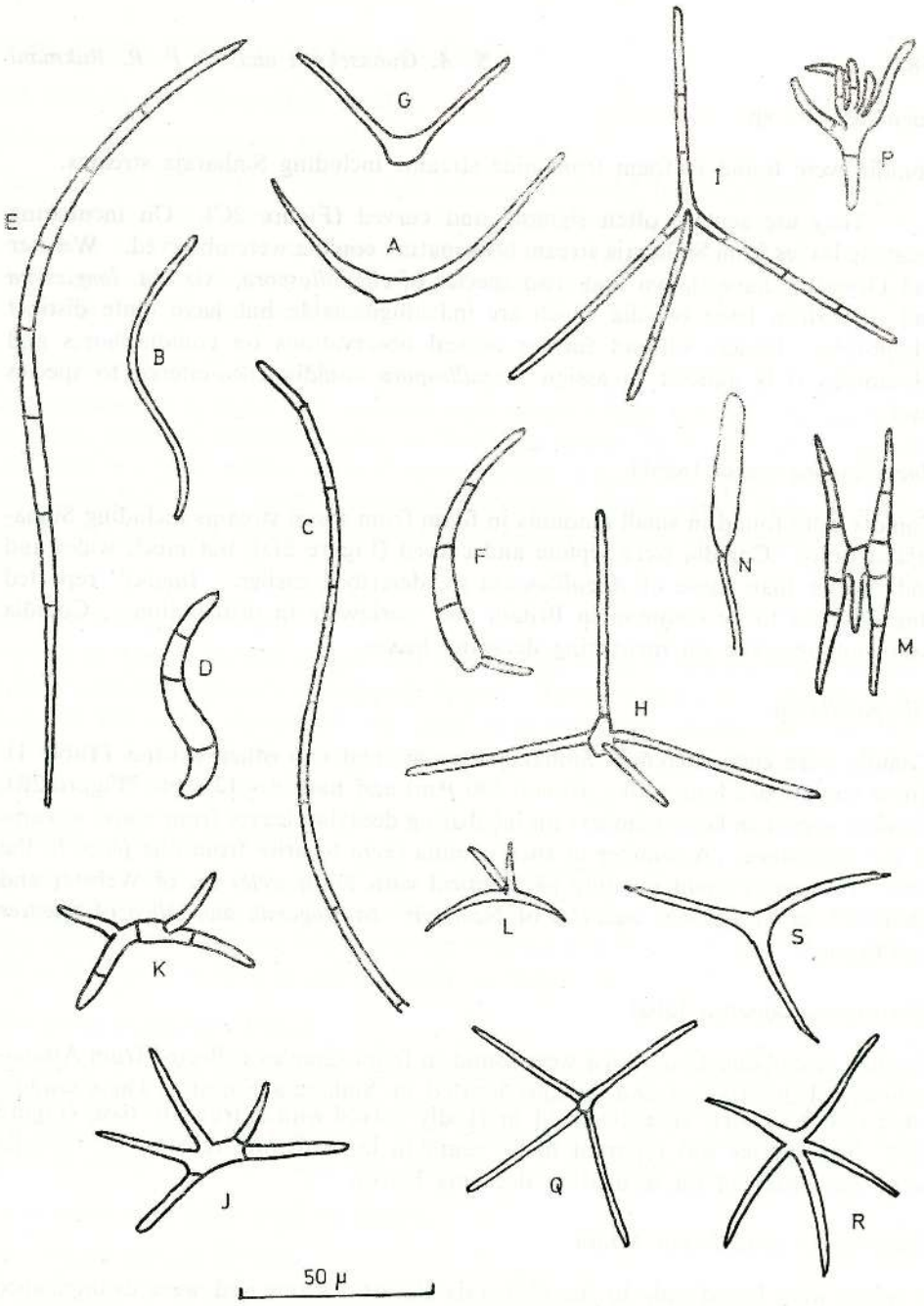

Figure 2

Eighteen types of conidia obtained from foam samples collected from some rivers of Sri Lanka

A. Lunulospora curvula
B. Flagellospora sp.
C. Anguillospora sp.
D. Anguillospora crassa
E. Filosporella sp.
F. Centrospora aquatica
G. Lunulospora cymbiformis
H. Triscelophorous monosporus
I. Lemonniera aquatica
J. Tricladium sp.
K. Tricladium angulatum
L. Alatospora accuminata
M. Triscelophorus monosporus
N. Dactylella submersa
P. Tetracladium setigerum
Q. R. S. Unidentified

Anguillosphora sp.

Conidia were found in foam from nine streams including Sinharaja streams.

They are septate often sigmoid and curved (Figure 2C). On incubating decaying leaves from Sinharaja stream beds mature conidia were observed. Webster and Descals[20] have shown that two species of *Anguillospora*, viz. *A. longissima* and *A. furtiva*, have conidia which are indistinguishable but have quite distinct telomorphs. Hence, without further critical observations on conidiophores and telomorphs it is difficult to assign *Anguillospora* conidia encountered to species level.

Anguillospora crassa Ingold

Conidia were found in small amounts in foam from seven streams including Sinharaja streams. Conidia were septate and curved (Figure 2D), but much wider and and shorter than those of *Anguillospora* sp. described earlier. Ingold[11] reported *Anguillospora* to be common in Britain and worldwide in distribution. Conidia were not observed on incubating decaying leaves.

Filosporella sp.

Conidia were encountered in Sinharaja streams and two other streams (Table 1). These conidia are long (often around 200 μm) and have 6 - 12 septa (Figure 2E). Conidia appear in large numbers on incubating decaying leaves from above streams in the laboratory. A number of such conidia seem to arise from one place in the leaf. The genus could possibly be identical with *Filosporella* sp. of Webster and Descals[20] or *Filosporella aquatica* of Nawawi[18] or *Rogersia annelidica* of Shearer and Crane.[19]

Centrospora aquatica Iqbal

Conidia resembling *C. aquatica* were found in foam samples collected from Attanagalu-oya, Uduwara-oya and streams located at Sinharaja Forest. These conidia were rather slender, elongated and markedly curved with a truncate base (Figure 2F). The species was reported to be common in temperate regions.[13] Conidia were not observed on incubating decaying leaves.

Lunulospora cymbiformis Miura

Conidia were found only in the Sinharaja Forest streams and were distinguished by a swelling in the middle region of the conidium (Figure 2G). The species was previously recorded only from Japan.[17] Webster and Nawawi (unpublished) have also found it in Malaya.

3.2 Genera with tetraradiate conidia

Triscelophorus monosporus Ingold

Conidia were found in all rivers and streams examined in fairly large numbers. These tetraradiate conidia were easily recognised from the projecting knob of the main axis and the whorl of three backwardly directed laterals (Figure 2H). The species was reported to be abundant in tropical streams.[7] Conidia were produced on incubating decaying leaves.

Lemmoniera aquatica de Wild

Conidia resembling those of *L. aquatica* were found in foam samples collected from Mee-oya, Kala-oya, and two streams at Sinharaja Forest (Table 1). These conidia have four divergent septate arms of similar length (Figure 2I). Abundant conidia were formed on leaves, decayed beyond recognition, collected from Mee-oya. The species was reported to be abundant in Britain and common throughout temperate regions.[7]

Tricladium sp.

Tricladium type of conidia (Figure 2J) were found in foam samples from Attanagalu-oya and three streams at Sinharaja Forest. The conidia on one hand resemble those of *Tricladium anomalum*[8] but were of considerably smaller size. On the other hand conidia closely resemble those of *Tricladium angulatum*, both in shape and size, recorded from Spain.[5]

Tricladium angulatum Ingold

Conidia resembling *T. angulatum*[7] were found only in foam samples collected from Uduwara-oya and this too in very small amounts. The conidium consists of a long axis and two laterals arising at two different levels (Figure 2K). The main axis of the spore is bent at points where the laterals arise.

