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Hydrology and Water Quality Assessment of the Tasik Chini's Feeder Rivers, Pahang, Malaysia

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Abstract: The purpose of the study was to assess the hydrological properties and water quality of the seven feeder rivers of Tasik Chini, Pahang, Malaysia. The study was carried out in October and December 2004 and in February, March and April 2005. A total of nine sampling stations were selected for this study: Datang River, Cenahan River, downstream Gumum River, central Gumum River, Kura-kura River, Melai River, downstream mouth of Merupuk River, upstream mouth of Merupuk River and Jemberau River. Eleven water quality parameters were analyzed based on *in-situ* and *ex-situ* analysis during two season periods. Laboratory analysis was carried out according to the HACH and APHA methods. *In situ* water quality findings were as follows: pH (3.2-6.32), dissolved oxygen (0.27-6.4 mg l^{-1}), conductivity (14.33-85.7 μS cm^{-1}) and temperature (24.07-32.1°C). For *ex-situ* water quality parameters, results of TDS ranged from 22.67 to 184 mg l^{-1}, TSS (1.17-79.11 mg l^{-1}) and turbidity (4.67-28.67 NTU) and nutrients (ammonical nitrogen: 0.007 to 0.57 mg l^{-1}; nitrate: 0.7 to 2.9 mg l^{-1}; phosphate: 0.0 to 0.50 mg l^{-1} and sulphate: 0.0 to 2.0 mg l^{-1}). Stream flows were determined during sampling to range from 0.0042 to 0.9083 m^3 sec^{-1} or, on average, 0.1674 m^3 sec^{-1}. The annual rainfall for the lake ranges from 1487.7 to 3071.4 mm. Recent activities such as illegal logging, agricultural activities and other unsustainable developments have taken place in the areas surrounding the lake. The impact of these activities may have caused environmental degradation to Tasik Chini and its adjacent areas by changing the water system's hydrological characteristics, with prospects of possible long term deterioration.

Key words: Water quality parameters · feeder river · hydrological characteristics · Tasik Chini

INTRODUCTION

Surface water resources have played an important function throughout the history in the development of human civilization. About one third of the drinking water requirement of the world is obtained from surface sources like rivers, canals and lakes [1]. Unfortunately, these sources seem to be used as convenient places for the discharge of domestic as well as agricultural and domestic wastes. Dams, according to UNEP [2], are a visible tool for managing freshwater resources, contributing to socio-economic development and protecting drinking water supply. However, dams may negatively affect changes in downstream water flows, degradation of water quality, increased in-lake sedimentation, lake and river bank scouring, blocked movement of migratory species and loss of aquatic biodiversity. Tasik Chini and its environment has undergone devastating changes since 1984 or earlier brought about by development in surrounding areas through mining, oil palm plantation and urbanization. Tasik Chini was once well-known as rich in biological sources. A study carried out by the MNS [3] found 288 species of plants, 21 species of aquatic plants and 92 species of birds and 144 species of freshwater fishes at the Tasik Chini environment.

The condition of Tasik Chini worsened when a small dam was built in 1995 to retain water in Tasik Chini for tourism purposes [4]. The dam made water movement more sluggish. Fishing activities were affected and water current was unstable. However, lake water has been declared safe for recreation purposes [5]. In this study, water quality was examined, along with various physico-chemical parameters, to determine the factors contributing to the pollution load of the lotic water bodies in and around the Tasik Chini. A better understanding of the hydrology of the Tasik Chini will promote the development and management of the lake environment in a more sustainable way.

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MATERIALS AND METHODS

Study area: Tasik Chini is located in the southeast region of Pahang, Malaysia. The lake system lies at 3° 15′ 40″N and 102° 45′ 40″E and comprises 12 open water bodies. The area has a humid tropical climate with two monsoon periods, characterized by a bimodal pattern: southwest and northeast monsoons bring annual rainfall from 1488 to 3071 mm. However, the open water area has expanded greatly since 1995, due to increased retention of water after the construction of a barrage at Chini River. Tasik Chini is surrounded by variously vegetated low hills and undulating lands which constitute the watershed of the region. Three hill areas surround the lake area; (1) Ketaya Hill (209 m) located at the southeast; (2) Tebakang Hill (210 m) at the northern and (3) Chini Hill (641 m) at the southeast. The lake drains northeasterly into Pahang River via the Chini River. The lake is drained by the Chini River, which meanders for 4.8 km before it reaches the Pahang River.

