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Subaquatic plants as geochemical samples

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Abstract: Along drainage systems, subaquatic plants invariably occur. These plants with their root systems immersed in water, behave as accumulator plants particularly towards soluble mobile heavy metals present in the water. The metal concentrations in these plants and in the stream sediments are compared.

The geochemical anomalies, determined from stream sediment samples, are always expressed by the subaquatic plants. The higher geochemical contrasts obtained from these plants, as compared to the stream sediments suggest that the plants can be used as samples for mineral prospecting.

INTRODUCTION

The biogeochemical method of prospecting has not been widely practised, particularly in Malaysia, as one of the methods in targeting mineral deposits. Various authors have repeatedly proven that there is a definite correlation between the metal content present in plants and in the environment in which the plants occur (Heckel, 1899; Hammett, 1928; Warren and Howatson, 1947; Warren and Delavault, 1949, 1955; Robinson *et al.* 1947; Vinogradov, 1954; Webb and Millman, 1951; Millman, 1957; Vinogradov and Malyuga, 1957; Webb and Toms, 1959; Cannon, 1960, 1971; Warren, 1962; Malyuga, 1964; Hawkes and Webb, 1965; Nicolls *et al.* 1965; Cole, 1971; Tan, 1973 a, b; and Tan and Nik, 1983). The concentration of heavy metals absorbed and accumulated by plants is a function of the concentration of these metals in the habitat. Other factors that may control the level of accumulation of metals in plants are as follows: the types or species of plants, the types of metals involved, the forms in which the metals are made available to the plants, the interactions of metals occurring in the habitat as well as within the plants, the physiology of the plants and the physiochemical conditions of the habitat.

This paper deals with the use of subaquatic plants present along the drainage system, as geochemical samples in the search for ore bodies. The term 'subaquatic plants' used in this paper is defined as those whose root systems are immersed in water, with some roots suspended freely in water and others attached to the substratum present along the river banks or in the crevices of boulders. The chlorophyllous portions of these plants may occur above the water level.

There are various species of plants occurring in the drainage system. These plants are not systematically distributed, occurring in an unsocial fashion with varying combinations even within a short distance of the river profile. Only those plants that are specifically restricted to the rivers are sampled for analysis. These plants generally belong to the lower forms of the plant kingdom, consisting mainly of bryophytes,

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mosses and ferns. Plants of higher forms also occur along the drainage system, but are also found growing away from the rivers, and are therefore not truly subaquatic.

SAMPLING PROCEDURE

The sampling of the subaquatic plants was carried out in areas with well-defined geochemical anomalies in heavy metals as well as in areas having geochemical background values. The areas were selected after a stream sediment geochemical survey was conducted along a tributary.

PREPARATION AND ANALYTICAL PROCEDURES

The entire population of subaquatic plants was sampled from each sampling point which spans a distance of about 5 meters along the river (Figure 1). These plants were simply removed as they were partly and loosely attached to the substratum, and were then placed into sample bags.

The plant samples in each population were then separated according to the species. Each species was then divided into three groups. One group was preserved for taxonomic identification, the other group was air-dried for subsequent analyses, and the remaining group was cleaned with distilled water and kept for subsequent analyses. The uncleaned and cleaned plant samples, after being air-dried, were separately ashed in a muffle furnace at 400 °C. The plant ashes derived were then analysed using Atomic Absorption Spectrophotometry method.