Alatospora accuminata Ingold

Conidia were found only in foam samples collected from three streams at Sinharaja Forest. These tetraradiate conidia consist of a main axis forming two arms and two laterals forming the other two arms (Figure 2L). This species was reported to be abundant in Britain and well distributed in the temperate world.[7]

3.3 Genera with other types of conidia

Wayaangam cornuta Descals

Conidia were found only in foam samples collected from Minuwangoda (Figure 2M). This type of conidium was first recorded by Ingold & Ellis[12], Willoughby & Archer[22] as an unidentified species—and has been subsequently described by Descals and Webster.[6]

Dactylella submersa (Ingold) Nilsson syn. *Pyricularia submersa* (Ingold)

Conidia were found in large numbers only in foam samples collected from streams located at Sinharaja Forest. Conidia were ellipsoid (Figure 2N) and were produced in large numbers under laboratory conditions on incubating decaying leaves.

Tetracladium setrigerum (Gove) Ingold

These conidia were found only in foam samples collected from Uduwara-oya in small quantities. Mature conidia consist of four divergent arms with three parallel finger like projections of which one appears to be derived as a basal branch from another (Figure 2P). Conidia were not observed under laboratory conditions.

Three unidentified types of conidia (Figures 2 Q, R, S,) were frequently found in foam samples collected from Sinharaja Forest streams. Most noteworthy were the five armed type (Figure 2R) and the three armed type (Figure 2S).

4. Discussion

This preliminary survey of aquatic Hyphomycetes is primarily floristic in nature and is the first in Sri Lanka.

L. curvula and *T. monosporus* conidia were found in large numbers at all sites sample and can be considered as widely distributed, confirming the view that they are abundant in warmer parts of the world.[11] *Flagellospora* and *Anguillospora* can be placed next in the order of abundance and distribution. These four spore types along with *D. submersa* (found only in Sinharaja streams) and *Filosporella* sp. can be considered abundant. Other types in Table 1 have restricted distribution and that too in low numbers in the foam samples examined. Conidia of *T. setigerum* and *W. cornuta* have been encountered only once in this survey.

Species diversity (Table 1) and their abundance in Sinharaja forest streams could be possibly attributed to two factors. Firstly, these streams flow through a natural undisturbed broad-leaved vegetation yielding a perennial supply of dead leaves and twigs and secondly, the presence of rocks and larger plant debris which induce abundant formation of foam. Other streams, except Attanagalu-oya, used for sampling were placid and near either urbanized or agricultural areas and the presence of urban residues and agro-chemicals coupled with the smaller amounts of foam present may have contributed to the fewer numbers of conidia in the samples. The high species diversity at Attanagalu-oya where the sampling site was located upstream from the urbanized and agricultural area and the abundance of rocks etc., which cause turbulence inducing foam formation adds supporting evidence for the suggested possibilities.

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එස්. ශ්‍යාමලි එම්. ද සිල්වා සහ එන්. සාවිත්‍රි කුමාර්

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Cystoseira trinodis, *Turbinaria conoides* සහ *Sargassum* විශේෂයන්ගෙන් නිස්සාරණය කරගත් sodium alginate වල ගුලුරොනික් අම්ල අවශේෂයන්ට මැනුරොනික් අම්ල අවශේෂයේ අනුපාතය (M/G අනුපාතය) අධි සාන්ද්‍ර ^{1}H-NMR වර්ණාවලික්ෂය භාවිතයෙන් නිර්ණය කරන ලදී. ගුලුරොනේට් අවශේෂයන්ගේ H - 5 සහ ගුලුරෝනේට් සහ මැනියුරොනේට් යන දෙවර්ගයෙහිම අවශේෂයන්හි H - 1 හේතුකොට ගෙන සඳුවන්හි ඇතිවූ තීව්‍රතාවන් උපයෝගී කරගන්නා ලදී. ඇල්ජිනේට් සැම්පල වල ගුලුරොනේට් අවශේෂ බහුල බව පෙනී ගිය අතර, පොලිමර් දම, දිගු ගුලුරොනේට් අවශේෂ කුට්ටි වලින්ද, කෙටි මැනියුරොනේට් අවක්ෂේප කුට්ටි වලින්ද, යුරොනයිඩ් අවශේෂ දෙවර්ගයෙන්ම සමන්විත කුට්ටි සුළු ප්‍රමාණයකින් ද සමන්විත විය හැකි බැව් පෙනී ගියේ ය.

සීරම් සිස්ටයිල් ඇමයිනෝ පෙප්ටිඩේස් සඳහා වර්ණවලිමාපක අන්ත ලක්ෂ්‍ය ආර්ගණය.

එම්. සී. පී. කනගරත්න

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මස්තු කෝෂ්ඨීය ඇමයිනොපෙප්ටිඩේස් (CAS) ක්‍රියාකාරිත්වය සඳහා වර්ණාවලිමාපක අන්ත ලක්ෂ්‍යයක් මෙම පරීක්ෂණාගාරයේ දී තහවුරු කරගන්නා ලදී. මෙම ක්‍රමයේ සුමු ඇතුලත සහ සුමු අතර ප්‍රතිජනකතාව යහපත් වූ අතර උපරිම සංගුණක විචල්‍යතාව පිළිවෙලින් 2.1% සහ 3.0% විය. සෙ.ග්‍රෙ. 8° හි දී එන්සයිමය ස්ථාවර වන බැව් පෙනී ගියේය. මෙම උෂ්ණත්වය යටතේ දින 21 ක් ගබඩා කර තැබීමෙන් ක්‍රියාකාරිත්වය හීනවීමක් නොවීය. එන්සයිමය 5mM EDTA වලින් නිශේධනය වන බව පෙනී ගියේය.

යාපන අර්ධද්වීපයේ වෙරළාසන්න ප්‍රදේශවල ඇතැම් මුහුදු ඇල්ගී වර්ගවල අන්තර්ගත අයඩින් ප්‍රමාණය පිළිබඳ මූලික අධ්‍යයන.

රාජේස්වරී මාගේස්වරන් සහ එස්. සිවසුබ්‍රමානියම්

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යාපන අර්ධද්වීපයේ විවිධ වෙරළබඩ කලාපයන්ගෙන් එක්රැස් කරගන්නා ලද මුහුදු ඇල්ගී වර්ග විසිහතක අන්තර්ගත අයඩින් ප්‍රමාණයන් නිර්ණය කරන ලදී. විශ්ලේෂණයට

භාජනය කරන ලද වර්ග අතුරින් *Gracilaria opuntia* (දශ ලක්ෂයට කොටස් 1277) *Gracilaria crassa* (දශලක්ෂයට කොටස් 889) සහ *Turbinaria ornata* (දශලක්ෂයට කොටස් 810) යන වර්ග වල සාපේක්ෂ වශයෙන් අධික අයඩීන් ප්‍රමාණයක් අන්තර්ගතව ඇත. *Gracilaria opuntia* වල වූ අයඩීන් ප්‍රමාණය අයඩීන් ලැබෙන ප්‍රධානතම ප්‍රභවය වන උතුරු විලිගි කැලිඹේ නිධිවල අන්තර්ගත අයඩීන් ප්‍රමාණයට (දශලක්ෂයට කොටස් 1500 ට) සසඳනු ලැබේ.

ශ්‍රී ලංකාවේ උතුරේ වෙරළබඩ ප්‍රදේශ වලින් ලබාගත් ඇතැම් මුහුදු ඇල්ගීවල බනිජ සහ ප්‍රෝටීන් අන්තර්ගතය.

