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WATER QUALITY AND CHEMICAL MASS BALANCE OF TROPICAL FRESHWATER WETLANDS, BERIAH SWAMP, PERAK

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Abstract. A chemical mass balance study was conducted in Beriah swamps, a tropical fresh water swamp in north Perak, Malaysia from June to October 1998, aimed at investigating the role and function of wetlands in filtering sediment and retaining sediment and/or nutrient. The flux of nutrient and sediment from two input streams (Beriah Kanan and Beriah Kiri) were compared with the output (Beriah). A fortnightly and an intensive hourly sampling on the 10-11th October 1998 for 48 hours, during high water conditions were carried out. Results showed no significant difference ($p>0.05$) in concentrations of almost all parameters except for SRP between two input rivers, but were significant different ($p<0.05$) between inputs and output during the fortnightly sampling. A very marked difference was observed during the intensive sampling, indicating an increase in phosphate concentration coming from the swamp. Generally, nutrients and suspended sediment are trapped in the swamp, showing the efficient role of the wetland as a nutrient and sediment trap. Based on this limited sampling, the retentions for nitrate, phosphate, TSS and TDS were 81, 58, 23 and 42%, respectively.

Keywords: Chemical mass balance, nutrient retention, tropical freshwater swamp, Beriah, Perak

Abstrak. Satu kajian imbangan jisim kimia dijalankan di kawasan paya Beriah, iaitu paya air tawar di utara Perak bermula dari bulan Jun hingga Oktober 1998. Kajian ini bertujuan untuk mengkaji peranan dan fungsi tanah bencah dalam menjalankan penurasan endapan dan mengekalkan endapan dan/atau nutrien. Fluks nutrien dan endapan dari dua input sungai (Beriah Kanan dan Beriah Kiri) dibandingkan dengan sebatang sungai output (Beriah) yang keluar dari sistem paya tersebut. Pensampelan dilakukan setiap dua minggu ditambah dengan satu kajian intensif melibatkan pensampelan selama 48 jam semasa musim basah pada 10-11 Oktober 1998. Keputusan menunjukkan tiada perbezaan yang signifikan ($p>0.05$) dalam kepekatan semua parameter kecuali SRP antara kedua-dua input. Namun perbezaan yang siginifikan ($p<0.05$) jelas antara input dengan output semasa pensampelan setiap dua minggu. Satu perbezaan ketara jelas dilihat semasa pensampelan intensif yang menunjukkan pertambahan dalam kepekatan fosfat dari kawasan paya. Pada amnya, nutrien dan ampaian terampai terperangkap di dalam paya mempamerkan peranan paya yang berkesan dalam memerangkap endapan dan nutrien. Berdasarkan pensampelan yang terhad ini, peratusan nutrien yang terperangkap bagi nitrat, fosfat, TSS dan TDS masing-masing adalah sebanyak 81%, 58%, 23%, 42%.

Kata kunci: Imbangan jisim kimia, perangkap nutrien, paya air tawar tropika, Beriah, Perak

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1.0 INTRODUCTION

Wetlands are called an “in between world” – between upland terrestrial ecosystem and deep-water aquatic systems [1]. Accordingly, they have characteristics of both systems. One of the major differences between wetlands and drier upland ecosystems is that, in the former, more nutrients are tied up in organic deposits and are lost from ecosystem cycling as peat deposits or organic exports. Wetlands are similar to deep aquatic systems in that most of the nutrients are often permanently tied up in sediment and peat. However, wetlands usually involved larger biotic storages of nutrients than deep aquatic systems which are predominantly plankton dominated [1].

Wetlands are generally characterized by alternating wet and dry phases (flood/flood recession or high water/low water). During recession of the water, the soil is aerated and, consequently, rapid decomposition of the organic matter and the release of mineral elements and soluble organic compounds derived from the wetlands [2, 3]. One of the most useful functions of wetlands is in regulating nutrient.

Nutrients can be stored in wetlands but retention efficiency depends on the internal mechanisms operating within the wetlands [4]. Nutrient export is another function of wetlands that allows them to supply other ecosystems downstream, with mineral elements and organic compounds.

