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Longitudinal Variation of Water Quality in Sungai Jarum Catchment - Linking Ecology with Hydrology for Reservoir Management

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ABSTRACT

In recent years, human activities, such as urbanization and agriculture, have been blamed for the degradation of water quality in many developing countries. Rivers draining agricultural land are susceptible to diffused or non-point source pollution. A study was conducted in Timah Tasoh catchment areas with the aim to investigate the effect of land use activities and eutrophication of the Timah Tasoh reservoir. A water quality monitoring programme was carried out from January 2001. This paper, however, focuses on the longitudinal variation of water quality parameters of Sungai Jarum as one of the two major water sources for the reservoir. The study was carried out from July to December 2001. Most physical parameters (temperature, dissolved oxygen, pH, conductivity, total dissolved solids, TDS; turbidity) and nutrients varied between stations along the river. The general trend was that the water quality was getting better approaching the reservoir, where nutrient contents decreased longitudinally from its sources in the upper catchment to the reservoir. A reduction of almost 80% and 90% was observed for nitrogen and phosphorus, respectively at Tasoh, and a further reduction from Tasoh to the reservoir. Sedimentation and nutrient uptake by plant along the river corridor and in the littoral zones is the most probable cause for the reduction in nutrient contents and help maintaining good water quality of the reservoir.

ABSTRAK

Kebelakangan ini, aktiviti manusia seperti pembandaran dan pertanian didakwa menjadi penyebab kepada kemerosotan kualiti air di kebanyakan negara membangun. Sungai yang mengairi tanah pertanian lebih mudah dicemari pencemaran merata atau pencemaran bukan poin. Kajian ini dijalankan di kawasan Timah Tasoh dengan tujuan untuk meneliti kesan aktiviti gunatanah dan eutrofikasi empangan Timah Tasoh. Program pemantauan kualiti air dijalankan sejak Januari 2001. Kebanyakan parameter fizikal (suhu, oksigen terlarut, pH, konduktiviti, TDS, turbiditi) dan nutrien berbeza di stesen di sepanjang sungai. Tren memperlihatkan kualiti air menjadi lebih baik menghala ke empangan di mana kandungan nutrien menurun secara longitud dari *sumbernya di kawasan tadahan bahagian atas dan semakin menurun apabila memasuki empangan. Penurunan hampir 80% dan 90% diperhatikan untuk masing-masing nitrogen dan fosforus di Tasoh, dan penurunan yang lebih tinggi dari Tasoh ke empangan. Pemendapan dan penyerapan nutrien oleh tumbuhan di sepanjang tebing sungai mungkin merupakan penyebab pengurangan kandungan nutrien dan membantu dalam mengekalkan kualiti air di empangan.*

INTRODUCTION

In recent years, human activities, such as urbanization and agriculture, have been blamed for the degradation of water quality in many developing countries. Rivers draining agricultural land are susceptible to diffused or non-point source pollution. Many issues concerning rivers like the above statements have received growing attention amongst scientist and engineers. However, for many years, different specialists have investigated different issues about rivers separately. River engineers, for example, only concerned with the engineering aspect of the river, while geomorphologists concerned with the effect of weathering and erosion of the river, and river ecologists focused their attention on the creatures and freshwater biota in the river. The knowledge became separated and linkages between each discipline e.g. hydrology and ecology should be tightened together to bring a more meaningful explanation of a river ecosystem.

Ecological studies that linked the distribution of freshwater biota to physical factors are not new. Debate as to how such linkages can be used in a river management context has continued for the past 30 years or more (Baxter 1961). Only recently we saw the upcoming new scientific work tries to link different science disciplines to tackle the same issues concerning rivers. In fact the terms hydro-ecology has been proposed (Poff et al. 1997). Hydro-ecology is *"the linkage of knowledge from hydrological, hydraulic, geomorphological and biological/ecological sciences to predict the response of freshwater biota and ecosystems to variation of abiotic factors over a range of spatial and temporal scales".* This enables us to open up sometimes a blurred distinction between applied hydro-ecology, and fundamental aquatic ecology, which is focused on understanding and explaining observed phenomena.

Linkages between ecology and hydrology are best described by the hydrology of wetland. Wetlands are transitional between terrestrial and open-water aquatic ecosystems. They are transitional in terms of spatial arrangement because they are usually found between uplands and aquatic systems. Ecologists normally disregard the importance of hydrology when studying wetland. The hydrology of wetland creates the unique physicochemical conditions that make such an ecosystem different from both well-drained terrestrial systems and deep water aquatic systems (Mitsch & Gosselink 2000).

