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Impacts of Land Use on Water and Sediment Quality of Sampadi River, Malaysia

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Abstract: Aquaculture is an important industry in Malaysia due to water availability. Recent commercial crop development in the Sampadi River watershed may have an impact on the water quality of the river. Therefore a study was conducted to determine the water and sediment status of selected stations along that river. Results showed that oxygen demand, nitrogen and phosphorus in the water at all stations were higher at low tide than at high tide except reactive phosphorus at the station near shrimp culture. The station near oil palm plantation showed the lowest pH and DO, the highest TKN and RP and the second highest in COD in the water and the highest in TOC, TKN and TP in the sediment. The station near shrimp farming showed the highest COD, second highest TKN and the highest high tide water reactive phosphorus. In addition, sediment copper and TKN was the highest and second highest among the stations. The station that was near the residential area was the highest in low tide reactive phosphorus and the second highest in BOD_5, the highest in sediment lead and cadmium.

Key words: Oil palm · Sediment · Nutrients · Trace metals · Water quality

INTRODUCTION

Due to the growing demand of animal protein in the world and the inability of capture fisheries to provide the needed fisheries products, most of the increase in demand has to be met by aquaculture [1]. Since both natural aquatic organism and aquaculture require unpolluted water, river water has to be conserved for the production of aquatic animals. The Sampadi River, situated 62 km away from the city of Kuching is a good site for aquaculture as there was no urban development in the watershed. However, in recent years, there were some new agriculture activities such as oil palm crop cultivation in the watershed in addition to shrimp aquaculture and villages.

Different activities in the watershed have different impacts on the receiving water [2] and sediment [3]. Oil palm cultivation has expanded greatly in tropical countries such as Malaysia in recent years to meet the demand of biofuel which is seen as a green solution to fossil fuel and also the looming depletion fossil fuel reserve. In addition, oil from palm is considered a cheaper oil to produce and the yield of oil palm is also higher as compared to other oil crops used as biodiesel [4]. Malaysia currently accounts for 39 % of world palm oil production and 44% of world exports [5]. As land became scarce in Peninsular Malaysia, expansion shifted to Sarawak and Sabah [6]. However, oil palm agriculture and palm oil processing has the potential to pollute surface water through fertilizer runoff [7] and palm oil mill effluent [8]. Palm oil mill effluent is high in organic matter and nutrients such as nitrogen and phosphorus [9, 10]. Wastewater discharged from residential areas has also been found to affect the quality of surface water as household wastewater is high in organic matter and also nutrients [11-13]. In view of these, the objective of this study was to determine the water and sediment quality of selected stations in the Sampadi River.

MATERIALS AND METHODS

Study Site and Sampling: Five stations based on land use activities were selected on Sampadi River in Lundu district for this study (Fig. 1). The stations were near jetty (1), shrimp farm (2), Langir Village (3), oil palm processing plant (4) and oil palm plantation (5). Samplings trips were

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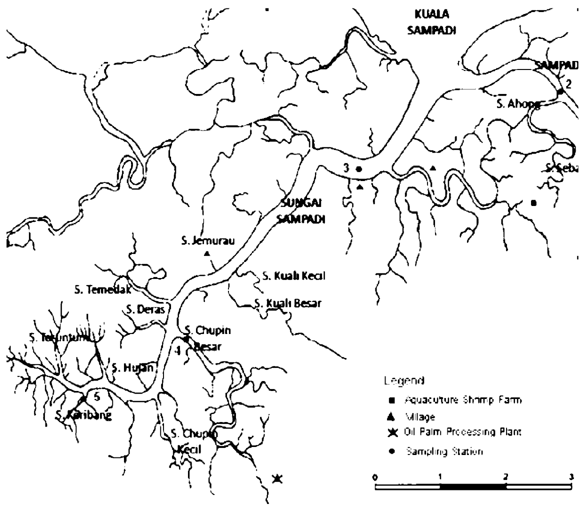

Fig. 1: The location of the five sampling stations and human activities in the watershed.

conducted between October 2009 and March 2010. *In situ* parameters were measured using a Multi-Parameter Water Quality Surveyor (Horiba U20XD). Triplicate grab samples of river water were collected using 2L polyethylene bottles during low tide and high tide for nutrients analysis. Surface sediment samples were collected during low tide and placed in polyethylene bag. All samples were stored in a cooler box at 4°C before being transported to the laboratory for analysis.