Sampling and preservation: Global Positioning System (GPS) was used to determine the actual coordinates of the sampling stations and to re-confirm the location of stations during the subsequent sampling periods. Nine sampling stations, selected during the first trip to Tasik Chini, were established as the main feeder rivers of Tasik Chini: Datang River (Station 1), Cenahan River (Station 2), downstream Gumum River (Station 3), central Gumum River (Station 4), Kura-kura River (Station 5), Melai River (Station 6), downstream at the mouth of the Merupuk River (Station 7), upstream of the mouth of the Merupuk River (Station 8) and Jemberau River (Station 9). Surface water was collected from each station for measurement of concentration levels using standard laboratory methods [6]. Surface water samples were collected about 10 cm below the water surface using a HDPE bottle (500 ml). The samples were stored in an icebox and transported back to the laboratory for analysis on the same day. Total rainfall during the study period was obtained from the nearby weather station at Chini 2, while rainfall data before year 2004 were obtained from Meteorological Department at Petaling Jaya, Selangor, Malaysia.

Analytical methods: The temperature, electrical conductivity, dissolved oxygen and pH of the water samples were measured in the field by *in-situ* measurement. Bottle samples were measured by laboratory analysis for turbidity, TSS, TDS, NH_3-N, NO_3^-, PO_4^{3-} and SO_4^{2-}. Total Suspended Solids (TSS) was measured using filtration methods with 45 μm membrane filter and vacuum pump (gravimetric methods). Total Dissolved Solids (TDS) was measured using sample water after filtration; turbidity was measured by spectrophotometer. Four chemical water quality parameters (NH_3-N, NO_3^-, PO_4^{3-} and SO_4^{2-}) were determined by the salicylate method (HACH kit DR 2010). Current flow and river width were measured by flow meter (model FP101) and Rangefinder (model Bushnell 20-0001) was used to measure the distance.

RESULTS AND DISCUSSION

Hydrology: Hydrological analysis was carried out to determine the water level of the water body and of its drainage systems [7, 8]. Between 1994 and 1997, annual total rainfall for the Chini area ranged from 1487.7 (1997) mm to 3071.4 mm (1994) (Fig. 1). The average rainfall was 2235 mm/year or 186 mm/month. The total annual rain days in the study area ranged from 154 to 197, for an average of 178 days/year or 15 days/month. The highest total rain days were observed in 1993 and 1994 (197 and 190 days, respectively), while 1997 saw the fewest total rain days-154 (Fig. 2). The total rain days during 2004 were 159 (Fig. 3). The highest number of rain days per