This study reports preliminary findings that link hydrology and ecological studies to investigate the longitudinal variation in water quality of a river and the effect of riparian plant in maintaining good water quality of the river and lake.

STUDY AREA

Jarum River catchment area lies between latitude 6^0 35'N to 6^0 40'N and longitude 100^0 15'E to 100^0 20'E (Figure 1). The Jarum River flows from the Thai border to the Timah Tasoh reservoir. It is one of the two main river inputs to the Timah Tasoh reservoir. Besides the main Sg Jarum, other major tributaries are Sg. Chuchuh and Sg. Mata Ayer making the whole catchment area around 126 km^2 and the catchment is located between Padang Besar and Timah Tasoh Reservoir. Most areas within the catchment are agricultural lands, mainly with rubber, paddy field mixed with vegetable and fruit farms. Rubber plantation schemes

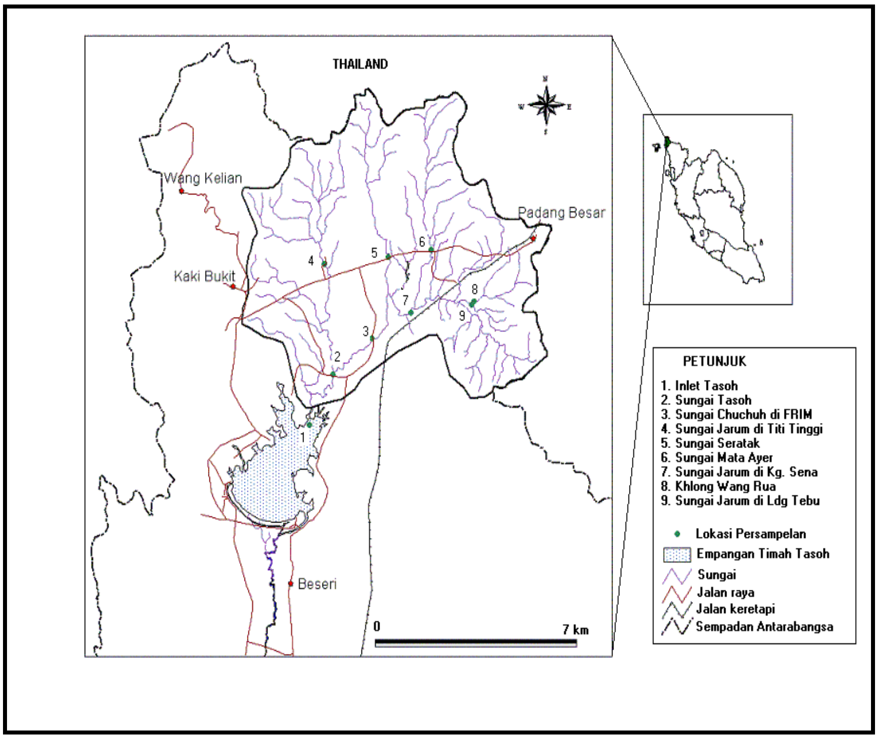

Figure 1. The study catchment area and lake showing sampling sites

include the FELCRA Mata Ayer, the FELDA Rimba Mas and the FELCRA Lubok Sireh. The paddy planting areas are at Kg. Masjid and Kg. Titi Tinggi. Crops are also grown along the river banks. Most parts of Sg. Chuchuh are planted with teak and rubber.

Precipitation

Figure 2 shows the weekly precipitation patterns of Timah Tasoh watershed for 2001. Total precipitation was 5927mm with the highest rainfall recorded at Wang Kelian (1909mm), followed by Lubok Sireh (1587mm), Kaki Bukit (1319mm) and Padang Besar (1111mm). In general, the distribution pattern of rainfall at Tasoh and Pelarit watershed was almost similar with an average recording of 64 mm. No significant difference ($p<0.01$) was found for the annual mean of rainfall between the stations.