In general, wetland accumulates nutrients during the plant growth season and then transforms and finally exports a percentage of them during the high water season [5]. When the water rises in some swamps, the dead vegetation undergoes rapid leaching and decomposition. In seasonally flooded wetlands, floodwater dissolves and carries off large quantities of nutrients during the first phase of flooding [6]. Tropical lakes bordered with papyrus swamps receive a large proportion of the susbstances accumulated by the swamp vegetation and the water flowing across the swamp discharges these substances to other adjacent water bodies [7]. Nutrient exported in this way enriches adjacent or downstream ecosystems and constitutes an essential source of food for organisms [8].

While it is not disputed that wetlands play an important role in nutrient retention [1], there is little work which quantifies the nutrient loading to and from humid equatorial wetlands. Many studies cited in the literature are from the USA and other western countries [1,9] and very little work has been done in Asia, and especially in Malaysia.

This study was conducted to investigate the ability of tropical wetlands to retain water and nutrients and to purify water where inputs to outputs from the swamp areas were monitored. This paper reports preliminary findings of the physico-chemical and an initial attempt on nutrient budget of that study based on limited sampling programme.

2.0 STUDY AREA

The study area is in the Beriah catchment system that stems out from Samagagah River along the Kerian River (Figure 1). Beriah Swamp, located within 100° 36'E – 100° 40'E and 5°3'N – 5°7'E is a lowland tropical black water swamp. The highest elevation at the uppermost part of the Beriah Kiri River is 30.9 m.a.s.l. The swamp is an integral part of the Kerian River system. Water flow in the swamps is stable and provides income to the local people through its abundant resources of fish [10, 11]. The water that feeds into the swamp is dark-coloured water rich in humic acids resulting from the decomposition of organic material.

The Beriah Swamp itself is a 55.0 km^2 wetland bordered by dykes, road systems and a railway track (Figure 1). The swamp receives inputs from two main Beriah river tributaries, namely the Beriah Kiri River (BL) and Beriah Kanan River (BR). The drainage area of the Beriah Kanan (BR) is 9.7 km^2 whereas the Beriah Kiri (BL) is 19.6 km^2. Thus the total area of Beriah River and the wetland system is 84.3 km^2.

2.1 Land Use and Topography

Land use in the Beriah Swamp consists mainly of swamp grasses (c.a. 80%) that thrive in the wet conditions with some encroachment by settlement and smaller areas of rubber and oil palms. The settlement pattern is linear, located along the roads which encircle the swamp (Figure 1). The Beriah Kiri and Beriah Kanan flow through bushes and grasses, rubber and oil palm estates, wet paddy, sundry non-tree cultivation, and forest before entering the swamps through the Beriah Kiri and Beriah Kanan, respectively.

2.2 Rainfall for the Area

Based on rainfall records, from 1951 to 1990 [12], of five meteorological stations surrounding the swamps (Table 1), the mean annual rainfall upstream of the swamp

Table 1 Rainfall stations around Beriah swamp showing locations, records length and mean annual rainfall + S.D.

Station	Latitude; Longitude	Records length	Mean annual rainfall (mm) + S.D.
Ladang Sg. Kerian, Parit Buntar	5°4'N, 100°34'E	1953-90	2377.2 + 742.4
Bukit Merah	5°2'N, 100°39'E	1953-90	2807.2 + 343.6
Ladang Pondoland, Pondok Tanjung	5°00'N; 100°43'E	1951-90	2975.3 + 697.1
Ladang Hibernia, Selama	5°8'N; 100°41'E	1951-90	3301.4 +397.6
Ladang Lumboh Keluang, Selama	5°9'N; 100°39'E	1951-90	2904.8 + 349.4