රාජේස්වරී මාගේස්වරන් සහ එස්. සිවසුබ්‍රමානියම්

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උතුරු ශ්‍රී ලංකාවේ වෙරළබඩ ප්‍රදේශ වලින් ලබාගත් මුහුදු ඇල්ගී වර්ග විසිපහක අන්තර්ගත ප්‍රෝටීන් සහ බනිජ ප්‍රමාණයන් මෙයින් වාර්තා කෙරෙයි. *Centroceras clavulatum, Ulva lactuca, Hypnea muscifomis, Acanthophora delilei* සහ *Gracilaria edulis* යන ඇල්ගී විශේෂයන්හි, ධාන්‍ය වර්ග, බිත්තර සහ මසුන් වැනි ආහාරයන්ට සමාන අධික ප්‍රෝටීන් ප්‍රමාණයන් අන්තර්ගත බැව් පෙනී යයි. *Gracilaria edulis, Laurencia obtusa, Sargassum polycystum Ulva lactuca* සහ *Gracilaria crassa* වැනි ඇල්ගාවල සහ *Thalasia hemprichi* (ආවෘත බීජ) වල නයිට්‍රජන්, පොස්පරස් සහ පොටෑසියම් සැළකිය යුතු තරම් විශාල ප්‍රමාණයක් අන්තර්ගත වන බැවින් මේවා පොහොර වශයෙන් භාවිතා කළ හැකිය.

ශ්‍රී ලංකාවේ තාප සුවපහසුව පිළිබඳව සෘතු අනුව සහ දෛනිකව ඇතිවන විවලනතා.

වී. බස්නායක

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සෘතු අනුව උෂ්ණත්වයේ මද විවලනතාවන් ඇතිවන නිවර්තනික රටක (ශ්‍රී ලංකාවේ) සෘතු අනුව තාප සුවපහසුවෙහි අනුකූලවීමක් වේද යන ප්‍රශ්නයට අදාළ සාක්ෂි, මෙම ලිපියෙන් වාර්තා වෙයි. මාස 10 - 12 දක්වා වූ අඛණ්ඩ කාලසීමාවක් තුල, අවස්ථා සියයකට ආසන්න සංඛ්‍යාවක දී, පුද්ගලයින් දෙදෙනෙකුගේ සුවපහසුතා වරණයන් ලබා ගැණිනි. වසර 12 කට ඉහතදී නොකඩවා මාස හයක කාලසීමාවක් තුල තබන ලද සටහන්ද ඉන් එක් අයෙකු අත තිබිණි. මනා තාප සුවපහසුතා සංවේදනයට අනුරූප වූ අවට උෂ්ණත්ව (සුවපහසුතා උෂ්ණත්වය) මට්ටම වඩා උණුසුම් සෘතුවල ඉහළ ගිය අතර, උණුසුම අඩු සෘතුවල එය පහළ වැටිණි. දෛනික උෂ්ණත්වයේ වෙනස්කම් වල සෘතු අනුව

ඇතිවන විචල්‍යතාවන් තාප සුවපහසුව කෙරෙහි බලපාන්නේ ද යන ප්‍රශ්නය පිළිබඳව සාක්ෂි ඉදිරිපත් වෙයි. මාස 12 ක කාලපරිච්ඡේදයක් තුල දින 73 කදී උදේ සිට සවස දක්වා තාප සුවපහසුතාවෙහි වූ වෙනස්කම් එක් පුද්ගලයෙකුට අදාලව සටහන් කරන ලදී. සෘතු අනුව අනුහුරු වීමේ බලපෑමක් මෙහිදී දක්නට ලැබිණ. තාප අපහසුතාව ඇති කළ අවට උෂ්ණත්වයේ වෙනස්වීම්, උණුසුම් මාසවලදී වැඩිවූ අතර, උණුසුම අඩුවන මාස වලදී අඩුවිය. සෘතු අනුව ඇතිවන මෙම අනුකූලතා බලපෑම් පෙන්නුම් කිරීමේ ලා, සළුල උෂ්ණත්ව පරිමාණය වියළි බල්බ උෂ්ණත්වයට වඩා සතුටුදායක නොවන බැව් පෙනී ගියේ ය.

ජලය ෆ්ලෝරික් හෙක්සතයෝසයනේට් වලින් ප්‍රකාශ ඔක්සිකරණය වීම.

කේ. තෙන්නකෝන්, පී. ඒ. අබේසූරිය සහ ඩී. එම්. පතිනායක

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දෘශ්‍යවූත්, පාරජම්බුල තත්වයට සමීපවූත් ආලෝකයෙන් (ප්‍රමාණය අවනතිය 0.2%) විකිරණ කිරීමේදී ෆ්ලෝරික් හෙක්සතයෝසයනේට් අයනවලින් ජලය ඔක්සිකරණය වන බැව් පෙනී ගොස් ඇත. මෙහි දී ප්‍රතික්‍රියා ප්‍රමාණයක් මැන, ප්‍රතිඵල පැහැදිලි කිරීම සඳහා සරල න්‍යායක් ඉදිරිපත් කර ඇත.

ඇතැම් ශාක ආසුතයන් සුහුඹුල් *Sitophilus* විශේෂයට දක්වන විකර්ශණතාව පිළිබඳ අධ්‍යයන

වී. කේ. ගනේෂලිංගම් සහ වී. ශිවනඩරාජා

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Ocimum sanctum, *Vitex negundo*, *Azadirachta indica*, සහ *Citrus aurantifolia* පත්‍රවල වාෂ්පශීලී ආසුැතයන් *Sitophilus* විශේෂයට දක්වන විකර්ශණතාව, Y හැඩයේ ආස්‍රාණමාපකයක් භාවිතයෙන් පරීක්ෂණාගාරයේ දී විමර්ශණය කරන ලදී. පරීක්ෂණයට භාජනය කරන ලද ශාඛ ආසුැතයන් අතුරින් *Sitophilus* විශේෂයට වඩාත්ම බලපාන විකර්ශකය වන්නේ *O. sanctum* බව පෙනී ගියේය. පරීක්ෂා කළ අනෙකුත් ශාඛ ආසුැත *O. sanctum* වලට වඩා සැළකිය යුතු තරම් අඩු විකර්ශණීයතාවක් දක්විය. *O. sanctum* සහ *A. indica* යන වාෂ්පශීලී ආසුැතයන්ගේ සහ ක්‍රියාකාරී සංයෝගයෙහි විකර්ශණීයතා බලපෑම් *O. sanctum* වල විකර්ශණීයතාවට සමබැව් පෙනී ගියේය. පරීක්ෂණයට භාජනය කළ ශාක කෙරෙහි හුමාල ආසවණයන් (දළ ජල නිස්සාරණයන්) ගේ විකර්ශණීය බලපෑම් පැවති කාලය සම්බන්ධයෙන් අළුත පිළියෙල කළ සහ දින දහයක් පැරණි *O. sanctum* වලින් ඇති වූ බලපෑම් එක හා සමාන බැව් පෙනී ගියේය. දින විස්සක් සහ දින තිහක් පැරණි *O. sanctum* මිශ්‍රණය අළුත පිළියෙල කළ හෝ දින දහයක් පැරණි *O. sanctum* වලට වඩා සැළකිය යුතු තරම් අඩු විකර්ශණීයතාවක් පෙන්නුම් කළේ ය.

මර්කියුරික් අයඩයිඩ — ප්‍රකාශ විඛාදන ප්‍රතිරෝධී අර්ධසන්නායකය.