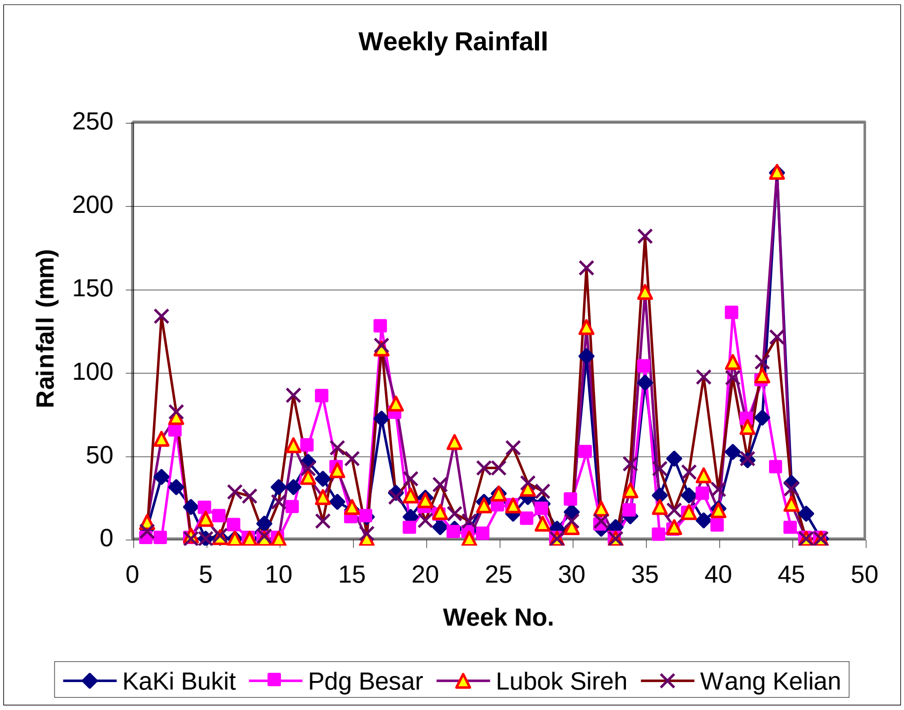

Figure 2. Weekly precipitation in 2001 at four locations: Kaki Bukit and Wang Kelian, Lubok Sireh, and Padang Besar representing the sampling stations of Hulu Pelarit, Sg. Chuchuh and Sg. Jarum, respectively

From January to early March was a dry season, with low precipitation which averages at 34mm per day. However, the dry condition was not obvious as some areas were having quite a high precipitation such as in January. A significant dry days were only observed during February to early March during which the area of Kaki Bukit and Padang Besar were having no rain nearly two weeks whereas Lubok Sireh might rain for nearly a month.

A significant increase ($p<0.01$) of rainfall above the annual average was observed during the shift of dry season to wet season by the end of March. The rainfall then decreased moderately until July but most of the values were lower than 50mm per day. The much frequent and higher precipitation was observed from August to November. Rainfall pattern seemed to concentrate in two weeks interval that give a significant increased ($p<0.01$) of precipitation in August and much higher in early September. A continuous rainfall with greater intensity was then surging the precipitation value at Lubok Sireh, Kaki Bukit and Wang Kelian to the highest mark for the whole year in November. Kaki Bukit and Lubok Sireh recorded the highest rainfall in a single day, measuring at 140 and 160 mm respectively during November. The highest precipitation value at Padang Besar was only 60.5 mm, recorded in the middle of October 2001. The rainfall dropped below 50mm at all stations at the end of November 2001.

MATERIAL AND METHODS

Samples were collected every fortnight at all sites from July 2001 to December 2001. Nine sampling sites (Table 1) were selected for this study over a distance of 50 km. Three replicates of samples were taken at each site. Water samples were taken using 2 litre Kemmerer water

Table 1. Sampling sites showing distances from the lake station to the upper catchment, and land uses

Site No.	River	Distance from Timah Tasoh Reservoir (km)	Description of Site
1	Inlet Tasoh	0	Open area
2	Tasoh River	11.8	Agriculture area
3	Chuchuh River	21.8	FRIM plantation
4	Jarum River at Titi Tinggi (JTT)	29.8	Domestic area
5	Seratak River	34.8	Water flow from FELDA agriculture
6	Mata Ayer River	38	Agriculture area
7	Jarum River at Kampung Sena	48.8	Paddy and rubber plantation
8	Khlong Wang Rua (KWR)	51.4	Water flow from Padang Besar and rubber plantation
9	Jarum River at Sugar cane plantation (JSC)	52	Sugar cane plantation

sampler. Samples were kept cooled and brought back to the Physical Geography Laboratory, School of Humanities, Universiti Sains Malaysia, Pulau Pinang for further analysis. Water quality parameters and methods used in this study are shown in Table 2. Nutrients analyses were determined following APHA (1989).