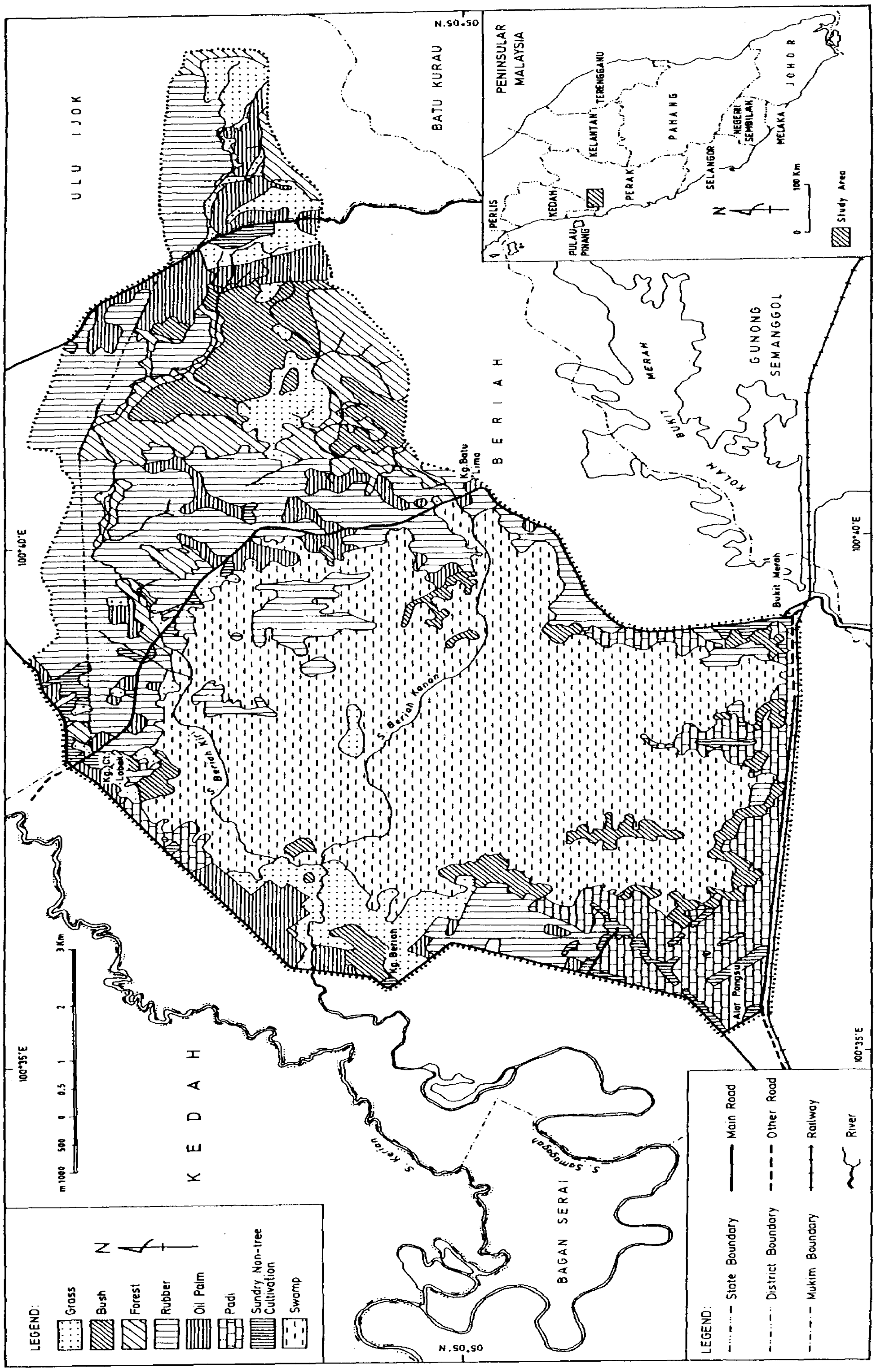

Figure 1 The study area showing land use pattern in the catchment area

is greater than 2800 mm. A higher mean annual rainfall of 3301.4 mm was recorded at Ladang Hibernia, Selama, while a lower mean annual rainfall of 2377.2 mm was recorded at the downstream station at Ladang Sg. Kerian.

The mean monthly rainfall for the area is shown in Figure 2. Generally, the rainfall of the area is typical of Peninsular Malaysia, having a double annual peak maxima, in April and October. The area received monthly rainfall greater than 100 mm in dry months such as January and June, which ensured the swamps were continually watered.