කේ. තෙන්නකෝන්

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ස්ථර සහිත ස්ඵටිකරූපී ව්‍යුහයකින් යුත් n - මර්කියුරික් අයඩයිඩ, ප්‍රකාශ විද්‍යුත් රසායනික කෝෂයන්හි ඇනෝඩය වශයෙන් භාවිතා කළ විට ප්‍රකාශ විඛාදනයට ප්‍රතිරෝධී වන බැව් පෙනී ගොස් ඇත.

රසායනික වශයෙන් පිළියම් කිරීමෙන් සහ ඵෙන්ද්‍රීය ද්‍රව්‍ය මිශ්‍ර කිරීමෙන් පස්වල *Pseudomonas solanacearum* (Smith) වල ව්‍යාධිජනකතාව සහ පැවැත්ම කෙරෙහි ඇතිවන බලපෑම්

ජේ. එම්. ආර්. එස්. බණ්ඩාර

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මිරිස් වගා දර්ශ MI 1 හැරුණු විට, ශ්‍රී ලංකාවේ වගාකරන සියළුම සොලනේසීය භෝග *Pseudomonas solanacearum* වල 3 වන ජීව දර්ශයට ගොදුරුවන බැව් පෙනී ගියේ ය. ඇතැම් වැඩි දියුණු කළ AVRDC තක්කාලි වගා දර්ශයනට ද බැක්ටීරියම ව්‍යාධි ජනක වන බැව් ඔප්පු විය. ආමුකුලනය කළ පසට ඵෙන්ද්‍රීය පොහොර, (කුකුල් පොහොර, ගොම පොහොර සහ ග්ලිරිසිඩියා පත්‍ර) එක් කළ විට, රසායනික පොහොර (හුණු, ඇසිටික් අම්ලය, බිනෝමයිල් සහ කැප්ටාන්) යෙදූ කල මෙන් නොව, රෝපිත සංඛ්‍යාවෙහි ද, අනතුරුව බිහිවූ ov. marglobe වර්ගයේ තක්කාලිවල මැලවුම් රෝගයේ දරුණුතාවයෙහි ද සැළකිය යුතු වැඩිවීමක් දක්නට ලැබිණ. බිනොමයිල් සහ කැප්ටන් පමණක් යෙදූ පස්වල බැක්ටීරියා ගහණය සහ රෝගයන්හි දරුණුතාවය සැළකිය යුතු අන්දමින් අඩුවිය. ඵෙන්ද්‍රීය පොහොර යෙදීමෙන් *P. solanacearum* වලත් වෙනත් මෘතෝපජීවී බැක්ටීරියාවලත්, වැඩිම උත්තේජනය විය. වෙනත් බැක්ටීරියා වර්ග වලට *P. solanacearum* අනුපාතය, අනතුරුව ඇතිවූ තක්කාලි වගාවෙහි මැලවුම් ප්‍රතිශතයට සෘජු සම්බන්ධතාවක් පෙන්නුම් කළේ ය.

සැපොනිකෘත පොල්තෙල් අඩංගු පද්ධතිවලට සහ පොල්තෙල්වල ඇති ඇතැම් ඇසිලේට වර්ග අඩංගු පද්ධතිවලට සිරියම් අයන නිස්සාරණය කිරීම පිළිබඳ අධ්‍යයනය.

ඩබ්ලිව්. මල්ලවාරච්චි, එම්. ඩබ්ලිව්. ඩයස්, එන්. රුවන්පතිරණ සහ ඩබ්ලිව්. යූ. ද අල්විස්

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විරල පාංශු අතරින් සිරියම් සහ (Ce) එහි සංයෝග කිහිපයක් කර්මාන්තවල විශාල වශයෙන් යොදා ගනු ලැබේ. ඛණිජ ද්‍රව්‍ය කිහිපයකම (උදා: මොනසයිට්වල) අධික වශයෙන් පවතින සිරියම්, වඩාත් ම බහුල වශයෙන් පවතින විරල පාංශු මූල ද්‍රව්‍ය ය ද වෙයි. සාමාන්‍ය යෙන් එය නිස්සාරණය කර ගනු ලබන්නේ මෙකී ඛණිජ ද්‍රව්‍ය පිරිසැකසීමේ දී ලැබෙන

භාගිකයන්ගෙනි. Ce (IV) නිස්සාරණයේ දී එක් නිස්සාරකයක් වශයෙන් පොටෑසියම් ස්ටියරේට් භාවිතා කර ඇත. මෙම අධ්‍යයනයේ දී ස්ටියරික්, ලෝරික්, පාමිටික්, කැප්‍රික්, ඔලෙයික් අම්ල, මෙම අම්ල මිශ්‍රණවල සෝඩියම් සහ පොටෑසියම් ලවණ සමග සහ සැපොනිකෘත පොල්තෙල් සමඟ අවක්ෂේපණය කිරීමෙන් Ce (IV) වශයෙන් ද Ce (III) වශයෙන් ද සිරියම් නිස්සාරණය කර ගැනීමේ ශක්‍යතාව පරීක්ෂා කරන ලදී. මෙහිදී ප්‍රධාන අරමුණ වූයේ සෝඩියම් හයිඩ්‍රොක්සයිඩ් (NaOH) වලින් සැපොනිකරණය වූ පොල් තෙල්වලින් Ce (III) සහ Ce (IV) නිස්සාරණය කර ගැනීමේ හැකියාව අධ්‍යයනය කිරීමයි. මක්නිසාද යත්, පොල්තෙල් මෙන් ම, සෝඩියම් හයිඩ්‍රොක්සයිඩ් ද, ශ්‍රී ලංකාවේ පවතින හෙයින් මෙම ක්‍රමය සාර්ථක වුවහොත්, එය වාසිදායක ලෙස විශාල පරිමාණයෙන් භාවිතා කළ හැකි බැවිනි. Ce (III) සහ Ce (IV) අයනවල නිස්සාරකතාවය ඉහත කී එක් එක් ක්‍රමයේ දී විවිධ pH අගයන් පරාසයක දී ඒවා ඇසිලේට් බවට පරිවර්තනය කිරීමෙන්, ප්‍රමාණාත්මක පදනමක් මත නිර්ණය කරන ලදී. (අ) සැපොනිකෘත පොල්තෙල්වල Ce (III) සහ Ce (IV) නිස්සාරණ ප්‍රමාණය සැළකිය යුතු තරම් අධික වන බව ද, (ආ) 5ට ආසන්න pH අගයක දී Ce (IV) සෝඩියම් ලවණයන්ගෙන් සහ Ce (III) පොටෑසියම් ලවණයන්ගෙන් වඩාත් ම හොඳින් නිස්සාරණය වන බව ද (ඇ) Ce(III), 0.5% කට වැඩි ප්‍රමාණයක් 3.5 - 6.8 අතර pH අගයන්හි දී මනාව පාලිත තත්ත්වයන් යටතේ සෝඩියම් ලවණයන්ගෙන් නිස්සාරණය කරගත හැකි බව ද, ප්‍රතිඵලවලින් පෙනී ගියේ ය. එහෙයින් සෝඩියම් හයිඩ්‍රොක්සයිඩ්වලින් සැපොනිකරණය කළ පොල් තෙල්, විශේෂයෙන් ම Ce (IV) අයන සඳහා සතුටුදායක නිස්සාරක මාධ්‍යයක් ලෙස සැළකිය හැකි වන අතර, සෝඩියම් සහ පොටෑසියම් යන දෙවර්ගයේ ම හයිඩ්‍රොක්සයිඩ්වලින් සැපොනිකරණය කළ තෙල් Ce (III) අයන නිස්සාරණය සඳහා සුදුසු වනු ඇති බැව් කිව හැකි ය.

ඝන කියුප්‍රික් ෆෙරිසයනයිඩ් වල බන්ධන සමායවයවිකතාවයක් පිළිබඳ සාක්ෂි.

