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Dissolved Nutrients and Chlorophyll *a* Status of the Setiu River, Terengganu, Malaysia

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Inorganic nutrients are emitted from natural and man-made sources into our river systems and ultimately transported to the coastal waters and the sea as the final sink. In order to monitor the distribution of nutrients in a given river system, water samples can be collected from a number of stations situated a given river system. The data obtained can then be plotted against the distance; this constructed diagram is called a longitudinal distribution (Head 1985). When the distribution of a particular nutrient differs considerably between the sampling stations, the researcher can interpret the data based on the knowledge of the geography of the study area and the potential sources of nutrient inputs into the study area. Phosphorus and nitrogen-based nutrients are the major inorganic nutrients that raise a great interest in studies because of their ecological significance and almost ubiquitous nature of the pollution. This is due to the increasing input of nutrients from the anthropogenic activities (Gasparini et al. 1992; Hart et al. 2002) and led to the phenomena of eutrophication (Lee et al. 1978; Schindler 1981) of the localised zones as the above two nutrients are key players in determining the ecological status of the aquatic systems (Wetzel 1983).

Despite the importance of the river to many users and the problems that prevail related to significant nutrient inputs, there remains very little available published data on the levels of nutrients in the Malaysian rivers especially in Terengganu, one of the fourteen states within the Malaysia. The aim of this paper is to illustrate how the nutrients concentration may be affected by human activities and how these may have an impact on the distribution of chlorophyll *a*. In this study, chlorophyll *a* has been chosen as an indicator of the ecological status. The N:P ratio will also be calculated in order to know the limiting nutrient in the study area. Results obtained for the nutrients parameters will also be compared with Malaysian Interim National Water Quality Standards (INWQS) to determine suitability of these water bodies with its respective potential beneficial users (Anon 2000).

MATERIALS AND METHODS

The Setiu River, which is situated in the east coast of Peninsular Malaysia, has been chosen as the study area. This river is approximately 60 km in length and receives runoff from its main tributaries such as Guntung River, Tarum River and Caluk

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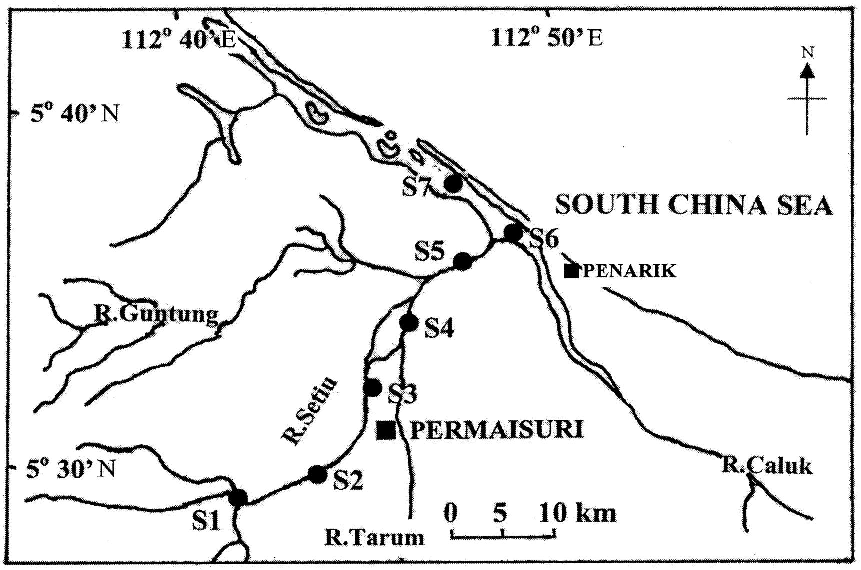

Figure 1. Map showing sampling stations in the study area.

River. The catchment area is approximately 188 km^2. Land use within the catchment is predominantly rural with a small scale of agricultural (paddy field) and aquaculture activities. There is no industrial development within the catchment. Population density is concentrated at two main towns of Permaisuri and Penarik. The river is important as it discharges into the wetland area near the river mouth. This wetland is a unique area as it covers many ecosystems such as estuary, mangrove, wetland and lagoon. Thus, any unregulated upstream activities could potentially result in serious disruption of the eco-hydrological balance in the wetland area.

Seven sampling stations (S1, S2, S3, S4, S5, S6 and S7) were identified within the study area as shown in Figure 1. During the present study, five sampling trips were carried out from May to July 2001. The water samples were collected at a depth of 1 meter from the surface water using a Van Dorn sampler. The samples were filtered through pre-washed Whatman GF/C glass fibre and Millipore 0.45 μm membrane filter within 1 to 4 hours after sampling. After the filtration, samples were stored in polyethylene bottle. The bottles were acid-washed and sample-rinsed. The samples were kept frozen at -20 °C until analysis. All solvents and chemicals used were from the Merck Chemical Company which was of analytical-reagent grade. The dissolved nutrients were determined by the colorimetric method based on Grasshoff et al. (1983). The nutrients analyzed were orthophosphate, total dissolved phosphate (TDP), nitrate plus nitrite (hereinafter referred to as nitrate), ammonia and total dissolved nitrogen (TDN). The detection limit in all nutrients was 0.01 μM. For chlorophyll *a* determination, APHA (1995) method was employed. Appropriate analytical quality controls have been made during sampling and analysis. These include field operation and reagent blanks, multiplicate samples and analysis of samples spiked with standards (standard addition).