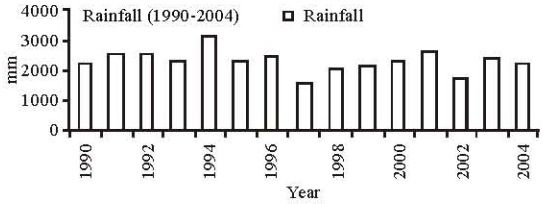

Fig. 1: Distribution of rainfall from 1990 to 2004

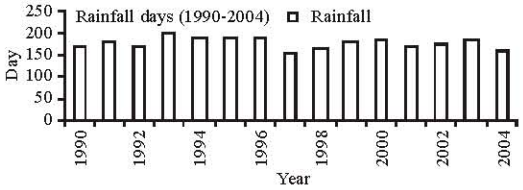

Fig. 2: Distribution of rain days from 1990 to 2004

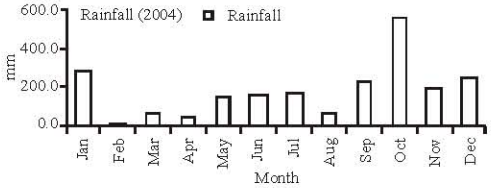

Fig. 3: Distribution of rainfall from January to December 2004

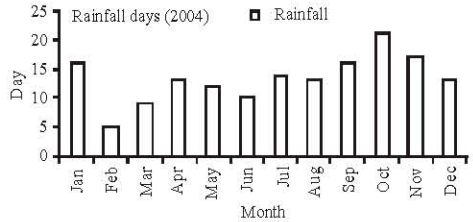

Fig. 4: Distribution of rain days from January to December 2004

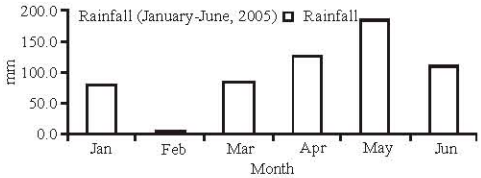

Fig. 5: Distribution of rainfall from January to June 2005

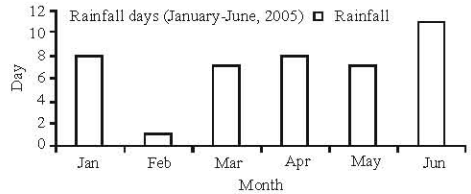

Fig. 6: Distribution of rain days from January to December 2005

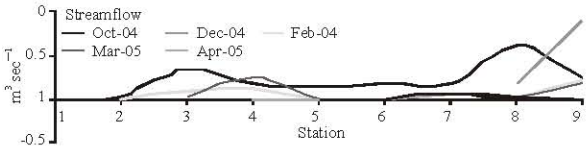

Fig. 7: Stream flow distribution in 9 sampling stations

month (21 days) was recorded during the wet season in 2004, during October to December, while February recorded the lowest number of rain days (5 days) in 2004. The highest rainfall (553.5 mm) was recorded in October 2004; the lowest (16.2 mm) was recorded in February 2004 (Fig. 4). The total annual rainfall was 2192 mm in 2004. During the first half of 2005, total monthly rainfall ranged from 5.3 mm (February) to 182.9 mm (May), for an average of 98 mm/month (Fig. 5). Total rain days for the same period ranged from 1 day (Feb) to 11 days (June) or an average of 7 days/month (Fig. 6).

Stream flow: Stream flow from each feeder river of Tasik Chini is relatively low, ranging from 0.0042 to 0.9083 m^3 sec^{-1} or, on average, 0.1674 m^3 sec^{-1} (Fig. 7). Daily discharge ranged from 362.88 to 78,477.12 m^3 or, on average, 14,463.36 m^3/daily. Stream flow of the Kuala Merupuk River was the highest (0.9083 m^3 sec^{-1}) and Melai River was the lowest (0.0042 m^3 sec^{-1}). Datang River is considered a dead river because no water is flowing. Similar inferences have been made on earlier observations in different feeder rivers of Tasik Chini [9, 10]. The ranges of discharge values from feeder rivers based on each sampling are as follow: 0.033 to 0.6166 m^3 sec^{-1} in October 2004, 0.172 to 0.9083 m^3 sec^{-1} in December 2004, 0.0118 to 0.207 m^3 sec^{-1} in February 2005, 0.0042 to 0.2448 m^3 sec^{-1} in March 2005 and 0.0029 to 0.0718 m^3 sec^{-1} in April 2005.

Average monthly measurement of stream flow of all nine feeder rivers of Tasik Chini in October and December 2004 and February, March and April 2005 were, respectively 0.2162, 0.5308, 0.0624, 0.0655 and 0.0157 m^3 sec^{-1}. Stream flows of these rivers mainly depend on rainfall. The highest stream flows were observed during the wet season, especially in October 2004 (0.6166 m^3 sec^{-1}) and December 2004 (0.9083 m^3 sec^{-1}), while in the dry season (February to April 2005) we recorded the lowest stream flows (0.0118, 0.0042 and 0.0029 m^3 sec^{-1}). Data could not be obtained from the Gumum, Kura-kura, Melai and Kuala Merupuk Rivers in December 2004 due to flooding.

Water quality: Figure 8 shows the water quality parameters *viz.* temperature, pH, conductivity, DO, TDS, TSS, turbidity, ammonical nitrogen, nitrate, phosphate and sulphate.

Temperature: Range of temperature value based on each sampling as described as follow: 24.07-25.47°C in October 2004, 24.87-27.97°C in December 2004, 24.87-28.4°C in February, 24.3-29°C in March 2005 and 24.57-32.1°C in April 2005 (Fig. 8). For all sampling stations, temperature of the water ranged from 24.07 to 32.1°C. Station 7 (downstream of the Kuala Merupuk River) recorded the lowest value (24.07°C) in the wet season and station 9 (Jemberau River) recorded the highest value (32.1°C) in the dry season. The range of temperature at these sampling sites during the different seasons seemed normal for the climate. The temperature values did not show any spatial change but indicated temporal variation.

pH: The ranges of pH value in the different sampling times were recorded: 4.96 to 6.32 in October 2004, 5.15 to 5.94 in December 2004, 4.17 to 5.39 in February 2005, 3.2 to 5.46 in March 2005 and 4.24 to 5.82 in April 2005 (Fig. 8). pH values ranged from 3.2 at Station 4 (central Gumum