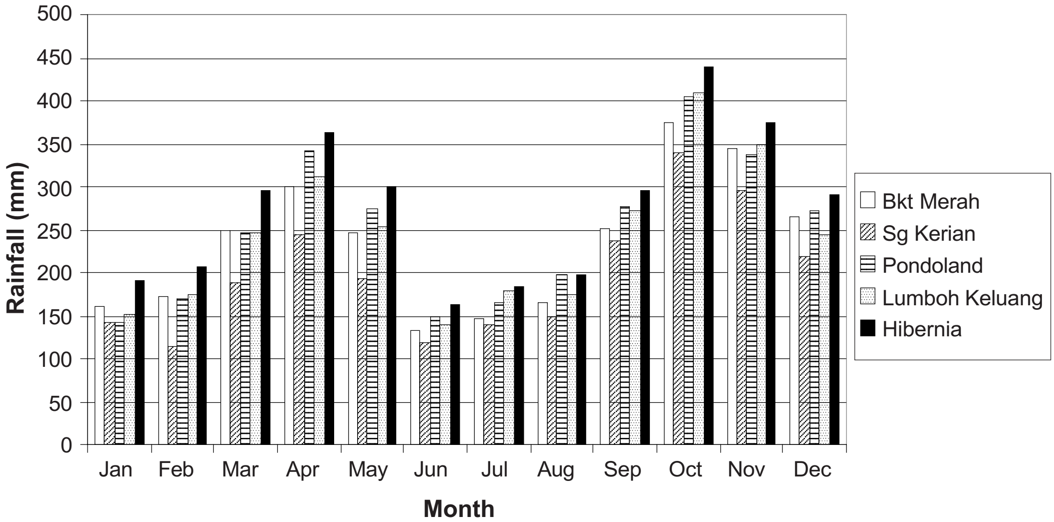

Figure 2 Mean monthly rainfall at 5 rainfall stations around the catchment area

3.0 MATERIAL AND METHODS

Three sampling sites (BR, BL and B) were maintained for this study (Figures 3 and 4). The water inputs from the upper section of the tributaries were monitored at sites BR and BL respectively, while the output from the whole system was monitored at Beriah river (B) (Figures 3 and 4). Water quality, river cross-section and flow measurements were carried out every fortnight at all sites for 11 sampling dates, from June 6 to October 24, 1998. Water samples from both the upstream and downstream sampling sites were collected at three points across the width of the river transect. Three replicates were collected at each point. Water quality parameters such as pH, conductivity, dissolved oxygen (DO), temperature and total dissolved solids (TDS) were measured *in situ*. pH was measured using an ORION Digi-sense digital pH meter model 230A; DO and temperature were measured using an oxygen meter YSI- model 57, while Hach conductivity/TDS meter model 44600 was used to measure conductivity and TDS. Other parameters such as alkalinity, nitrate, nitrite, ammoniacal nitrogen, soluble