Laboratory Analysis: Parameters analyzed from the water samples included biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), reactive phosphorus (RP) and total Kjeldahl nitrogen (TKN) and trace metals (Zn, Cu, Ni, Pb, Cr and Cd). BOD_5 analysis was performed according to [14]. COD was analyzed using Reactor Digestion method of Hach [15] and RP was analyzed using the Ascorbic Acid method and the concentration determined with a spectrophotometer (Hach DR/4000) [15]. Sediment samples were air-dried for two weeks prior to analysis. Loss-on-ignition method was used to determine organic matter content of the sediment and the TOC content was taken to be 58% of the organic matter content [16]. TP analysis followed that of Kuo [17] where the sediment was digested using perchloric acid method and subsequently and the resulting digest was neutralized using NaOH and the concentration determined by ascorbic acid method [15]. TKN analysis of sediment samples followed that of Nesslers method of Hach [15]. For heavy metals sediment was digested using concentrated nitric acid and hydrochloric acid Amacher [18] and the digest was analyzed by using a Flame Atomic Absorption Spectrometer (Thermo Scientific iCE3500). All samples were analyzed in triplicates.

Statistical Analysis: Data were analyzed using two-way ANOVA. Tukey's multiple comparisons method was also conducted to test for significant difference between all pairs of stations. All statistical analysis was conducted using SPSS version 17.0.

RESULTS AND DISCUSSION

Results of *in situ* parameters are shown in Table 1. The stations temperature ranged from 28.39 to 30.17°C with station 2 showing the highest temperature. Station 2 also showed the highest mean pH value, though not significantly different from stations 1 and 4 (P=0.999 and 0.057 respectively). The mean value of DO was the highest at station 1 and the lowest in station 5. The lowest and second lowest DO values were near oil palm industry and they are not significantly different from shrimp farming area (P=0.107).

BOD_5 values of the stations are shown in Table 2. The values ranged between 10.1 and 11.1 mg/L during low tide and though station 4 showed the highest value, there was no significant difference among the stations (P=0.274). However, during high tide, station 4 which showed the highest value was significantly higher when compared to station 1 and 5 (P=0.001 and 0.048 respectively). Overall, all stations showed lower concentrations during high tide than low tide. Mean BOD_5 values at all stations exceeded the value for unpolluted water (2 mg/L) and the values exceeded the European Union's standard for fisheries and aquatic life (6.0 mg/L)

Table 1: Mean values of temperature, pH and DO in the water of the five sampling stations

St	Temperature (°C)	pH	DO (mg/L)
1	28.75±1.58^{a}	7.47±0.39^{a}	6.39±2.49^{a}
2	30.17±0.85^{b}	7.49±0.17^{a}	5.47±1.50^{ab}
3	28.69±1.59^{a}	7.27±0.09^{b}	5.89±1.72^{a}
4	28.86±1.31^{a}	7.29±0.15^{ab}	5.37±0.86^{ab}
5	28.39±1.26^{a}	7.15±0.22^{b}	4.57±0.81^{b}

*Means within a column followed by the same letter are not significantly different at 5% level.

Table 2: Mean values of BOD_5, COD, TKN and TP in the water of the five sampling stations

	BOD_5 (mg/L)		COD (mg/L)		TKN (mg/L)		RP (mg/L)	
St	LT	HT	LT	HT	LT	HT	LT	HT
1	10.5±0.7^{a*}	8.2±0.5^{a}	38.3±1.9^{a}	33.2±5.2^{a}	1.3±0.1^{a}	0.9±0.3^{a}	0.064±0.005^{b}	0.028±0.020^{ab}
2	10.1±1.1^{a}	9.6±0.6^{bc}	44.5±1.2^{b}	36.3±8.8^{ac}	4.2±0.3^{b}	3.6±0.7^{b}	0.027±0.027^{a}	0.034±0.005^{b}
3	10.9±1.5^{a}	10.0±0.8^{bc}	28.5±5.9^{c}	26.8±6.0^{b}	2.7±0.8^{c}	2.2±0.5^{c}	0.084±0.039^{bc}	0.015±0.007^{cd}
4	11.1±1.4^{a}	10.4±0.4^{c}	42.4±4.6^{b}	36.4±6.2^{ac}	3.3±0.7^{d}	2.9±0.3^{bc}	0.074±0.008^{b}	0.020±0.006^{ad}
5	10.7±0.5^{a}	8.9±1.3^{ab}	43.6±3.6^{b}	37.9±7.6^{c}	12.2±0.7^{e}	10.1±2.1^{d}	0.104±0.119^{c}	0.007±0.002^{c}