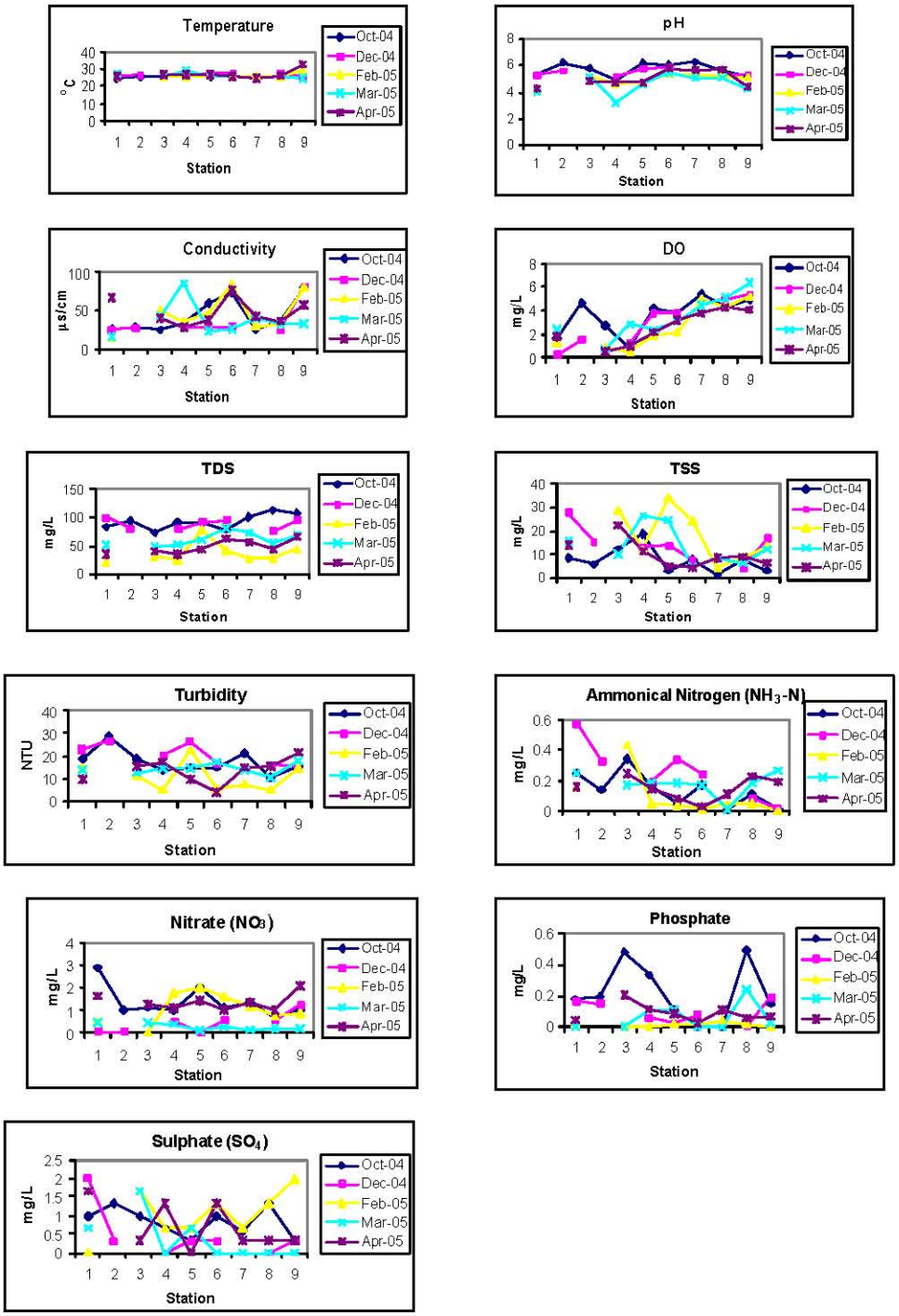

Fig. 8: Distribution of 11 water quality parameters; i.e. Temperature; pH; Conductivity; DO; TDS; TSS; Turbidity; Ammonical nitrogen; Nitrate; Phosphate and Sulphate

River) to 6.32 at Station 7 (downstream Kuala Merupuk River). Most stations showed slightly acidic pH, indicating that the water is in Class III according to Interim National Water Quality Standards (INQWS) [11]. It is clear that, the pH values increased from the dry season to the wet season. Our findings are similar to pH values found by Sim [12]. The pH value is controlled by the dissolved carbon dioxide (CO_2), which forms carbonic acid in water [13]. The INWQS threshold range of pH for Malaysian rivers is 5.00 to 9.00 [11].