RESULTS AND DISCUSSION

Table 1 shows the results of quality control measures taken during the analysis of the sample. The recovery was determined by using standard additions and the results show more than 98% recovery. Each sample was analysed in triplicate and comparison was made between them. The deviations from precision between the triplicates were < 3%.

Table 1. Data for analytical control during the nutrients analysis.

Nutrient	Recovery (%)	Deviations from precision (%)
Orthophosphate	98	< 1
TDP	99	< 1
Nitrate	98	< 3
Ammonia	98	< 2
TDN	99	< 2

Figure 2 shows the mean concentration of the nutrients plotted against distance from the river mouth for each sampling stations. The mean concentrations for the orthophosphate were in the range of 0.033 μM P recorded at station S7 to 0.221 μM P recorded at station S3. For TDP, the range mean concentrations were 0.297-0.761 μM P. The lowest concentration was measured at station S6 whereas station S3 recorded highest concentration. Nitrate and ammonia mean values ranged from 5.20-16.35 μM N and 1.49-7.56 μM N, respectively. Station S4 recorded highest values for both nutrients. The lowest value for nitrate and ammonia were measured at stations S6 and S1, respectively. A mean of 14.29 μM N (lowest concentration) TDN was found at station S1 and 36.60 μM N as a highest mean concentration was found at station S4. Comparison with INWQS showed that for orthophosphate, nitrate and ammonia, all the stations can be categorised in Class I water quality indicating a natural level. Class I representing water body suitable for conservation of natural environment, protection of very sensitive aquatic species and for water supply with practically no treatment necessary. However, no comparison could be made for TDP and TDN because these parameters are still not listed in the INWQS for Malaysia.

The mean range of concentration for nutrients was compared with the mean concentration known for the unpolluted rivers of the world (Wafar et al. 1989). The comparison was presented in Table 2. The mean concentration of phosphorus-based nutrients was relatively lower compared to the values recorded for unpolluted rivers

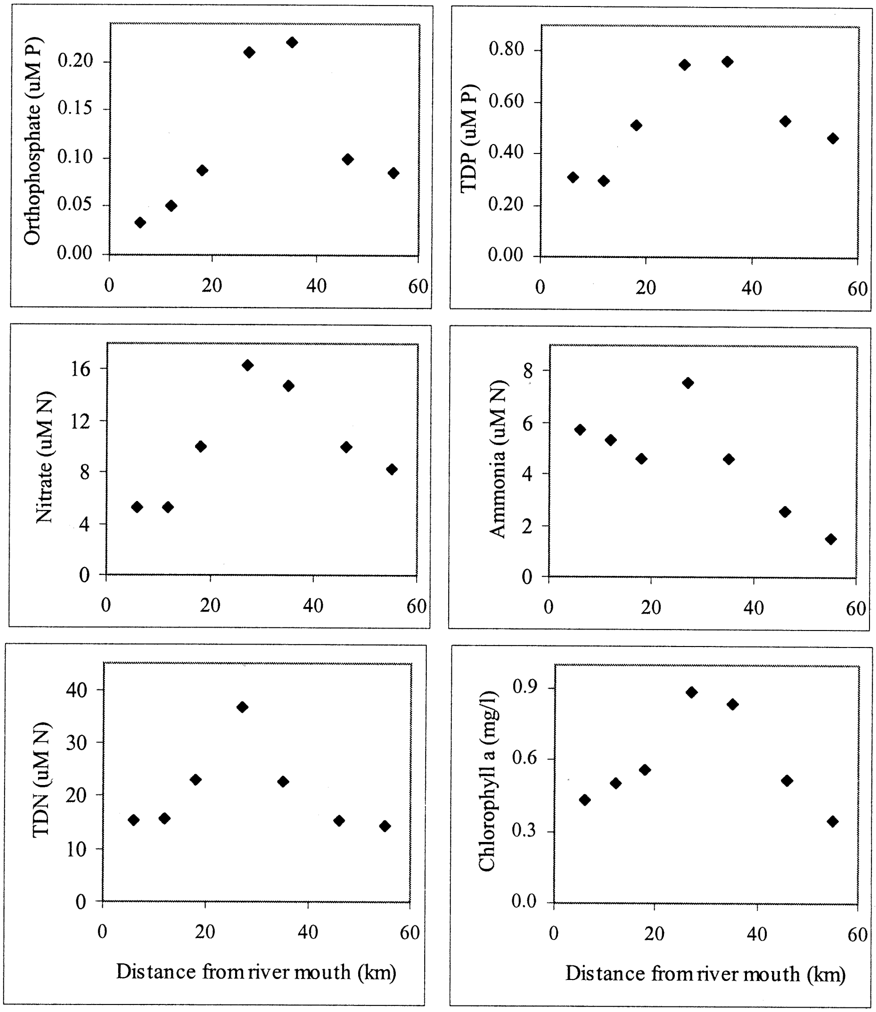

Figure 2. Mean concentrations of nutrients and chlorophyll *a* in Setiu River.