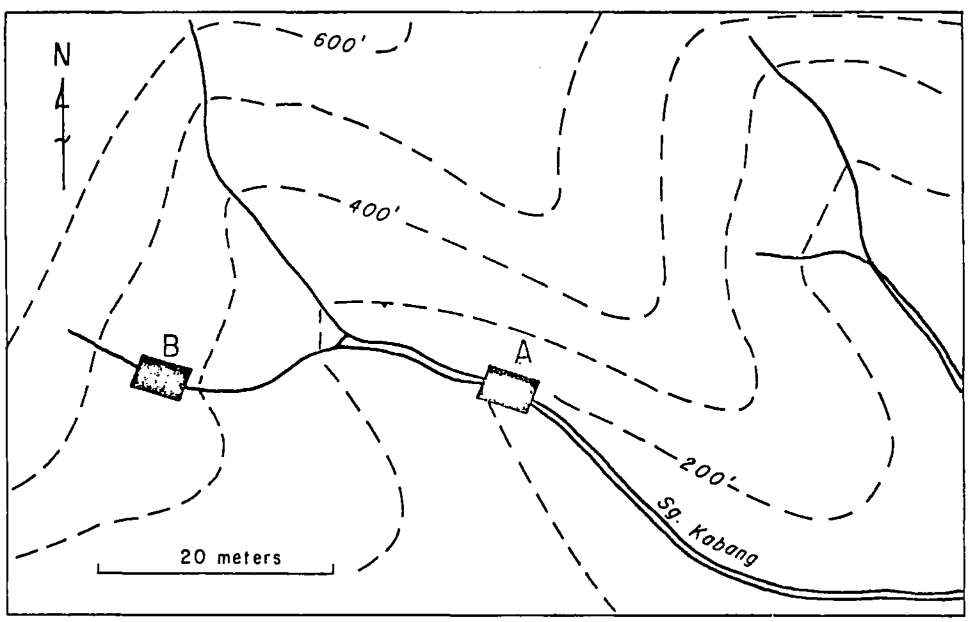

Fig. 1 Sample localities of stream sediments and subaquatic plants along Sungai Kabang, Pahang. Stream sediments at locality A have heavy metals with anomalous values, whereas at locality B with background values.

RESULTS

The subaquatic plants sampled for analysis, are identified as *Bryum*, *Marchantia*, *Riccardia*, *Pallavincinia*, *Ceratiopteris*, *Dipteris*, *Lindsaya*, *Azolla*, *Salvinia* and *Hydrilla*. The predominant species are *Bryum*, *Ceratopteris* and *Dipteris*. Entangled among the freely suspended root systems of these plants are algae which consist mainly of *Chara*, *Spirogyra*, *Ulothrix* and *Tetraspora*.

In sample locality A (Fig. 1) the stream sediments, both the upstream and downstream sections of the river, contain anomalous values of heavy metals i.e. values exceeding the threshold values which are taken as mean value plus twice standard deviation of the background values obtained from larger scale sediment geochemical survey of the area (Tan and Nik, 1983). As shown in Tables 1 and 2, the subaquatic plants there have relatively high concentrations of Cu, Zn and Pb. The other metals determined, Sn and As, are not detected or only present in very low concentrations in the plants. The level of concentrations of Cu, Zn and Pb in the various plant species differs slightly as shown by the low standard deviation values.

In addition, there are some differences in the concentrations of Cu, Zn and Pb between cleaned and uncleaned plant samples. The latter have relatively higher metal content compared to the cleaned samples.

In locality B of the river where the stream sediments contain background concentrations of Cu, Zn, Pb, Sn and As, the subaquatic plants there have almost similar concentrations of Cu, Zn and Pb (Tables 3 and 4). Sn and As were again not detected or of very low concentrations. The differences in the concentrations of Cu, Zn and Pb in cleaned and uncleaned plant samples are not as marked as those observed in plants from the anomalous locality.

DISCUSSION

From the comparative studies between the various species of subaquatic plants and the stream sediments, either from anomalous or non-anomalous localities, there is no necessity to distinguish the various plant species occurring along the drainage system. The differences in the level of concentrations of heavy metals, viz. Cu, Zn and Pb in various plant species are not excessive in view of errors that are involved during sampling and analysis. The slight variation in the metal values between species as indicated by the low values in standard deviation, could be due to that fact these plants belong to the lower plant kingdom, having relatively simple anotomy and non-complex physiology. All the species could thus be assumed to behave in a similar or almost similar manner to the chemical conditions prevailing in their habitat. Without having to labouriously identify the various plant species, these subaquatic plants can thus be considered as a community and be used on the whole as geochemical samples.

The relatively high concentrations of Cu, Zn and Pb present in plants collected from the anomalous locality suggest that the plants absorb and accumulate these metals which are present in forms that are easily assimilated by the plants. Thus, ore deposits having constituents that are soluble and are dispersed chemically in the secondary environment (such as the drainage system) can be traced by analysing these

TABLE 1

ANALYTICAL DATA, EXPRESSED IN PARTS PER MILLION, OF HEAVY METALS PRESENT IN SUBAQUATIC PLANTS AND IN STREAM SEDIMENTS FROM THE ANOMALOUS AREA (UPSTREAM SECTION)