Conductivity: Conductivity (EC) values ranged from 14.33 μS cm^{-1} to 85.7 μS cm^{-1} at different locations and times, as indicated by the *in situ* readings obtained during sampling (Fig. 8). The average value was 40.96 μS cm^{-1}. The ranges of conductivity were recorded: 24.83 to 80.33 μS cm^{-1} in October 2004, 25.3 to 81.4 μS cm^{-1} in December 2004, 14.33 to 84.7 μS cm^{-1} in February 2005, 16.5 to 85.7 μS cm^{-1} in March 2005 and 27.93 to 76.43 μS cm^{-1} in April 2005. The highest and lowest values were recorded respectively at Station 4 (14.33 μS cm^{-1}) in March 2005 and station 1 (85.7 μS cm^{-1}) in February 2005. Conductivity values were higher compared to the ranges 13.2 to 25.13 μS sec^{-1} found by Sim [12].

Dissolved oxygen: The dissolved oxygen (DO) concentration ranged from 0.56 to 6.4 mg l^{-1} (Fig. 8). The DO value did not show any difference between wet and dry seasons. The range of DO values measured monthly were recorded: 0.88 to 5.48 mg l^{-1} in October 2004, 1.23 to 5.37 mg l^{-1} in December 2004, 0.59 to 5.16 mg l^{-1} in February 2005, 0.72 to 6.4 mg l^{-1} in March 2005 and 0.56 to 4.21 mg l^{-1} in April 2005. The highest value (6.4 mg l^{-1}) was recorded at Jemberau River in March 2005 and the lowest value (0.56 mg l^{-1}) occurred at downstream Gumum River during the dry season (April 2005). The DO value was very low (0.56 to 0.88 mg l^{-1}) at downstream Gumum River during the dry season (February to April 2005). Our findings on DO are similar to those obtained in earlier observations in different feeder rivers of Tasik Chini [14]. The DO values are higher (4.03 to 6.4 mg l^{-1}) at Jemberau River during both wet and dry seasons. The water flows of the Jemberau River during both wet and dry seasons were higher, providing more oxygen to dissolve into the water. The threshold range for Malaysian rivers is 3.00 to 5.00 mg l^{-1} [11].

Total dissolved solids: The range of total dissolved solids (TDS) values recorded in each monthly sampling were: 73.33 to 112.76 mg l^{-1} in October 2004, 75.33 to 100.67 mg l^{-1} in December 2004, 22.67 to 78.33 mg l^{-1} in February 2005, 50 to 8.67 mg l^{-1} in March 2005 and 35.33 to 66.67 mg l^{-1} in April 2005 (Fig. 8). TDS of water samples collected during different seasons varied from 22.67 to 112.67 mg l^{-1}, well within the permissible limits of the World Health Organization [15]. The highest concentration (112.67 mg l^{-1}) was measured at the upstream Kuala Merupuk River (Station 8) during the wet season and the lowest value (22.67 mg l^{-1}) was recorded at the Datang River during the dry season (February 2005). According to INQWS, all the feeder rivers are in Class I (TDS<500 mg l^{-1}). In general, TDS increased from dry to wet seasons. In the dry season (February to April 2005) TDS ranged from 22.67 to 80.67 mg l^{-1} and in the wet season (November to December 2004) TDS ranged from 73.33 to 112.67 mg l^{-1}. The TDS values were always higher at the Jemberau River (Station 9), across both wet and dry seasons TDS ranged 45.33 to 108 mg l^{-1}.

Total suspended solids: The Total Suspended Solids (TSS) of water samples collected from 7 feeder rivers during the different seasons varied from 1.17 to 34.0 mg l^{-1} (Fig. 8). The mean concentration of TSS was 12.27 mg l^{-1}; the highest (34.0 mg l^{-1}) was recorded at the Kura-kura River (Station 5) during the dry season and the lowest (1.17 mg l^{-1}) at the Kuala Merupuk River (Station 7) during the wet season. The ranges of monthly measurement of TSS in the different seasons were recorded: 1.17 to 19 mg l^{-1} in October 2004, 4.25 to 27.83 mg l^{-1} in December 2004, 4.0 to 34.0 mg l^{-1} in February 2005, 4.5 to 26.67 mg l^{-1} in March 2005 and 4.17 to 22.5 mg l^{-1} on April 2005. The TSS values were comparatively higher at the Gumum River during both wet and dry seasons. There was sudden rise in the TSS values of the Gumum River (Stations 3 and 4) in February 2005 and March 2005, respectively. The TSS value also rose at the Kura-kura River (Station 5) in February 2005 and March 2005. Overall, TSS concentrations recorded in this study show a low value. The INWQS recommends maximum threshold levels of TSS for Malaysian rivers from 25 to 50 mg l^{-1}. The INQWS threshold level of TSS for supporting aquatic life in fresh water ecosystems is 150 mg l^{-1} [11].