කේ. තෙන්නකෝන්

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බන්ධිත අතරැසි ජලය ඉවත්කළ විට ඝන කියුප්‍රික් ෆෙරිසයනයිඩ් ව්‍යුහාත්මක සංක්‍රමණය කට භාජනය වන බැව් පෙන්නුම් කිරීම සඳහා පරීක්ෂණ සාක්ෂි ඉදිරිපත් කෙරෙයි. මෙම සංක්‍රමණය CN^- වල C, Fe^{2+} වලට ද N, CU^{++} වලට ද ඇති සංගතය, ප්‍රතිවර්තනය වන බන්ධන සමායවිකතාවක් තේතුකොටගෙන සිදුවෙය යන අදහස ඉදිරිපත් කෙරේ.

ශ්‍රී ලංකාවේ භූ විද්‍යාව සහ මැණික් පිහිටීම.

ජේ. ඩබ්ලිව්. හේරත්

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පිහිටි ස්ථානයන්හිම හමුවන පුනක්කන්, ඇතැම් නොරමල්ලි සහ රඹඹ හැරුණු කොට ශ්‍රී ලංකාවේ මැණික් ගල් සියල්ල ලැබෙනුයේ පැරණි දියළු නිධි වලිනි. මැණික් ඒවායේ පාෂාණ න්‍යාසයෙහි පවතින අවස්ථා විරළ වන නමුදු, ඒවා කිසියම් ආකාරයෙක ආක්‍රාන්ත ද්‍රව්‍යයක් ආශ්‍රිත කොටගෙන පවතින බවත්, පෙග්මටයිටික ස්වභාවයකින් යුත් ද්‍රව්‍යයන්

ගෙන් ආරම්භ වන්නට ඇති බවත් නිසැකය. දියඵ මැණික් බිම්වල දක්නට ලැබෙන ආකෘති අනුප්‍රාප්තියේ ස්වභාවය ඒවා තැන්පත් වී ඇත්තේ කවර ද්‍රව්‍යයන් සහ තත්වයන් යටතේ ද යන්න අනුව බෙහෙවින් වෙනස් වෙයි. ශ්‍රී ලංකාවේ, රත්නපුරය ප්‍රධාන මැණික් වෙළඳ මධ්‍යස්ථානය කොටගත් සබරගමු පළාත තරම්, සාපේක්ෂක වශයෙන් සීමිත වූ කඳුකර බිම් ප්‍රදේශයක, (සුලභ සහ දුර්ලභ) මැණික් ගණයට අයත් විවිධ මැණික් වර්ග මෙසා විශාල සංඛ්‍යාවක් ඒකරාශිවී පවතින වෙනත් ස්ථානයක් ලොව නොමැති විය හැකිය.

ශ්‍රී ලංකාවේ ඇතැම් ජලජ Hyphomycete වර්ග.

එස්. ඒ. ගුණසේකර සහ එම්. පී. ආර්. රුක්මණී

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ගංගා ඇල දෙලවලින් එකතු කරන ලප පෙන ආදර්ශකවල Hyphomycete කොණ්ඩ බීජානු වර්ග දහ අටක් දක්නට ලැබුනි. මෙම කොණ්ඩ බීජානුවලින් 13 ක් විශේෂ දක්වා හඳුනා ගෙන ඇති අතර දෙකක් ගණ මට්ටමට පමණක් හඳුනාගෙන ඇත. බීජානු වර්ග තුනක් කිසියේත් හඳුනා ගැනීමට නොහැකි වී ඇත. නාගරීකරණය වූ හා කෘෂිකාර්මික ප්‍රදේශ ඔස්සේ ගලා බසින ගංගා ඇලදෙලවල ඇති ප්‍රමාණයට වඩා විශාල කොණ්ඩ බීජානු සංඛ්‍යාවක් හා වර්ග පරාසයක් සිංහරාජ වනාන්තරයේ ඇල දෙලවල දක්නට ලැබිනි.

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இந்த இதழின் கட்டுரைகளின் சுருக்கங்கள்

இலங்கைக் கடல் அல்காக்களிலுள்ள காபோவைதரேற்றுக் கூறுகள் பாகம் II சில கபில நிறக் கடற்பாசி அல்சினேற்றுக்களிலுள்ள பூரோனேற்று மீதிகளின் அமைப்பும் தொடர்பியையும்.

எஸ். சியாமலி எம். த சில்வா, என். சாவித்திரி குமார்.

J. Natn. Sci. Coun. Sri Lanka 1984 **12** (2): 161—166

சிஸ்ரே செய்ரு திரினேடிஸ், துர்பினரியா கொன்னேய்டேசு, சர்கஸ்ஸும் எஸ். பீ என்னும் அல்காக்களிலிருந்து பிரித்தெடுக்கப் பெற்ற சோடியம் அல்சினேற்றின் குளுரோனிக் கமில மீதிகளுக்கு மன்னுரோனிக்கமில மீதி காட்டுகின்ற விகிதாசாரம் (ம/கு விகிதாசாரம்) அதி பிரிப்புவது கொண்ட ^{1}H-NMR வண்ணப்பட்டை அளவாய்வு முறையின் மூலம் துணியப் பெற்றது. குளுரோனேற்று மற்றும் மன்னுரோனேற்று மீதிகளின் H-7 காரணமாகவும் குளுரோனேற்று மீதிகளின் H-5 காரணமாகவும் உண்டான சமிக்கைகளின் செறிவுகள் இதற்குப் பயன்படுத்தப் பட்டன. அல்சினேற்று மாதிரிகள் குளுரோனேற்று மீதிவள மிக்கதாய் காணப் பட்டன. மீச் சேர்மச் சங்கிலிகள் குளுரோனேற்று மீதிகளின் நீள்பாளங்களையும் மன்னுரோனேற்று மீதிக் குறும்பாளங்களையும் இருவகை யூரோனேட்டு மீதிகள் அடங்கப் பெற்ற பாளங்கள் சிலவற்றையும் கொண்டிருக்கலாம்.

சீரம் சிஸ்தில் அமினே செல்லாக்க நொதியத்துக்கு வண்ணப்பட்டை ஒளி அளவியல் முடிவுநிலைப் பரீட்சை.

எம். சி. பி. கனகரத்தினு.

J. Natn. Sci. Coun. Sri Lanka 1984 **12** (2): 167—171

இப்பரிசோதனைச் சாலையில் சீரம் சிஸ்தில் அமினே செல்லாக்க நொதியத் (CAS) தொழிற்பாட்டுக்காக வண்ணப்பட்டை ஒளி அளவியல் முடிவுநிலைப் பரீட்சை யொன்று நிலைநாட்டப் பெற்றுள்ளது. இம் முறை சார் தொகுதிக்குள் மற்றும் தொகுதிகளுக்கிடையான இனப்பெருக்கத்தகவு நன்று அமையப் பெற்றதுடன் அவ்விரண்டிற்கான உயர் மாறற் குணகம் முறையே 2.1% ஆகவும் 3.0% ஆகவும் காணப்பட்டது. இந் நொதியம் 8°C வெப்பநிலையில் உறுதியாக இருந்த தோடு அந்த வெப்பநிலையின் கீழ் 21 நாட்களுக்கு மேலாக அதனைச் சேமித்து வைத்திருந்த போதிலும் அதன் தொழிற்படல் சக்தி குறையவில்லை. 5 mM EDTA மூலம் இந்நொதியத்தின் தொழிற்பாடு நிரோதிக்கப்படுமென்பதும் கண்டறியப் பட்டது.

