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# Sulphur and Sodium Inputs from Rainfall in Relation to Proximity of Sites from the Coast in Peninsular Malaysia

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## ABSTRAK

*Penentuan pengumpulan sulfur (S) dan natrium (Na) menerusi hujan pada tempat-tempat yang berlainan jarak dari pantai di Semenanjung Malaysia telah dijalankan. Pengumpulan S pada lokasi didapati bersumber dari laut dan kegiatan manusia dengan pengumpulan di kawasan tengah dan selatan lebih dipengaruhi oleh aktiviti industri. Pengumpulan Na pada lokasi dipengaruhi oleh monsoon, pengumpulan yang tinggi di kawasan timur pada musim tengkujuh dan kawasan barat pada musim monsoon barat-daya. Nisbah Na:S terkumpul didapati rendah dari nisbah mereka dalam air laut, ini menunjukan kesan kehadiran S bersumber daratan dan kegiatan manusia teradap S terkumpul.*

## ABSTRACT

*Sulphur (S) and sodium (Na) accessions through rainfall at sites of varying distances from the coast in Peninsular Malaysia were monitored. Results indicate that S accession was of anthropogenic and marine origin, with S deposition at sites in the central and south transects being influenced more by industrial activities. Na accession was related to the monsoons, with sites on the east coast having high accumulations during the northeast monsoon, and sites on the west coast during the southwest monsoon. Na:S ratio was lower than their ratio in sea water, indicating that S accession was from anthropogenic and terrestrial origins.*

## INTRODUCTION

Peninsular Malaysia lies between 1° to 7° N latitude and 100° to 105° E longitude. It has an annual average of 2500 mm rainfall and experiences two monsoons, the northeast and southwest. Strong winds during the monsoons bring sea-spray containing appreciable amounts of sulphur (S). Major inputs of S in Peninsular Malaysia are of marine and terrestrial origin (Lefroy and Aminuddin 1990). The source of marine S as wind-driven sea-spray is an integral of S accession from the atmosphere and is highly correlated with the monsoonal seasons. Decline in S accession with distance from the coast has been observed in other regions. In Korea, for example, a decline from 28.3 to 11.7 kg S $ha^{-1}$ from the coast to the interior mountain areas was observed (Shin 1987). In Queensland, Australia, a reduction from 6 to 3 kg S $ha^{-1}$ occurred from the coast to a location 40 km inland (Probert 1976). Lefroy (1988) reported a decline from 22 to 7 kg S $ha^{-1}$ from the coast to a site 13 km inland in New South Wales, Australia. In the Federal Republic of Germany, an average deposition (wet and dry) on bare soil of 23 kg S $ha^{-1}$ $y^{-1}$ was reported (Mayer and Ulrich 1978). In the Zhejiang province in China, annual rates of S deposition were in the range of 13-27 kg S $ha^{-1}$ $y^{-1}$ (Lu and Shi 1979). Martin (1980) reported that rain-deposited S at 20 open-country sites over the United Kingdom depended on rainfall amount and was typically 8-12 kg S $ha^{-1}$ $y^{-1}$. When dry deposition is included, the values range from 10-16 kg S $ha^{-1}$ $y^{-1}$. With sea spray, especially at sites within 10 km of the west coast, values increased to a range of 20-50 kg S $ha^{-1}$ $y^{-1}$. The purpose of this paper is to determine the accession of S at different sites in relation to Na and the influence of proximity of sites to the coast in Peninsular Malaysia.

## MATERIALS AND METHODS

Transect lines were drawn on the geographical map of Peninsular Malaysia. These transects cover the north, central and south regions (*Fig. 1*). They were drawn so as to parallel the direction of the incoming monsoonal winds (ca. 45°). Sites on the transects were selected based on distances of 1, 5, 15 and 45 km away from both the west and east coasts except for sites on the south transect where the innermost distance was 30 km, due to the narrow land mass. A total of 24 sites were chosen.