Turbidity: The turbidity of water samples varied from 4.67 to 28.67 NTU (Fig. 8). The mean concentration was 16.41 NTU; the highest was 28.67 NTU at the Cenahan River (Station 2) during the wet season and the lowest was 4.67 NTU at the Melai River (Station 6) during the dry

season. The ranges of turbidity in each sampling period were: 11.0 to 28.67 NTU in October 2004, 16.0 to 27.33 NTU in December 2004, 5.33 to 22.67 NTU in February 2005, 10.67 to 18.33 NTU in March 2005 and 4.67 to 21.67 NTU in April 2005. Overall, during the wet season turbidity was higher than in the dry season. The highest turbidity value was measured at the Kura-kura River during both wet and dry seasons. According to international standards, water is acceptable for domestic use when its turbidity lies within 5-25 NTU [16]. INWQS does not propose any threshold level for turbidity of fresh waters for the support of aquatic life. The Ministry of Health has set a threshold level of raw water turbidity at 1000.00 NTU.

Ammonical nitrogen (NH_3-N): The ranges of ammonical nitrogen at each sampling are as follows: 0.007 to 0.34 mg l^{-1} in October 2004, 0.013 to 0.57 mg l^{-1} in December 2004, 0.003 to 0.43 mg l^{-1} in February 2005, 0.014 to 0.26 mg l^{-1} in March 2005 and 0.03 to 0.24 mg l^{-1} in April 2005 (Fig. 8). The value of ammonical nitrogen of all water samples collected ranged from 0.003 to 0.57 mg l^{-1}. The highest concentration (0.57 mg l^{-1}) was observed at the Datang River (Station 1) during the wet season. The lowest (0.003 mg l^{-1}) was recorded at the Jemberau River (Station 9) in February 2005 during the dry season. The average concentration of ammonical nitrogen was 0.17 mg l^{-1}. All the samples collected during the dry season were well below the maximum permissible limit set by the World Health Organization [15]. Even samples collected during the wet season did not exceed the WHO limit. The INWQS recommends maximum threshold levels of ammonical nitrogen for Malaysian rivers at 0.90 mg l^{-1} to support aquatic life.

Nitrate (NO_3^-): The range of nitrate values recorded were 0.7 to 2.9 mg l^{-1} in October 2004, 0.0 to 1.27 mg l^{-1} in December 2004, 0.0 to 2.03 mg l^{-1} in February 2005, 0.09 to 0.44 mg l^{-1} in March 2005 and 1.03 to 2.1 mg l^{-1} in April 2005 (Fig. 8). Nitrate concentrations varied from 0.0 to 2.9 mg l^{-1}. The NO_3^- ion is usually derived from anthropogenic sources like agricultural fields, domestic sewage and other waste effluents containing nitrogenous compounds [1]. In February 2005, the nitrate concentrations recorded were comparatively low at 0.0 to 0.44 mg l^{-1}. During the wet season nitrate concentrations were higher, ranging from 0.7 to 2.9 mg l^{-1}. The nitrate level was recorded zero dowmstream at Gumum River (Station 3) during the dry season. According to the INQWS classification, all the feeder rivers are in Class I, which is considered as not contaminated.

Phosphate: The phosphate levels of water samples measured across the seasons varied from 0.0 to 0.50 mg l^{-1} (Fig. 8). The mean phosphate concentration was 0.11 mg l^{-1}; the highest concentration was 0.50 mg l^{-1} recorded at upstream of Kuala Merupuk River (Station 8) during the wet season and the lowest 0.0 mg l^{-1} at downstream of Kuala Merupuk River (Station 6) during the dry season. The ranges of phosphate levels across sampling times were recorded as 0.01 to 0.5 mg l^{-1} in October 2004, 0.01 to 0.19 mg l^{-1} in December 2004, 0.01 to 0.04 mg l^{-1} in February 2005, 0.0 to 0.25 mg l^{-1} in March 2005 and 0.03 to 0.21 mg l^{-1} on April 2005.