யாழ்ப்பாண தீவுகற்பக் கடற்கரைப் பகுதியைச் சேர்ந்த கடல் அல்காக்கள் சிலவற்றில் உள்ள அயடீன் பொருள்பற்றிய தொடக்க ஆய்வுகள்.

இராஜேஸ்வரி மகேஸ்வரன், எஸ். சிவசுப்பிரமணியம்.

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யாழ்ப்பாண தீவகற்பத்துக் கடற்கரைப்பகுதிகள் பலவற்றிலிருந்து சேகரிக்கப் பெற்ற இருபத்து ஏழு கடல் அல்கா இனங்களின் அயடீன் உள்ளடக்கங்கள் துணியப் பெற்றன. இரசாயனப் பகுப்பு செய்யப் பெற்ற இவ்வினங்களுள், கிராசிலாறியா ஓபுன்சியா (1277 ppm),[1] கிராசிலாறியா கிராஸ்ஸா (889 ppm), துர்பினுரியா ஒறன்று (810 ppm) ஆகிய அல்காக்களில் மற்றவைகளுடன் ஒப்புநோக்குகையில் அதிக அயடீன் பொருள் இருக்கிறது. கிராசிலாரியா ஒபுன்சியாவில் உள்ள அயடீன் அளவு, அயடீன் பெறப்படும் பிரதான வள மூலமான வட சிலி நாட்டு சிலி சேப்படிவுகளில் (1500 ppm) அடங்கும் அயடீன் அளவுடன் ஒப்பிடத்தக்க வாறு அமைந்திருக்கிறது.

வட இலங்கைக் கடற்கரைப் பகுதிகளில் உள்ள கடல் அல்கா சிலவற்றில் அடங்கும் கனிமப் பொருளும் புரதமும்.

இராஜேஸ்வரி மகேஸ்வரன், எஸ். சிவசுப்பிரமணியம்.

J. Natn. Sci. Coun. Sri Lanka 1984 **12** (2): 179—189

வட இலங்கைக் கடற்கரைப் பகுதிகளைச் சேர்ந்த இருபத்து ஐந்து கடல் அல்கா இனங்களில் உள்ள புரதப் பொருளும் கனிமங்களும் இக்கட்டுரையில் விளக்கப் பெற்றுள்ளன. செஞ்ரே செருசு கிலாவுலாதும், உல்வா லக்றுக்கா, ஹிப்னியா முஸ்கிபோர்மிஸ், அகந்தோபோரு டெலிலேயி, கிராசிலாரியா ஏதூலிஸ் ஆகிய அல்லகா இனங்களில் உணவு வகைகளான தானியங்களிலும் முட்டைகளிலும் மீன்களிலும் அடங்கப்பெறும் அளவுக்குச் சமமான புரதப்பொருள் அதிக அளவில் காணப்பட்டன. கிராசிலாரியா ஏதூலிஸ், உலோரென்ஜியா ஒத்தூசா, சர்கஸ்ஸும் பொலிசிஸ்தும், உல்வா லக்றுக்கா, கிரிசிலாரியா கிராஸ்ஸா, தாலாசியா எம்பிரிக்கி (வித்துமூடியுளி) ஆகிய அல்காக்களில் நைதரசன், பொசுபரசு, பொற்றுசியம் எனும் கனிமங்கள் பெருவாரியாக அடங்கியிருப்பதனால் அவை இரசாயன உரங்களாகப் பயன்படுத்தப்படலாம்.

இலங்கையின் வெப்ப இன்னமைதியின் பருவத்துக்குரிய மற்றும் பகல் சார் மாறல்.

வீ. பஸ்நாயக்கா.

J. Natn. Sci. Coun. Sri Lanka 1984 **12** (2): 191—203

பருவத்துக்குப் பருவம் ஏற்படும் மாற்றம் மிகச் சிறிதாகவுள்ள அயனமண்டல நாடொன்றில் (இலங்கையில்) பருவ மாற்றங்களுக்கேற்ப வெப்பநிலை இன்னமைதி இணக்கமுறும் தன்மையினை அறிதற்பாலதான சான்றுகள் இக்கட்டுரையில் விளக்கப்பட்டுள்ளன. 10—12 அடுத்து வருகின்ற மாதக் காலப்பகுதியினுள்ளே ஏறக்குறைய நூறு சந்தர்ப்பங்களில் இச்சோதனைக்கு உட்பட்ட ஆள் இருவருடைய வெப்பநிலை இன்னமைதி வாக்குகள் தனித்தனியாக சேகரிக்கப்பட்டன. இவர்களுள் ஒருவர் 12 வருடங்களுக்கு முன்னர் அடுத்து வந்த ஆறுமாதக் காலப் பகுதியொன்றில் அத்தகைய சோதனைக்கு உட்பட்டு சேகரிக்கப் பெற்ற தரவுகளைக் கொண்டிருந்தார். திருத்தியுறும் வெப்ப இன்னமைதி (இன்னமைதி வெப்ப நிலை) யோடு ஒத்தியலும் சுற்றுப்புற வெப்பநிலை மட்டம் சூடான பருவத்தில் ஏறி சூடு குறைவான பருவத்தில் இறங்கியது.

வெப்ப இன்னமைதி மீது பகல் வெப்பநிலை மாற்றம் பருவத்துக்கு ஏற்ப மாற்றமுறும் தன்மை எங்களம் அமையும் என்பதை அறிதற்பாலதான சான்றுகளும் இங்கு சேகரிக்கப்பட்டுள்ளன. 12 மாதங்களின் போது 73 நாள்களில் ஒருவரினது வெப்பநிலை இன்னமைதி காலை முதல் மாலை வரை மாற்றமுறும் பாங்கு குறிக்கப்பெற்றுள்ளது. ஒருவகையான பருவத்துக்குரிய இணக்கப்பாட்டு விளைவு கண்டறியப்பட முடிந்தது. அதன்படி வெப்ப இன்னமைதியை உண்டுபண்ணும் சுற்றுப்புற வெப்பநிலை சூடு குறைவான மாதங்களிலும் பார்க்க சூடான காலங்களில் அதிகமாகவே இருந்தது.

இப்பருவம் சார் இணக்கப்பாடுகளை எடுத்துக் காட்டும், விடயத்தில் பயன்படுவெப்பநிலை அளவுத் திட்டம் உலர்க்குமிழி வெப்பமுறையினும் பார்க்க நல்லதெனத் தோன்றவில்லை.

பெரிக்கு அறுகந்தக சயனேற்றின் மூலம் நீரின் ஒளியொட்சியேற்றம்.

கே. தென்னகோன், பி. ஏ. அபேசூரியா,
டீ. எம். பத்தினயக்கா.

J. Natn. Sci. Coun. Sri Lanka 1984 **12** (2): 205—211

கட்புலனாகும் வெளிச்சத்திலும் கட்புலனாகா U.V. வெளிச்சத்திற்கு அணிமையிலும் ஏற்படும் வீசுகதிர்வீழ்வினைக் கொண்டு நீரை ஒட்சியேற்றும் சக்தி பெரிக்கு அறுகந்தகசயனேற்று அயனில் உள்ளதெனக் கண்டறியப்பட்டது. (இதன் சக்திச் சொடுவிளைச்சல் ~ 0.2% ஆகும்). தாக்க விகிதங்கள் அளவிடப் பெற்று பெறுபேறுகளை விளக்குதற்கு எளிய கோட்பாடொன்றும் முன்வைக்கப்பட்டுள்ளது.

சிற்ரேபிலசு S P முதியவை மீது சில தாவரவடி நீர்மங்களில் உள்ள வெறுப்பூட்டல் பண்பு பற்றிய ஆய்வு.

வி. கே. கணேசலிங்கம், வி. சிவானந்தராசா.