A rainfall sampler containing mixed ion exchange resins, Amberlite IR-120 an acidic cation exchange resin and IRA-400, basic anion exchange resin (Lefroy 1988), was placed at each site from April 1990 to March 1991. Every two months, adsorbed ions were eluted from the resins in the laboratory with 2M HCl. Sulphur and sodium (Na) contents in eluents were determined as proposed by Freney (1986) and Pratt (1965). The rainfall for the sites was calculated based on the accumulated rainwater present in the container of the sampler.

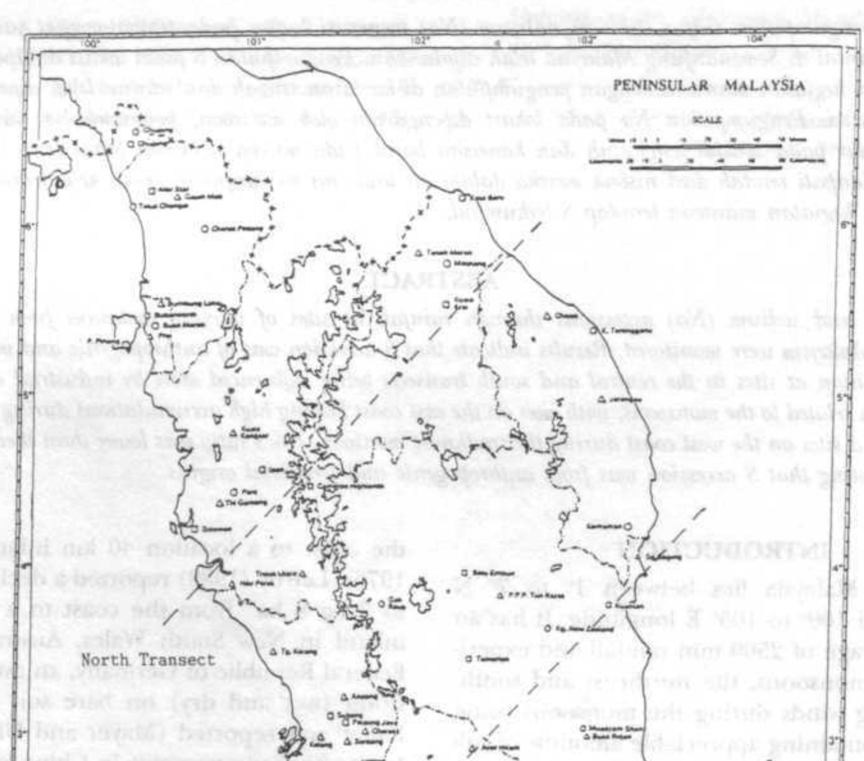


*Fig.1: Locations of transects*

TABLE 1
Rainfall data of sites on transects (mm)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | North Transect | | | | |
| Distance(km) | 1 | 5 | 15 | 45 | 45 | 15 | 5 | 1 |
| N.E.Monsoon | 1748 | 1255 | 1176 | 1069 | 2126 | 887 | 1185 | 1017 |
| S.W.Monsoon | 831 | 637 | 648 | 1768 | 919 | 887 | 840 | 1034 |
| | | | | Central Transect | | | | |
| N.E.Monsoon | 2006 | 1945 | 1357 | 950 | 2259 | 1755 | 2971 | 1432 |
| S.W.Monsoon | 1012 | 761 | 1552 | 1099 | 1945 | 1043 | 772 | 1131 |
| | | | | South Transect | | | | |
| Distance(km) | 1 | 5 | 15 | 30 | 30 | 15 | 5 | 1 |
| N.E.Monsoon | 1406 | 2157 | 1724 | 1704 | 1746 | 1892 | 1991 | 1193 |
| S.W.Monsoon | 1512 | 1782 | 1665 | 1348 | 1886 | 1754 | 1264 | 1085 |