*Means within a column followed by the same letter are not significantly different at 5% level. LT: Low tide; HT: High tide.

Table 3: Mean values of nutrients and trace metals in the sediment of the five sampling stations

	Mean concentration							
St	TOC (%)	TKN (mg/kg)	TP (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Cr (mg/kg)	Pb (mg/kg)	Cd (mg/kg)
1	3.7±1.0^{a}	68.9±11.6^{a}	132.3±1.9^{a}	26.2±2.4^{a}	29.2±9.6^{a}	16.6±2.7^{a}	21.4±2.0^{a}	0.66±0.05^{a}
2	6.3±0.5^{b}	175.5±17.9^{b}	105.5±10.4^{b}	12.1±0.7^{b}	29.6±6.2^{a}	26.2±5.3^{b}	18.8±1.3^{b}	0.48±0.09^{b}
3	4.8±0.3^{a}	108.5±16.8^{c}	189.2±7.9^{c}	22.9±1.3^{c}	21.1±2.2^{b}	19.5±4.1^{c}	11.8±1.4^{c}	0.17±0.01^{c}
4	7.4±1.4^{b}	133.2±24.4^{c}	230.5±5.9^{d}	13.6±2.1^{b}	24.4±4.4^{b}	34.1±1.3^{d}	14.2±1.4^{d}	0.05±0.02^{d}
5	8.9±1.6^{c}	567.4±36.8^{d}	245.1±6.8^{e}	2.3±0.2^{d}	24.5±1.2^{b}	29.8±3.5^{e}	17.8±1.5^{b}	0.06±0.01^{d}

*Means within a column followed by the same letter are not significantly different at 5% level.

[19]. Ling *et al.* [12] also reported that stations near residential areas showed the highest BOD_5 (8.5-11.7 mg/L) among the 10 stations studied in Santubong River. Previous studies on shrimp farm pond water showed that discharged at harvest was high in BOD_5 (7-34 mg/L) [20].

During low tide, COD ranged from 28.5 mg/L at station 3 to 44.5 mg/L at station 2. COD of station 2, 4 and 5 were all high and were not significantly different (P=0.398) but were significantly higher than those from station 1 and 3 (P=0.028). During high tide, all values were lower than during low tide and stations 2, 4 and 5 showed higher COD values when compared to stations 1 and 3 with station 3 showing significantly lower value compared to all other stations (P<0.0005). The high values of COD near oil palm plantation and processing mill was likely due to the runoff from the plantation which may have originated from the waste from plantation settlement and palm oil mill effluent (POME). It has been reported that POME was high in COD with the range of 15,000-100,000 mg/L. COD of shrimp farm harvest discharge was reported to be about 150 mg/L [22]. This likely explained the high COD near shrimp farm discharge.

TKN ranged from 1.3-12.2 mg/L during low tide and were higher than high tide concentrations at all stations (0.9-10.1 mg/L). In both tide levels, station 5 showed the highest value followed by station 2 and subsequently station 4. Fertilizers and waste from oil palm plantation likely contributed to the high TKN observed at station 5. During both tide levels, station 2, which was near the shrimp farm showed significantly higher concentrations than station 1 (P<0.0005), the station upstream of it, indicating the contribution of TKN by the shrimp farm. According to Thakur and Lin [23] (2003), shrimp have low assimilative capacity and only 23-31% of total input nitrogen was taken up by the shrimp which means that the rest was lost in pond water and sediment. Shrimp farm pond water at harvest was found to have high total nitrogen (8.5 mg/L) [22] and ammoniacal nitrogen (1.3-2.7 mg/L) [20, 22].