J. Natn. Sci. Coun. Sri Lanka 1984 **12** (2): 213—218

ஓசிமும் சன்றும், வீற்றெற்சு நேகுண்டோ, அசாதிரற்ரு இந்திக்கா, சிற்றசு ஓளரன்றி போலா ஆகிய தாவர இலைகளின் ஆவிப்பறப்புள்ள வடிநீர்மங்களின் வெறுப்பூட்டும் பண்பு சிற்ரேபிலசு SP மீது ஏற்படுத்துகின்ற தாக்கம் ஆராயப்பட்டது. இச் சோதனையானது Y வடிவ மோப்பமானியின் உதவியைக் கொண்டு ஆய்வுகூடத்தில் இடம் பெற்றது. பரிசோதிக்கப்பெற்ற தாவரங்களுள் ஓ. சன்றும் இலை வடிநீர்மம் மிகவும் பயனுறுதி வாய்ந்ததாகக் காணப்பட்டது. மற்ற தாவரவடி நீர்மங்கள் இதைவிடக் குறைவான வெறுப்பூட்டல் பண்பினைக் கொண்டிருந்தன. ஓ. சன்றும் மற்றும் ஏ. இந்திக்கா ஆகியவற்றின் ஆவிப்பறப்புள்ள வடிநீர்மங்களின் ஒன்றிய உழைப்புச் சேர்க்கையின் வெறுப்பூட்டல் பண்பும் தனிப்பட்ட ஓ. சன்றும் வடிநீர் மத்தின் பயனுறுதியைக் கொண்டிருந்தது. பரிசோதிக்கப் பெற்ற தாவர ஆவி வடி நீர்மங்களின் (பண்புரு நீர் வடிச்சத்து) வெறுப்பூட்டல் பண்பின் பயனுறுதி யான நிலைப்பேற்றுக் காலம் ஓ. சன்றும் புதிய வடி நீர்மம் பொறுத்தவரை 10 நாள் வரை நீடித்திருந்தது. ஓ. சன்றும் தயாரிப்பு 20 அல்லது 30 நாள் வரை வைக்கப்பெற்ற பின்னர் 10 நாள் வயதுடைய புதிய வடி நீர்மத் தயாரிப்பினை விடக் குறைவான வெறுப்பூட்டல் சக்தியைக் கொண்டிருந்தது.

மேக்கூரிக்கயடைட்டு — ஒளியிரிப்புத் தடை அரைகடத்தி.

கே. தென்னகோன்.

J. Natn. Sci. Coun. Sri Lanka 1984 **12** (2): 219—222

அடுக்குப் பளிங்கு அமைப்புடனான n — மேக்கூரிக் கயடைட்டு, ஒளிமின் இரசாயனக்கலங்களில் அனோட்டாகப் பயன்படுத்தப் பெற்ற போது ஒளியிரிப்பினைத் தடுக்கும் ஆற்றல் கொண்டதென்பது கண்டறியப்பட்டுள்ளது.

சூடோமொனஸ் சொலானேசேரும் (சிமிது) பற்றீரியா மண்ணுள் உயிர்வாழுகை, அதன் நோய் உண்டு பண்ணும் ஆற்றல் மீது இரசாயனச் செயற்பாடும் கரியுறுப்புப் பொருட் கூட்டினவும் கொண்டுள்ள விளைவு.

ஜே. எம். ஆர். எஸ். பண்டார.

J. Natn. Sci. Coun. Sri Lanka 1984 **12** (2): 223—233

இலங்கையில் பயிரிடப் பெறும் cvmi 7 மிளகாய்ச் செடி வகையைத்தவிர மற்றெல்லாச் சொலனேசே இனம் சார்ந்த செடிவகைகளும் சூடோமோனஸ் சொலானேசேரும் பற்றீரியாவின் உயிரின வகை 3க்கு எளிதில் ஆளாகக்கூடியனதென்பது கண்டறியப்பட்டது. இந்த பற்றீரியாவானது விருத்தியாக்கப்பெற்ற AVRDC தக்காளிச் செடி வகைகள் சிலவற்றில் நோய் உண்டுபண்ணும் ஆற்றல் கொண்டுள்ளதென்பதும் நீரூபிக்கப்பட்டது.

சுண்ணும்பு, அசற்றிக் கமிலம், பெனேமில், கப்றன் போன்ற இரசாயனப் பொருள் சேர்க்கப்பெற்ற நிலங்களுடன் ஒப்புநோக்குகையில் கோழி உரம், மாட்டு உரம், கிளிரிசிடியா இலைகள் போன்ற கரியுறுப்புப் பசளை இப்பற்றீயா கிருமிகளைக் கொண்ட மண்ணில் சேர்க்கப்பட்டதன் விளைவாக பீ. சோலானுசேரும் இனப் பெருக்கிகள் குறிப்பிடத்தக்கவாறு மலிந்ததுடன் அதனையடுத்துத் தக்காளி துளரித் தண்டுகளில் கடுமையான வாடல் நோயும் ஏற்பட்டதென்பது அவதானிக்கப் பட்டது. கப்றன், பெனேமில் சேர்க்கப் பெற்ற மண்ணில் மாத்திரமே பற்றீரியா இனப் பெருக்கம் பெரும்பாலும் குறைதல் உற்று வாடல் நோயின் கடுமையும் தணிவது காணப் பெற்றது.

பீ. சோலானுசேரும் பற்றீரியாவினதும் ஏனைய அழுகற்ருவர பற்றீரியாக்களினதும் வளர்ச்சி கரியுறுப்புப் பசளை இடுவதனால் அதிகரித்தது. அடுத்து நடுகை செய்யப் பெற்ற தக்காளிப் பயிரின் இலைவாடல் நோய் விகிதாசாரத்திற்கும் ஏனைய பற்றீரியாக்கள் பீ. சோலானுசேரும் பற்றீரியா இனத்துடன் கொண்ட விகிதாசாரத்திற்கும் இடையில் நேரிய தொடர்பு உண்டென்பது புலனுகியது.

சவர்க்காரமாக்கப்பெற்ற தேங்காய் எண்ணெய்த் தொகுதிக்குள் சீரியம் அயன் வடிய விடல் ஆய்வும் தேங்காய் எண்ணெய் அசிலேற்றுக்கள்பற்றிய ஆய்வும்.

டபிள்யு. மல்லவராய்ச்சி, எச். டபிள்யு. டயஸ், என். ருவன்பத்திரனை, டபிள்யு. பூ. த அல்விஸ்.

J. Natn. Sci. Coun. Sri Lanka 1984 **12** (2): 235—250

அருமண் வகைகளில் ஒன்றாகிய சீரியம் (ce) உம் அதன் பல சேர்வைகளும் கைத் தொழில்கள் பலவற்றிற்கு உபயோகமுள்ளவை. அருமண் மூலகங்களில் சீரியம் மிக மலிந்து கிடக்கின்றது. அது பல கனிமங்களில் (எடுத்துக்காட்டு - மொனசைற்று) பெருவாரியாகக் காணப்படுகிறது. இக்கனிமங்களை கரிடும் போதெல்லாம் அவற்றின் பகுதிகளிலிருந்து சீரியம் பிரித்தெடுப்பது வழக்கமாகும்.