Overall, in the wet season phosphate levels were higher than in the dry season. Comparatively higher phosphate concentrations were measured at Gumum River during both seasons, presumably because of human activities at the nearby village of Kampung Gumum. Concentrations of nutrients and pesticides in major rivers reflect the proportion of urban and agricultural land in the drainage basin [17]. Similarly, in the surrounding areas of Gumun River, there are plenty of oil palm plantations with heavy use of fertilizers. The fertilizer may wash to Gumun River and may cause high nutrient contents in the water.

Sulphate: The sulphate content of water samples ranged from 0.0 to 2.0 mg l^{-1} (Fig. 8). The highest value (2.0 mg l^{-1}) was recorded at Datang River (Station 1) during the wet season and the lowest value (0.0 mg l^{-1}) was recorded during the dry season. The ranges of sulphate levels were: 0.33 to 1.33 mg l^{-1} in October 2004, 0.0 to 2.0 mg l^{-1} in December 2004, 0.0 to 2.0 mg l^{-1} in February 2005, 0.0 to 1.67 mg l^{-1} in March 2005 and 0.0 to 1.67 mg l^{-1} in April 2005. Across seasons the sulphate levels were higher at Gumun River, again perhaps due to the nearby village of Kampung Gumum and the activities of the local residents. According to Hem [13]. The major sources of sulphate in streams are rock weathering, volcanoes and human activities such as mining, waste discharge and fossil fuel combustion processes. All the samples collected across seasons were well below the maximum permissible limit set by the World Health Organization [15].

Analytical statistics: There are no significant correlations between stream flow and TSS, TDS, turbidity and levels of nitrates and ammonical nitrogen (NH_3-N) during the wet and dry seasons. Most correlations show a very weak R^2 of 0.16 and below (Fig. 9). However, TSS and TDS were correlated as positive and negative slope with stream flow during the wet and the dry season,