During low tide, RP was found to be the highest at station 5 followed by station 3, 4 and 1 and the lowest was at station 2. However, during high tide station 2 showed the highest value. Runoff from the oil palm plantation may have contributed to the high concentrations of RP at station 4 and 5. For station 1 and 3, being near to settlement, household phosphorus from laundry and septic tank discharge might have given rise to the high phosphorus in those stations. During high tide the high RP at station 2 was higher than low tide likely due to the discharge of shrimp pond water during high tide. It has been reported that shrimp assimilate only 10-13% of the total input phosphorus [23] and thus the rest were lost in water or sediment. During harvesting, RP in shrimp farm discharge were reported to range from 0.05-0.18 mg/L depending on stocking density [20].

Table 3 shows sediment carbon, nutrients and heavy metals. Sediment organic carbon was the highest at station 5 followed by 4 and 2. Stations 1 and 3 showed the lowest organic carbon. This is likely due to the positive effect of partial sewage treatment in septic tanks. TOC of two stations in the present study were lower than those reported by Ling *et al.* [24] in Semariang Batu River (6.1-15.3%). TKN in the sediment showed the trend of stations 5>2>4>3>2. Station 5 also showed the highest sediment TP followed by station 4 and 3. TP at all stations were significantly different ($P \leq 0.004$).

For heavy metals (Table 3), Zn was the highest near the jetty station. Cu was the highest at station 2 and was not significantly different between stations 1 and 2. Leaching of Zn and Cu from galvanized steel or copper pumping fixtures, pipes and roofing materials at the village near the jetty may have contributed to the high Zn and Cu in sediment of Station 1 [25]. Compounds of Cu have been used to eliminate protozoans and bacterial diseases, inhibit phytoplankton growth and to induce molting in shrimps [26, 27]. In addition, Cu, Zn and Cd were found in prawn feed and prawn pond sludge [28]. In shrimp pond sludge, concentrations of Zn, Cu and Cd ranged from 51-92 mg/kg, 14-36 mg/kg and 1.1-3.7 mg/kg dw respectively. Lacerda *et al.* [29] 2009 reported that Cu export from shrimp farms to the adjacent environments is significant and occurs mostly as particulate Cu due to the flowing out of surface sediment layers during pond draining. These explain the high metals in sediment near shrimp farm effluent. Pb was found to be highest near jetty and elevated near shrimp farm discharge and oil palm plantation. This is likely due to the fuel used in boat near the jetty and land vehicles used in oil palm plantation. Mendiguchia *et al.* [30] also reported elevated metals, Cu (~12-28 mg/kg), Zn (41-92 mg/kg) and Pb (~13-20 mg/kg) concentrations in the sediment downstream of fish aquaculture. Cr was the highest at station 4 and second highest at station 5 near oil palm mill and plantation. Fertilizer is also one of the contributors to the heavy metals as they contain trace elements. Ajiwe *et al.* [31] reported that purified palm oil contained 276 mg/kg Zn, 22 mg/kg Cu, 153 mg/kg Cr and 23 mg/kg Pb. In the palm oil mill effluent [9, 10 cited in 8], it was reported that Cu and Zn were 0.89 and 2.3 mg/L respectively. In addition, BOD, COD, total nitrogen and phosphorus were reported to be 25,000 mg/L, 50,000 mg/L, 750 mg/L and 180 mg/L respectively. In oil palm plantation, the change of vegetation to oil palm often leads to soil erosion resulting in the deposition of sediment in the nearby stream bottom. Trace metals and nutrients which are often associated with organic matter and fine particles [24] are transported to the surface water as a result. This explains the high BOD_5, COD, TKN and RP in water and TOC, TKN and RP in sediment of the stations near oil palm area. Comparing the concentrations of trace metals in the sediment with USEPA guideline classification [32], the location is slightly polluted with Cu at stations 1 and 2 where the values exceeded 25 mg/kg. The sediment from all the stations was not polluted in Zn, Pb and Cd.

CONCLUSIONS

Different industries have their impact in the water and sediment. The station near oil palm plantation showed significantly higher TKN in water and sediment and TOC and TP in sediment compared with other stations. High concentrations of trace metals were found near the jetty station. Near shrimp farming area, the water showed the highest reactive phosphorus in high tide the highest Cu in sediment.

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