Table 2. Parameters and methods used for water quality analysis

Parameters	Method
Temperature	YSI 58 Meter
Dissolved Oxygen	YSI 58 Meter
pH	Cyber scan 20 Meter
Conductivity	Hach conductivity/TDS Meter
Turbidity (FTU)	Hach DR/2000
Total Dissolved Solid	Hach conductivity/TDS Meter
Total Suspended Solid	Filtration using 0.45µm filter paper
Alkalinity	Titration
Nitrate	Cadmium reduction
Nitrite	Diazotization
Orthophosphate	Ascorbic acid reduction

RESULTS AND DISCUSSIONS

Physico-chemical Parameters

The average of chemical and physical parameters during this period is shown in Table 3. Temperatures were high at Jarum River at Ladang Tebu (29.0 ± 1.6^{0}C) and Inlet Tasoh (29.7 ± 1.9^{0}C) due to the open sites compared to others. Dissolved oxygen varied between 3.3 ± 0.9 mg/l (Mata Ayer River) to 6.0 ± 0.8 mg/l (Inlet Tasoh). Mata Ayer River had the lowest concentration because the water is stagnant there, meanwhile Inlet Tasoh records the highest because of the open sites and the action of wind for aeration.

The water was mostly alkaline with pH 7.1 ± 0.3 to 7.5 ± 0.2 except for Inlet Tasoh (6.8 ± 0.7) and Chuchuh River (6.9 ± 0.3). Alkalinity showed variation among all sites and ranged from 133.37 ± 60.20 at Chuchuh River and 266.86 ± 169.58 at Mata Ayer River. High total alkalinity is a measure of bicarbonates ions.

There was little variation of conductivity and TDS among the various sampling sites. The conductivity ranged between 0.5 ± 0.1 mS/cm and 0.2 mS/cm, and TDS ranged between 233 ± 50.6 mg/l and 104.4 ± 25.0mg/l. Seratak River recorded the highest conductivity than others and it showed that it had high dissolved mineral. Turbidity showed some distinct variations between sampling sites. They ranged between 55.1 ± 39.8 FTU and 18 ± 17.8 FTU.

Suspended Sediment

High suspended sediment concentration (TSS) was recorded at Jarum river at Sugar Cane plantation (JSC) at 51.9±90.6 mg/l. The TSS values ranged from 11.7 ± 14.4 mg/l at Mata Ayer River to a maximum concentration of 151.3 ± 314.9 mg/l at Inlet Tasoh. Most of sediment input came from JSC where the concentration reached up to 51.9 ± 90.6 mg/l. The second contributor of sediment came from Seratak river at 40.1 ± 41.7 mg/l and Chuchuh river having concentration of 24.8±15.7 mg/l. The concentrations decreased downstream due to possible deposition along the river course. The reduction in TSS could explain the function of wetland as water filters. The river meanders from Jarum river at Titi Tinggi (JTT) towards Tasoh river. There were water plants and grasses in the channel that trap or slowed down flows causing deposition of sediment.

The concentration increased again at Tasoh river (28.9±24.7 mg/l) due to input from Chuchuh river and then stored at the inlet Tasoh where the sediments were deposited when the velocity dropped. Inlet Tasoh was covered with submerged as well floating aquatic plants. They could act as sediment trap as well as reducing agent to flow of water. Here the river water started to spread and most of the sediment deposited. However due to the continual input of water there could be some form of mechanism that re-suspended the sediment causing highest recorded sediment concentration.

Many studies have shown how runoff, river and lake waters are slowed down when they enter a wetland due to the spread of floodwater over a large area, its immobilization in low-lying basins and depressions or the moderating effects of the vegetations (e.g. swamp vegetation). In lakes, aquatic vegetation slows down the water movement both on the surface (waves) and at depth (current). All these mechanisms encourage the settling of suspended detrimental materials (Howard-Williams & Gaudet, 1985, Howard-Williams & Thompson 1985, Meade 1988, Sather & Smith 1984).

Nutrients

Nutrient concentration tends to decrease from upstream towards the reservoir (Figure 3). Orthophosphate was high at upstream sites like Khlong Wang Rua (0.34 ± 0.24 mg/l) and 0.30 ± 0.41 mg/l at Jarum River at Kampung Sena but decreasing towards the reservoir. Nitrate concentration ranged from 0.20 ± 0.17 mg/l at Inlet Tasoh and 2.03 ± 0.69 mg/l at Khlong Wang Rua. The land use activities, such as agriculture and domestic activities, and also precipitation correlated highly with concentration. The low values at inlet could due to several factors affecting the nutrient content, such as buffering by the littoral zones vegetation, deposition and dilution.