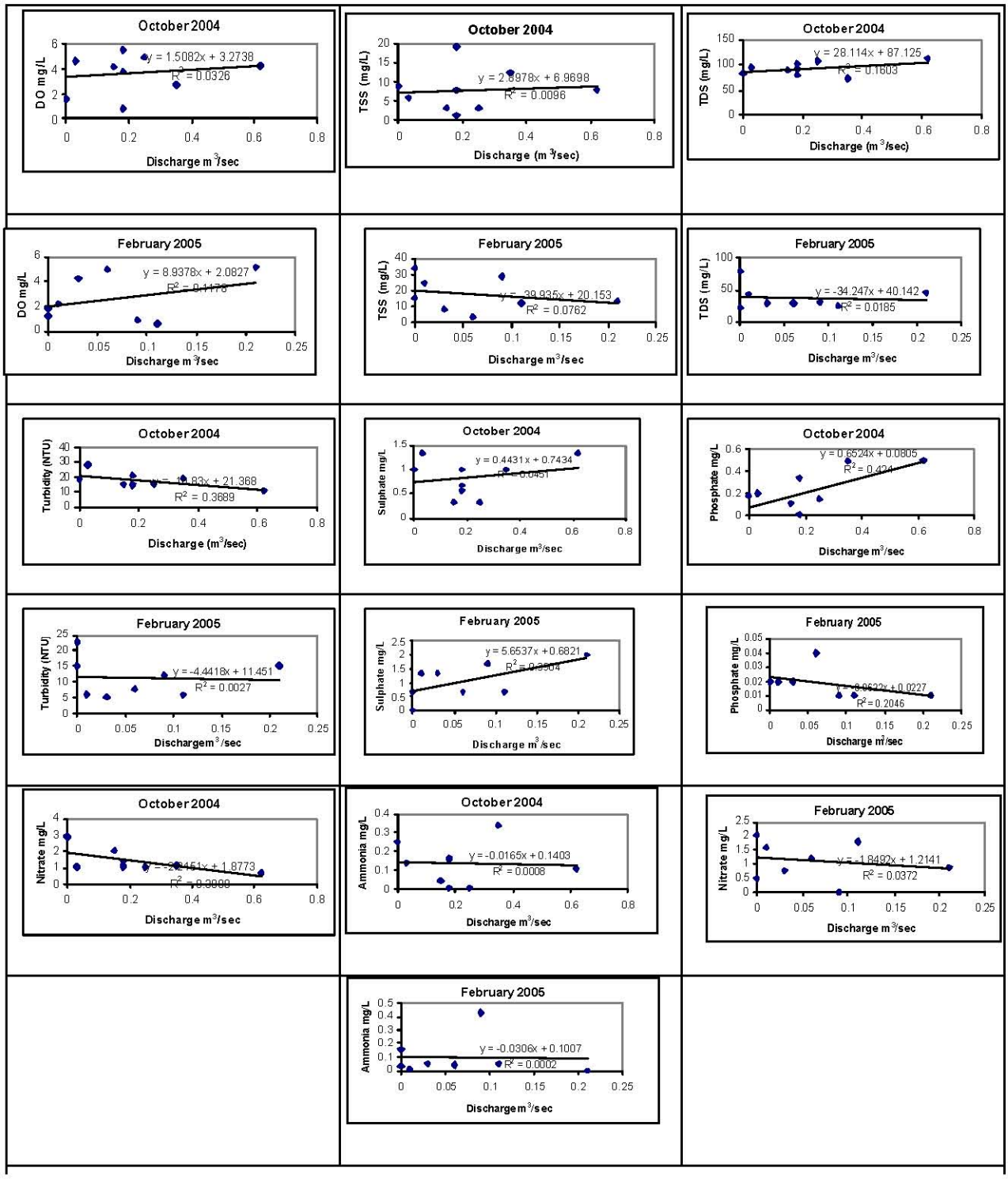

Fig. 9: Relationship between discharge and DO, TDS, TSS, turbidity, Sulphate, Phosphate, Nitrate, and NH_3-N during the wet and dried seasons sampling

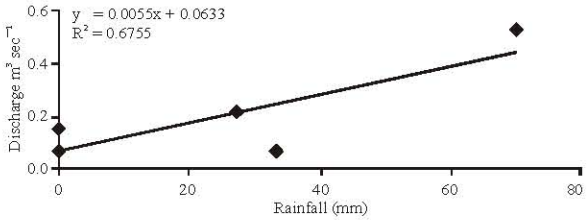

Fig. 10: Relationship between rainfall and discharge

respectively. Levels of DO and sulphate were correlated as positive slope and turbidity and nitrate as negative slope with stream flow during both seasons. Levels of phosphate and sulphate were positively correlated ($R^2 = 0.424$; $R^2 = 0.3904$) with stream flow during wet and dry seasons, respectively. This correlation indicates that pollutant loads probably came from dilution and not from erosion. Raining during the wet season had diluted the soil into the river, increasing the concentration of TSS and turbidity.

Stream flows were recorded during the wet and dry seasons and rainfall data of the earlier five days of sampling days were collected. The measurement of discharge and rainfall showed a statistically significant correlation ($R^2 = 0.6755$) between rainfall and discharge (Fig. 10).

CONCLUSIONS

A detailed physico-chemical study of the lotic water of the feeder river of Tasik Chini during the wet and dry seasons revealed that the seven feeder rivers showed different seasonal fluctuations in various physico-chemical parameters. The results of water quality trends clearly showed that most water quality parameters were quite high in the wet season compared to in the dry season. Water quality analysis shows that pH, NH_3-N, NO_3^-, phosphate, sulphate, TDS, TSS and turbidity were lower in the dry season, but DO was higher. That is, in the wet season all the parameters were higher except DO. From the above investigation it is clear that Gumum River (Station 3) and Datang River (Station 1) were comparatively more polluted than the other sampling sites, presumably due to human activities in nearby Kampung Gumum. Cenahan River (Station 2), Kura-kura River (Station 5), Melai River (Station 6) and Jemberau River (Station 9) were less polluted. The least polluted river was Kuala Merupuk River (Station 7). The main sources of pollutants were likely to be residential areas, illegal logging, development and agricultural activities, generating both organic and inorganic wastes which ultimately contaminate the water bodies. According to the INWQS classification, all the feeder rivers are in Class II, which is considered as slightly contaminated. Stream flow discharge from each feeder river to Tasik Chini is directly related to rainfall. In the dry season rainfall is low, so discharge from feeder rivers is lower than in the wet season. The feeder rivers' water quality status in the catchment is mainly influenced by the stability of the catchment area. A basin protection strategy comprising development of the monitoring system, assessment of pollution, pollution control and basin conservation should be implemented in order to minimize the impact of changes to the lake areas. If proper attention is not paid to sustainable management of water resources, supervision of logging and raising awareness of local people, then the situation may deteriorate and threaten the environment of Tasik Chini.

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