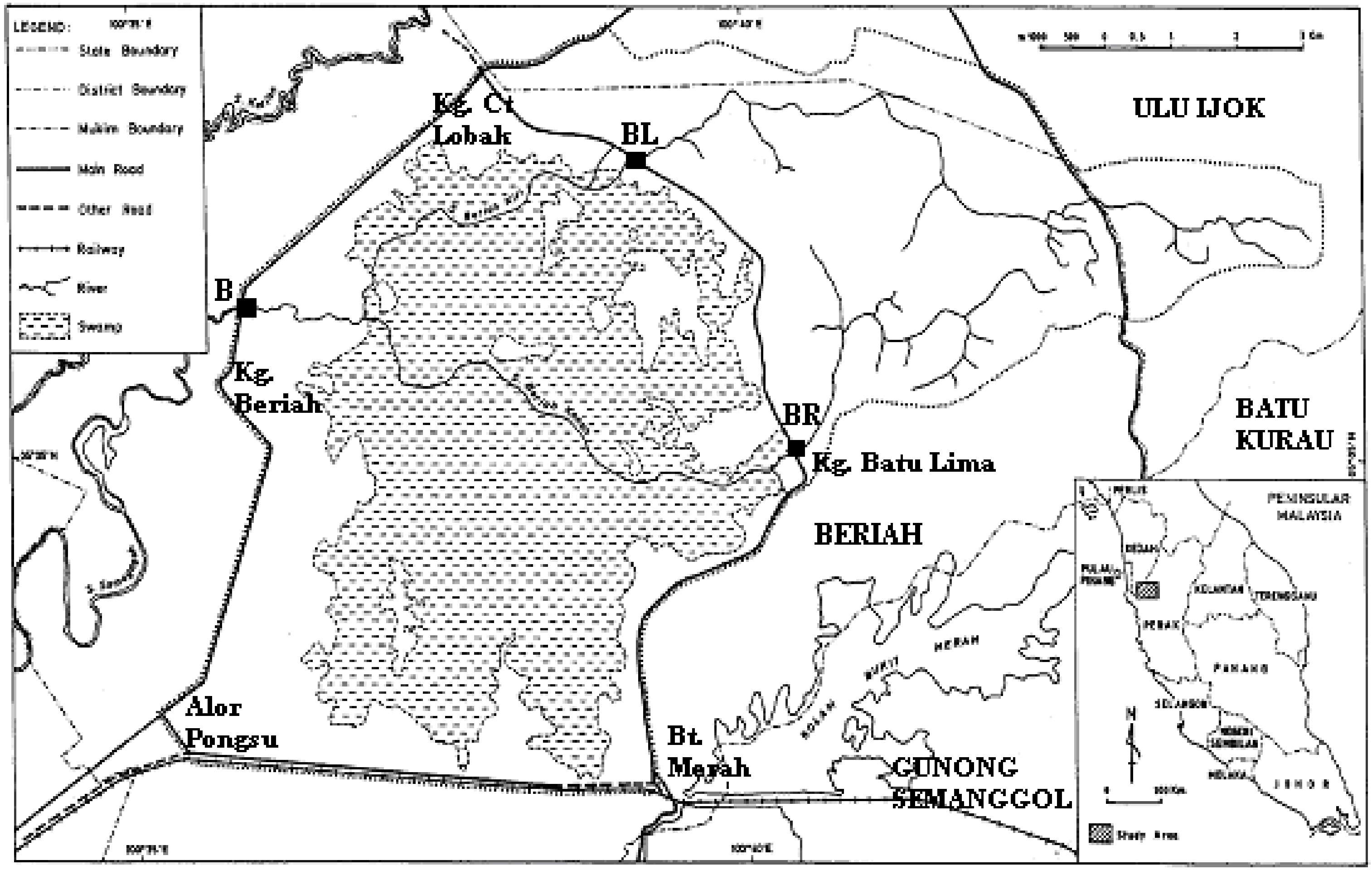

Figure 3 Study sites showing the gauging stations in bold rectangle

a) Sungai Beriah Kanan (BR)

b) Sungai Beriah Kiri (BL)

c) Sungai Beriah (B)

Figure 4 Study sites mentioned in Figure 3 reactive phosphorus (SRP) and suspended solids were determined in the laboratory using the standard method [13].

River flow was measured using a propeller type "Owen and Boyd" current meter and discharge was calculated using a velocity–area method [14, 15]. Rainfall was recorded in an open space near BL (Figure 3). Measurements were conducted fortnightly from May through October 1998 with varying water discharge and rainfall conditions. An additional intensive hourly sampling programme was undertaken in the wet October month 1998, from the 5th (1900 h) to 7th (1600h), totaling up to almost 48 hours.

The collected data was analyzed to find any significant difference within the station studied and sampling time. Any significant difference that was found using ANOVA test ($p<0.05$) was further analyzed with Fisher's PLSD to specify the differences using Statview Programme.

4.0 RESULTS

4.1 Physical Parameters

a) Discharge

The average fortnightly rainfall was 110 mm ranging from about 100 mm to a maximum of about 300 mm (Figure 5). River discharge, varied from station to station and was related to rainfall input. The average discharge at Beriah River was 4.32 $m^3 s^{-1}$; 2.31 $m^3 s^{-1}$ for Beriah Kiri (BL) and 1.26 $m^3 s^{-1}$ for Beriah Kanan (BR).

Some fluctuations were observed in September 1998. Among the three sites, the lowest discharge was recorded at Beriah Kanan (BR) River. This river is a small tributary and has the smallest catchment area of the three catchments.

During the intensive 48-hour sampling in October 1998, discharge was rising when sampling started at 1900 on the 5th of October (Figure 6A). Discharges at BR and BL were low, starting at about 1 $m^3 s^{-1}$ and rising to about 2 $m^3 s^{-1}$ at noon on the 6th. Due to continuous rain, the water discharge then rose up to 5 $m^3 s^{-1}$ and 3 $m^3 s^{-1}$ at BL and BR, respectively. Discharge at BR was constantly maintained at about 3 $m^3 s^{-1}$ until the end of the sampling, whereas at BL it continued to rise to about 6 $m^3 s^{-11}$ at midnight on the 7th, declining to 4 $m^3 s^{-1}$ at 2 a.m. and peaked again at 6.5 $m^3 s^{-1}$ at 1100 h on the 7th. At outlet B, discharge rose at the start of sampling from 3.5 $m^3 s^{-1}$ to a maximum of 8 $m^3 s^{-1}$ and declined to about 5 $m^3 s^{-1}$ and finally continued falling to about 3.5 $m^3 s^{-1}$.