Plant species	Cu		Zn		Pb		Sn		As	
	a	b	a	b	a	b	a	b	a	b
Dipteris	212	315	139	147	183	194	—	—	—	—
Lindsaya	234	296	145	155	165	172	—	—	—	—
Bryum	218	280	142	178	172	185	2	2	—	—
Ceratopteris	230	302	128	134	178	188	—	—	—	—
Azolla	235	285	136	145	180	196	—	—	—	—
Pallavincinia	216	288	140	173	164	170	—	—	—	—
Riccardia	214	300	145	150	168	178	2	3	2	2
Machantia	234	324	138	172	182	210	—	—	—	—
Salvania	229	287	157	184	160	175	2	2	2	2
Hydrilla	238	313	150	162	188	202	2	2	—	—
Mean	226	299	142	160	174	187	0.80	0.90	0.40	0.40
Standard deviation	9.39	13.85	7.54	15.53	9.00	12.76	—	—	—	—
Stream sediments (− 80 mesh)	165		84		115		332		40	
c/d	1.37	1.81	1.69	1.90	1.51	1.63	0.002	0.003	0.01	0.01

a = cleaned plant samples
b = uncleaned plant samples
c = mean metal value in plants
d = metal value in stream sediments

TABLE 2

ANALYTICAL DATA, EXPRESSED IN PARTS PER MILLION, OF HEAVY METALS PRESENT IN SUBAQUATIC PLANTS AND IN STREAM SEDIMENTS FROM THE ANOMALOUS AREA (DOWNSTREAM SECTION)

Plant species	Cu		Zn		Pb		Sn		As	
	a	b	a	b	a	b	a	b	a	b
Ceratopteris	215	265	156	188	148	155	2	2		
Dipteris	228	288	142	165	158	182			—	
Riccardia	206	270	153	160	156	170	2	4	2	4
Lindsaya	222	296	145	158	164	188	2	2	3	3
Bryum	234	284	152	180	145	164	4	6		
Marchantia	225	302	138	156	150	182	—	2	2	2
Pallavicinia	219	275	156	168	149	159	—	—	3	4
Hydrilla	219	300	150	185	170	192	4	4	—	
Mean	221	285	149	170	155	174	1.75	2.50	1.25	1.63
Standard deviation	7.94	13.09	6.22	11.82	8.11	12.99	1.56	1.94	1.45	2.07
Stream sediments (−80 mesh)	158		92		106		310		45	
c/d	1.40	1.80	1.62	1.85	1.46	1.64	0.01	0.01	0.03	0.04

a = cleaned plant samples
b = uncleaned plant samples
c = mean metal value in plants
d = metal value in stream sediments

TABLE 3

ANALYTICAL DATA, EXPRESSED IN PARTS PER MILLION, OF HEAVY METALS PRESENT IN SUBAQUATIC PLANTS AND IN STREAM SEDIMENTS FROM THE BACKGROUND AREA (UPSTREAM SECTION)

Plant species	Cu		Zn		Pb		Sn		As	
	a	b	a	b	a	b	a	b	a	b
Dipteris	22	25	15	18	12	14				
Ceratoptaris	24	30	18	18	10	12				
Lindsaya	20	24	20	22	14	14				
Azolla	18	28	22	22	9	12				
Marchantia	25	28	18	24	12	15				
Bryum	16	20	20	25	14	15				
Riccardia	20	22	16	20	12	15	2	2		2
Pallavinenia	24	25	18	18	10	12				
Salvinia	18	20	20	24	10	10				
Hydrilla	20	25	15	20	12	15				
Mean	21	25	18	21	12	13	0.20	0.40		0.20
Standard deviation	2.83	3.20	2.23	2.55	1.63	1.69				
Stream sediments (-80 mesh)	25		20		15		30		5	
c/d	0.84	1.00	0.90	1.05	0.80	0.87	0.01	0.01		0.04

a = cleaned plant samples
b = uncleaned plant samples
c = mean metal values in plants
d = metal content in stream sediments.

TABLE 4

ANALYTICAL DATA, EXPRESSED IN PARTS PER MILLION, OF HEAVY METALS PRESENT IN SUBAQUATIC PLANTS AND IN STREAM SEDIMENTS FROM THE BACKGROUND AREA (DOWNSTREAM SECTION)

Plant species	Cu		Zn		Pb		Sn		As	
	a	b	a	b	a	b	a	b	a	b
Lindsaya	22	25	19	22	8	10				
Riccardia	28	28	20	25	12	15				
Dipteris	25	28	17	20	10	10				
Machantia	24	28	22	25	8	10				
Bryum	20	25	20	25	8	12				
Ceratopteris	25	20	18	20	10	10				
Azolla	22	15	20	22	5	8				
Mean	23	27	19	23	9	11				
Standard deviation	2.36	1.85	1.50	2.12	2.05	2.05				
Stream sediments (-80 mesh)	28		22		12		25		2	
c/d	0.82	0.96	0.86	1.05	0.75	0.92				

a = cleaned plant samples
b = uncleaned plant samples
c = mean metal values in plants
d = metal content in stream sediments

constituents present in the subaquatic plants. The method is, however, not suitable for the search of ore deposits whose constituents are insoluble and are dispersed by physical means.