Table 2. Comparison between Setiu River and world unpolluted river.

Nutrient	Setiu River	World unpolluted river
Orthophosphate (μM P)	0.033 – 0.221	0.403
TDP (μM P)	0.297 – 0.761	0.887
Nitrate (μM N)	5.20 – 16.35	7.14
Ammonia (μM N)	1.49 – 7.56	1.07
TDN (μM N)	14.29 – 36.60	26.89

Table 3. Data for mean nitrate to mean orthophosphate ratio for each station.

Station	Nitrate (μM N)	Orthophosphate (μM P)	N:P ratio (by atoms)
S1	8.25	0.086	96:1
S2	10.01	0.099	101:1
S3	14.73	0.221	67:1
S4	16.35	0.210	78:1
S5	10.01	0.088	114:1
S6	5.20	0.051	102:1
S7	5.26	0.033	160:1

of the world. On the other hand, the mean concentrations of nitrogen-based nutrients were found to be much higher. This is probably cause by the input of domestic wastes from the urban area of Permaisuri and Penarik towns. The excessive use of fertilizers that contained high nitrogen compounds in the agricultural area (paddy field) and from the aquaculture activities in the form of cage cultures of fish also contributed to high nitrogen contents in this study area although these were relatively small-scale activities.

With the exception of ammonia, generally, other nutrients concentrations during the period of study showed a decreasing trend in going from the upper reaches to the lower reaches of the river. The decreasing trend was probably due to the dilution effect from the seawater at downstream, which was having low nutrients concentration. However for ammonia, there were relatively higher levels of ammonia observed at stations S6 and S7 as compared to the upper reaches of the river. These higher concentrations may be primarily the result of discharge of untreated domestic effluents from the nearby town of Penarik that flow into the river. The present results also recorded that there were significantly higher level of nutrients at the middle reaches of the river (stations S3 and S4). The discharge of domestic effluents from Permaisuri town was the main reason that contributed to high nutrients levels observed at these particular two stations. Many studies have also used nutrients particularly phosphorus- and nitrogen-based nutrients as important indicators of the enriched discharges from domestic sewage inputs in their study area (Robson and Neal 1997; Suhaimi et al. 1999; Hart et al. 2002).

Many studies have been carried out to assess the N/P ratio in the aquatic area since their concentrations are involved in biological processes and were usually present in aquatic system in concentrations that limit plant growth (Redfield, 1958; Emmerson, 1989; Suhaimi et al. 1999). Redfield (1958) has proposed the N:P ratio of 16:1 and this ratio has been used as a reference to many other studies in order to assess which nutrient act as a limiting nutrient. A N:P ratio lower than 16:1 indicates that N is the limiting nutrient whereas a N:P greater than this value is indicative of P limiting condition. In this present study, the ratio of N:P was calculated as the ratio of mean nitrate to mean orthophosphate (Table 3). The result showed that the ratios were in the range of 67:1 to 160:1 where most of the higher ratios were recorded at the downstream stations. An overall N:P ratio for the Setiu River was calculated to be about 89:1, which was significantly higher compared to often cited Redfield ratio (16:1). This value implying that the limiting nutrient for the plant growth in Setiu River was phosphorus-based nutrients. The result was in good agreement with Schindler (1981) who suggested that phosphorus-based nutrients appear to be the element ultimately limiting the plant growth in the freshwater environment. Other studies also reported the same nutrient as a limiting nutrient. For examples, studies by Emmerson (1989) in Sundays River estuary, South Africa and Suhaimi et al. (1999) in Selangor River estuary, Malaysia. However, their N:P ratio was much lower compared to this study area with the values of 3.25:1 (Emmerson, 1989) and 27:1 (Suhaimi et al. 1999). The high N:P ratio appears to be due to high level of nitrate at Setiu River.

Chlorophyll *a* concentrations were in the range of 0.35 mg/l to 0.89 mg/l. The lowest and the highest concentrations of this parameter were recorded at station S1 and station S4, respectively. Chlorophyll *a* concentrations followed similar trend as observed for the nutrients parameters i.e there was a general increase in concentrations with a maximum concentration recorded at the middle stretch of the river and lower values both in the headwaters and near to the river mouth. This relationship suggested that the distribution of chlorophyll *a* in this study area was controlled mainly by the concentration of nutrients.

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