சீரியம் (iv) பிரித்தெடுக்கும் கருவியாக பொற்றாசியம் தீயரேற்று உபயோகப்பட்டு வருகிறது. இப்பரிசோதனையின்போது, தீயரிக்கமிலம், உலோரிக்கமிலம், பல்மைற்றிக்கமிலம், காப்பிரிக்கமிலம், ஒலியிக்கமிலம் ஆகியவற்றுக்குப் பதிலாகவும் இவ்வமிலக் கலவைகளுக்குப் பதிலாகவும் சவர்க்காரமாக்கப் பெற்ற தேங்காய் எண்ணெய்க்குப் பதிலாகவும் சோடியம் மற்றும் பொற்றாசியம் உப்புக்களைப்பயன்படுத்தி படிவு வீழ்த்தல் மூலம் சீரியம் (IV), சீரியம் (III) ஆகிய இரண்டினையும் பிரித்தெடுக்கும் இயல் தகவு ஆராயப்பட்டுள்ளது. சீ. (III), சீ. (IV) ஆகியவை சோடியம் ஐதரொட்சைட்டு (NaOH) மூலம் சவர்க்கார மாக்கப்பட்ட தேங்காய் எண்ணெயிலிருந்து பிரித்தெடுக்கப்பட முடியுமாவெனக் கண்டறிதல் இச்சோதனையில் முக்கிய நோக்கமாகும். தேங்காய் எண்ணெயும் சோடியம் ஐதரொட்சைட்டும் இலங்கையில் எளிதில் பெறத்தக்கதாக விருப்பதனால் இம்முயற்சி வெற்றிகண்டால் பெரிய அளவில் இலாபகரமாக பயன்பாட்டுக்குக் கொண்டுவரப்படலாம். சீ. (III), சீ. (IV) ஆகியவற்றின் பிரித்தெடுத்தல் தகவுகள் மேற்கூறிய தொகுதி ஒவ்வொன்றிலும் அவற்றிற்குரிய அகிலேற்றுக்களுக்கு மாற்றுவதனால் பல pH பெறுமானங்களின் அனுசரணைக்குட்பட்டுக் கணிய அடிப்படையில் துணிபு செய்யப்பட்டன. இப்பெறுபேறுகளின் படி, (அ) சவர்க்காரமாக்கப்பெற்ற தேங்காய் எண்ணெயில் சீ. (III), சீ (IV) ஆகியவற்றின் பிரித்தெடுப்பு எல்லை போதிய அளவில் உயர்ந்திருக்கிறது. (ஆ) ஏறத்தாழ 5 pH பெறுமான நிலையில் சீ. (III) பொற்றாசியம் உப்பினைக் கொண்டும் சீ. (IV) சோடியம் உப்பினைக் கொண்டும் நன்றாகப் பிரித்தெடுக்கப்பட முடிகிறது. (இ) கவனம் மிக்க கட்டுப்பாட்டு சூழமைதிகளின் கீழ் 3.5—6.8 வரையான pH பெறுமான வீச்சினுக்குள்ளே சோடியம் உப்பு மூலம்65% க்கும் மேற்பட்ட சீ. (III) பிரித்தெடுக்கப்பட முடியும் ஆகிய உண்மைகள் கண்டறியப்பட்டன. எனவே, விசேடமாக, சீ. (IV) அயன் பிரித்தெடுப்பு சார்வளமிக்க ஊடகமாக சோடியம் ஐதரொட்சைட்டால் சவர்க்காரமாக்கப் பெற்ற தேங்காய் எண்ணெய் கருதப்படலாம். அத்துடன். சோடியம், பொற்றாசியம் ஆகிய இரண்டின் ஐதரொட்சைட்டு மூலம் சவர்க்காரமாக்கப்பெற்ற எண்ணெய் சீ. (III) அயன்களைப் பிரித்தெடுக்க உதவும் என்பது தெளிவாகிறது

திண்மக் குப்பிரிக்குப் பெரிசயனேட்டில் இணைப்பு சமபகுதிச் சேர்வுக்கான சான்றுகள்.

கே. தென்னகோன்.

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பிணைப்புற்ற இடைவெளிக்குரிய நீர் நீக்கப்பெற்றதன் பின்னர் திண்மக்குப்பிரிக்குப் பெரிசயனேட்டு கட்டமைப்புத் தாண்டலுக்கு உட்படுகிறதென்பதை நிரூபிக்க பரி சோதனை சான்றுகள சமர்ப்பிக்கப்பட்டுள்ளன. இத் தாண்டலானது C, Fe 2+வுக் கும் CN—இல் N, Cu ++க்கும் இணைப்புறும் தொழிற்பாடு மீளப்பெறுமிடத்து ஏற்படும் இணைப்புசமப்பகுதி சேர்வு மூலம் இடம்பெறலாமென இங்கு கருத்து தெரிவிக்கப்பட்டுள்ளது.

இலங்கையின் புவிச்சரிதவியலும் இரத்தினக்கல் தோன்றுதலும்.

ஜே. டபிள்யு. ஹேரத்.

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சந்திரக்காந்தக்கல், துவரைமல்லி, சிவப்புக்கல் போன்ற முன்னிருந்த இடத்திலேயே அகப்படும் இரத்தினங்களைத் தவிர்ந்த இலங்கையின் மற்றெல்லா இரத்தினங் களும் பண்டைய வண்டல் படிவங்களிலிருந்து பெறப்படுகின்றன. இரத்தினங்கள் அவை உற்பத்தியான பாறைத்தாயத்தில் அகப்படுதல் அரிதான சம்பவமெனினும், அவை ஒருவகையான தலீயீட்டுப் பொருளுடன் தொடர்பு கொண்டுள்ளன. பிசினியப் பண்புகொண்ட பொருளில் அவை தோன்றி இருப்பதற்கு சான்றுகள் பல உள்ளன. அவை படியவிடப் பெற்றுள்ள பொருளுக்கும் சூழமைதிக்கும் ஏற்ப இரத்தினங்களின் பண்பு பெரிதும் வேறுபடுகிறதென்பது வண்டல் இரத்தினப் படிவுகளில் அவை அமைந்துள்ள ஒழுங்கு வரிசையினை உற்று நோக்குமிடத்துப் புலனாகும். இலங்கையில் பிரதான இரத்தினக்கல் வியாபாரம் இடம் பெறும் இரத் தினபுரி நகரம் அமைந்துள்ளதும் எளிதில் பெறத்தகு அல்லது அரும் பெறல் பல மணிகள் மலிந்ததும் ஒப்பியல் வகையில் மிகச் சிறியதும் மலைகள் மலிந்ததுமான சபரகமுவா மாகாணம் போன்றதோர் நிலப்பகுதி உலகில் வேறெங்கும் இல்லை யெனலாம். (*1983* இலங்கையில் நடத்தப்பெற்ற *19*ஆம் சருவதேச மாணிக்கக் கல் மாநாட்டில் வாசிக்கப் பெற்ற கட்டுரை)

இலங்கையில் காணப்படும் சில நீர்வாழ் ஐப்போமை சேற்றுக்கள்.

எஸ். ஏ. குணசேகரா, எம். பீ. ஆர். ருக்மணி.

J. Natn. Sci. Coun. Sri Lanka 1984 **12** (2): 273—282

அருவி, ஆறுகளின் நுரை மாதிரிகளிலிருந்து பதினெட்டு வகை நீர்வாழ் ஐப் போமை சேற்றுக் கொனிடியங்கள் கண்டுபிடிக்கப்பட்டன. இவற்றுள் 13 கொனி டியங்களின் (பங்கசு வித்திகள்) இனங்களும் 2 இன் சாதிகளும் இனம் கண்டறியப் பட்டன. மூன்றின் இனம் கண்டு பிடிக்கப்படவில்லை. சிங்கராசா காட்டினூடாகப் பாயும் நீரோடைகளிலுள்ள கொனிடியங்களின் வகையும் தொகையும் நகர்ப் புறங்களினூடாகவும் கமத்தொழில் செய்யும் நிலங்களினூடாகவும் பாயும் ஆறு களினதும் அருவிகளினதும் காணப்பட்டதைவிடப் பெரிதாக இருந்தது.

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