In addition, the metal contents of Cu, Zn and Pb in plants occurring in the anomalous locality are comparatively higher than that in the stream sediments. As shown in Tables 1 and 2, the ratios of Cu, Zn and Pb mean content in cleaned plant samples to that in stream sediments are greater than one, indicating that these plants not only absorb but accumulate the metals to concentrations exceeding the amount present in the stream sediments. This ratio is, however, less than one for plants occurring in non-anomalous locality (Tables 3 and 4). Thus, a biogeochemical anomaly appears to be better defined than a geochemical anomaly expressed by the stream sediments.

The differences in the Cu, Zn and Pb values between cleaned and uncleaned plant samples are probably due to additional metals present outside the plant body. It is observed that the root systems of these plants, especially those roots suspended freely in water, exude slimy substances onto which green algae, clay particles, colloids and organic materials are usually entrapped. These extragenious materials around the root systems adsorb as well as absorb heavy metals (particularly Cu, Zn and Pb) and nutrients from the flowing water before passing them into the plant body. The extragenious materials around the root systems are neither restricted to any particular plant species nor to locality since the metal content present in these materials is almost similar for all plant species studied within a locality. Hence, plant samples can be directly ashed without being cleaned to trace biochemical anomalies particularly for Cu, Zn and Pb especially in areas with least contamination.

The geochemical contrast, i.e., the ratio between the anomalous and the background values for Cu, Zn and Pb, in plant samples is relatively higher, almost by a factor of 2, than that in stream sediment samples (Table 5). Hence, the higher geochemical contrast expressed by the subaquatic plants will facilitate the delineation of anomalous areas from which ore bodies can be subsequently traced.

CONCLUSION

During reconnaissance geochemical survey, stream sediment, heavy mineral concentrate and perhaps water sampling are routinely conducted to outline geochemical anomalies which may then be traced to their sources by follow-up and more detail sampling. The subaquatic plants present in the drainage system, can be used as geochemical samples since:

a. they occur ubiquitously along the river bank, whereas fine fractions of stream sediments may occasionally be lacking along certain sections of the river.

b. the method of sampling the plants is relatively easier than that of stream sediments, especially in rivers that are deep and fast-flowing,

c. there is an aerial correspondence in heavy metal anomaly expressed by both plants and stream sediments particularly for Cu, Zn and Pb. Those heavy metals

TABLE 5

AVERAGE ANOMALOUS AND BACKGROUND VALUES (IN PARTS PER MILLION) AND GEOCHEMICAL CONTRAST OF CU, ZN, AND PB IN SUBAQUATIC PLANTS AND STREAM SEDIMENTS

Metals	Cu			Zn			Pb		
	a	b	s	a	b	s	a	b	s
Average anomalous values (A)	224	292	162	146	165	88	165	181	111
Average background values (B)	22	26	27	19	22	21	11	12	14
Geochemical contrast (A/B)	10.2	11.2	6.0	7.7	7.5	4.2	15.0	15.1	7.9

a = cleaned plant samples
b = uncleaned plant samples
s = stream sediments (– 80 mesh).

that are soluble and mobile are readily absorbed and accumulated in the plants. Insoluble and immobile metals are, however, not accumulated to any significant level of concentrations by these plants,

d. the geochemical contrast for Cu, Zn and Pb in plants is relatively higher than that in stream sediments. The biochemical method will enhance the possibility of locating anomalous areas, and

e. the cleaning of subaquatic plant samples though not as labourious compared to the preparation of stream sediments prior to analysis, can be dispensed off since the metal content in the extragenious materials surrounding the root systems is almost uniform for any plant species within a locality.

From this steady, the method of using subaquatic plants of the lower plant kingdom present along rivers can be used either on its own or to supplement other methods of geochemical survey, in the search for ore deposits particularly the base-metal deposits.

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