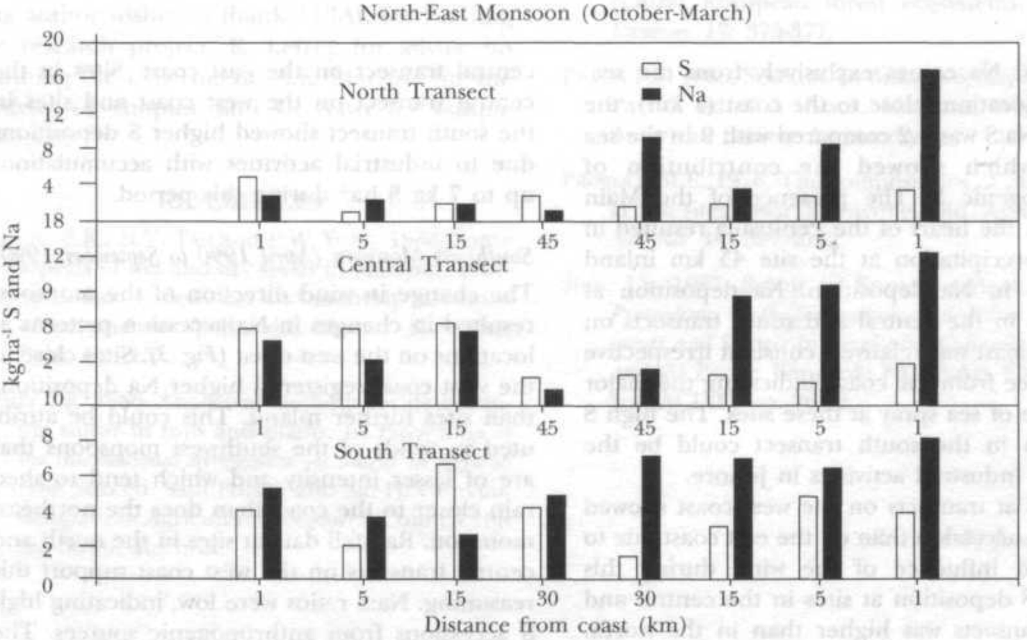


*Fig.2: Sulphur and sodium accessions during N.E. monsoon*

## RESULTS AND DISCUSSION

*Northeast Monsoon (October 1990 to March 1991)*

Rainfall during this period was higher than that of the southwest monsoon (Table 1). The difference in rainfall between the monsoons was highest in the north transect and lowest in the south transect. Similar rainfall trends, especially for sites on the east coast, have been reported by Cheang *et al.* (1986). Na accessions at locations on the east coast in the north transect decreased at sites located further inland; however, S accession remained relative constant (*Fig. 2*). This can be explained by the fact that S in rainfall can be of both anthropogenic and marine ori-