The general trend was that the water quality becoming better approaching the reservoir, where nutrient contents decreased longitudinally from its sources in the upper catchment to the entrance of the reservoir. Nitrate and phosphate were higher at KWR, attributed to the pollution sources coming from urban area of Padang Besar. The longitudinal variation of nitrate concentration (Figure 3) decreased from 2.03 mg/l at Khlong Wang Rua (KWR) to as low as 0.9 mg/l Jarum river at Titi Tinggi (JTT). This is about 81% reduction. The concentration was further reduced to as little as 0.37 mg/l in the lake at Inlet Tasoh, representing another 47%. The reduction in phosphate was higher (at 94%) from KWR to JTT. However, there was no more reduction from JTT to the lake. This reduction could be associated with sedimentation along the course and that it was being used up by the plant. Sedimentation and nutrient uptake by plant along the river corridor and in the littoral zones was the most probable cause for the reduction in nutrient contents and help maintaining good water quality of the reservoir.

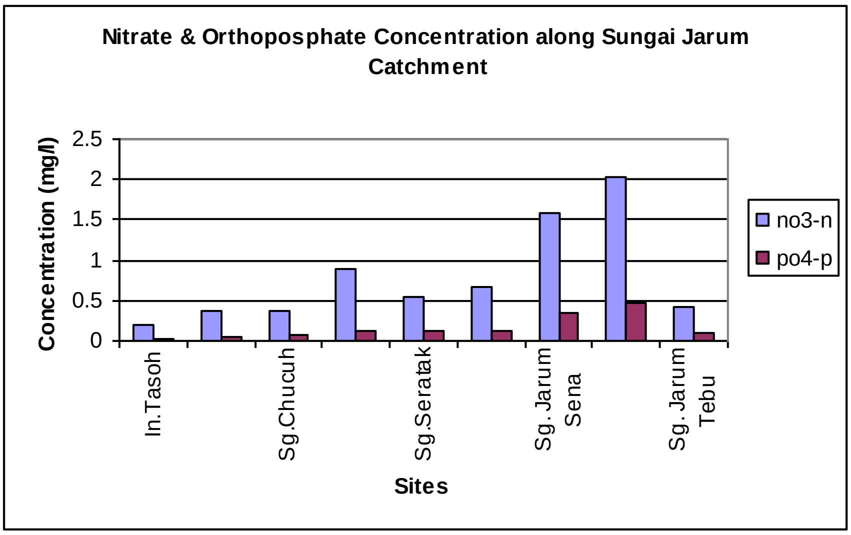

Figure 3. The distribution of nitrate and orthophosphate along the Sungai Jarum. The trend decreases from upper catchment area (right) towards the lake (left)

The presence of wetland in river system has been shown to affect nitrogen loading. Many constructed wetlands, for example, work efficiently in trapping nitrogen. Arheimer (1998) showed that a conversion of, as little as, 1% of drainage basin into wetland would reduce N transport by 10-16%. Nutrients are supplied from upstream and favourable alteration of soil chemistry results from periodic overbank flooding especially at the lake periphery. The alterations include nitrification, sulfate reduction and nutrient mineralization. This could have happened here at the Inlet Tasoh causing the decrease in nitrate concentration compared to the upstream stations.

CONCLUSION

Generally, we can conclude that land use and precipitation influence water quality along this river catchment. Monitoring of point and non point sources is one of the effective ways to control the water quality and biodiversity of this catchment.

The vegetation in the river corridor as well as macrophytes and floating aquatic plants in the littoral zones could have filtered the nutrient and sediment flowing from upstream. This maintained a good water quality of the water entering the lake ecosystem. A reduction of almost 80% and 90% was observed for nitrogen and phosphorus respectively at Tasoh, and a further reduction from Tasoh to the reservoir. Sedimentation and nutrient uptake by plant along the river corridor and in the littoral zones is the most probable cause for the reduction in nutrient contents and helps maintain good water quality of the reservoir.

In lake management, we should integrate knowledge acquired from different fields of science such as hydrology and ecology. Further linkages between academic disciplines as well as between universities (national or international) should be encouraged. This collaboration enables more exchanges of ideas. This could be done through student exchange programmes that will later benefit the country and contribute to nation building.

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