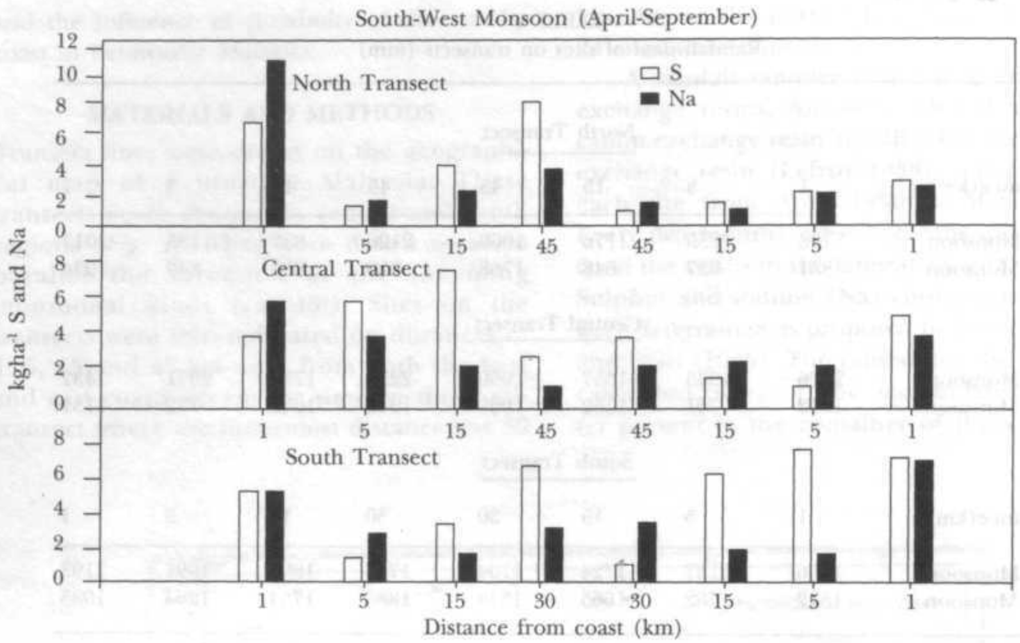


*Fig.3: Sulphur and sodium accessions during S.W. monsoon*

gin whilst Na comes exclusively from the sea. Even at locations close to the coast (1 km), the ratio of Na:S was 5.2 compared with 9 in the sea water, which showed the contribution of anthropogenic S. The presence of the Main Range in the heart of the Peninsula resulted in higher precipitation at the site 45 km inland and also in Na deposition. Na deposition at locations in the central and south transects on the east coast was relatively constant irrespective of distance from the coast, indicating the major influence of sea spray at these sites. The high S accession in the south transect could be the result of industrial activities in Johore.

Sites at transects on the west coast showed lower Na accession than on the east coast due to decreased influence of the wind during this period. S deposition at sites in the central and south transects was higher than in the north. This could again be the result of industrial activities in the central and southern regions of west Peninsular Malaysia. Such activities include a power generating plant using coal, oil refineries, palm oil refineries and pineapple processing plants. The low Na:S ratio indicates that S deposition was of terrestrial and anthropogenic origin. In general, during the northeast monsoon, S deposition at sites in the north transect was below 4 kg ha$^{-1}$ and was similar to sites in the central transect on the east coast. Sites in the central transect on the west coast and sites in the south transect showed higher S depositions due to industrial activities with accumulations up to 7 kg S ha$^{-1}$ during this period.

*Southwest Monsoon (April 1990 to September 1990)*

The change in wind direction of the monsoon resulted in changes in Na accession patterns at locations on the west coast (*Fig. 3*). Sites close to the west coast registered higher Na depositions than sites further inland. This could be attributed to winds of the southwest monsoons that are of lesser intensity and which tend to shed rain closer to the coast than does the northeast monsoon. Rainfall data at sites in the north and central transects on the west coast support this reasoning. Na:S ratios were low, indicating high S accessions from anthropogenic sources. The fact that S accessions for sites in the central and south transects on the west coast were comparable during the southwest and northeast monsoons could indicate that anthropogenic S sources are dominant over marine sources. Sites in all transects on the east coast had lower Na depositions during the southwest than during the northeast monsoon. S deposition in the north transect on the east coast was similar for both seasons, whilst deposition in the central and south transects showed the influence of anthropogenic sources, possibly from industries located in the south region.

## CONCLUSION

Sulphur accessions at sites monitored in Peninsular Malaysia were of anthropogenic and marine origins. The influence of the strong monsoon winds on Na deposition was recognised; however the pattern of S deposition was less affected. Sites in the central and south transects on the west coast and south transect on the east coast had S accessions which were influenced more by the presence of S-emitting industries. The Na:S ratio was high at sites exposed to the particular monsoon, with the northeast monsoon resulting in a higher ratio. S depositions at sites in the north transect of Peninsular Malaysia were lowest, while central and south transect sites had the highest deposition.

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