The aim of the intensive study was to investigate the pattern of the rising and falling hydrographs. However, the rising limbs of the river inputs were slow, at BR it took about 48 hour to rise and 42 hours at BL. The rising hydrograph at the outlet was about 24 hours. The slow rising and falling hydrograph shows how wetland ecosystems resist flow, thus slowing down the water flow in spite of a faster water release at outlet (B).

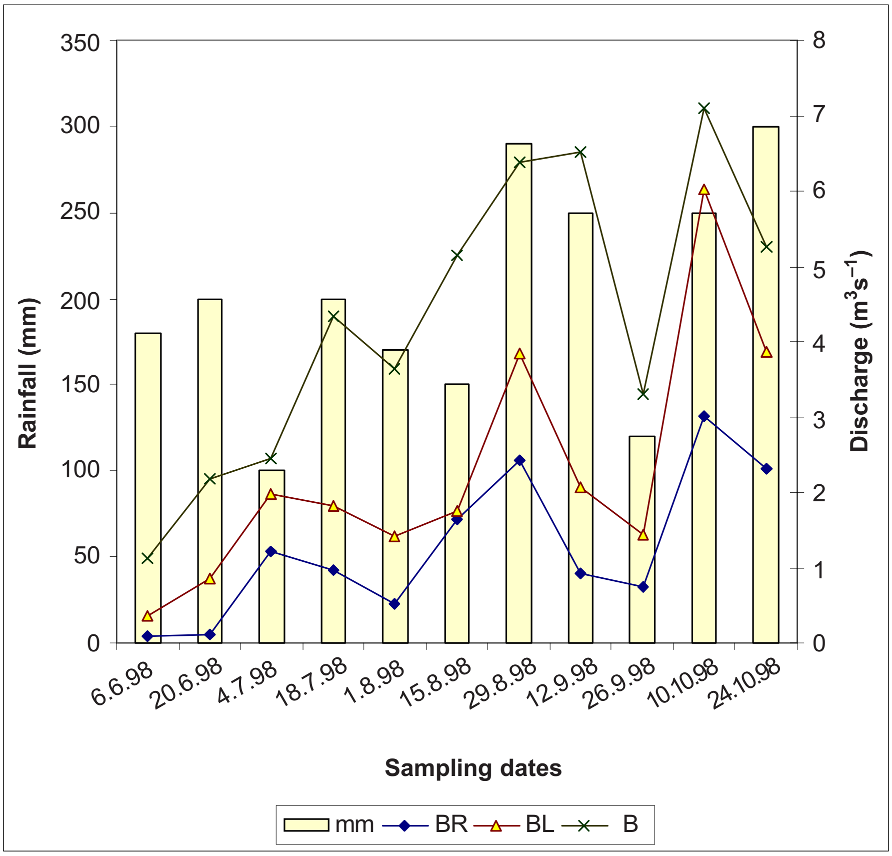

Figure 5 Fortnightly variations of rainfall and discharge during the study period

b) Temperature

The water quality varied from month to month during the study period. The mean water temperature was lower at the input sites, which are surrounded with riparian vegetation that shaded the river from direct insolation. The average temperature at BL was 26.7°C and ranged from 25.5°C to 28.4°C. A slightly higher temperature was observed during the study period at BR with an average of 26.9°C (range 26.0 – 28.6°C), but a much higher temperature (mean = 27.8°C) was observed at outlet B (range 26.1 to 29.2°C) (Table 2). A quite similar situation was observed during intensive sampling whereby higher temperature was observed at outlet B compared to the inlets, and temperatures were higher at BL than BR (Figure 6B).

c) pH

The mean biweekly pH were 4.77 ± 0.33 and 4.87 ± 0.37 at BR and BL, respectively, while a higher acidity of 4.29 ± 0.34 was observed at outlet (B). This is a characteristic of acidic swamp water. There was a statistically significant difference ($p<0.05$) in pH between the intensive and biweekly samples for all stations. pH was slightly higher at

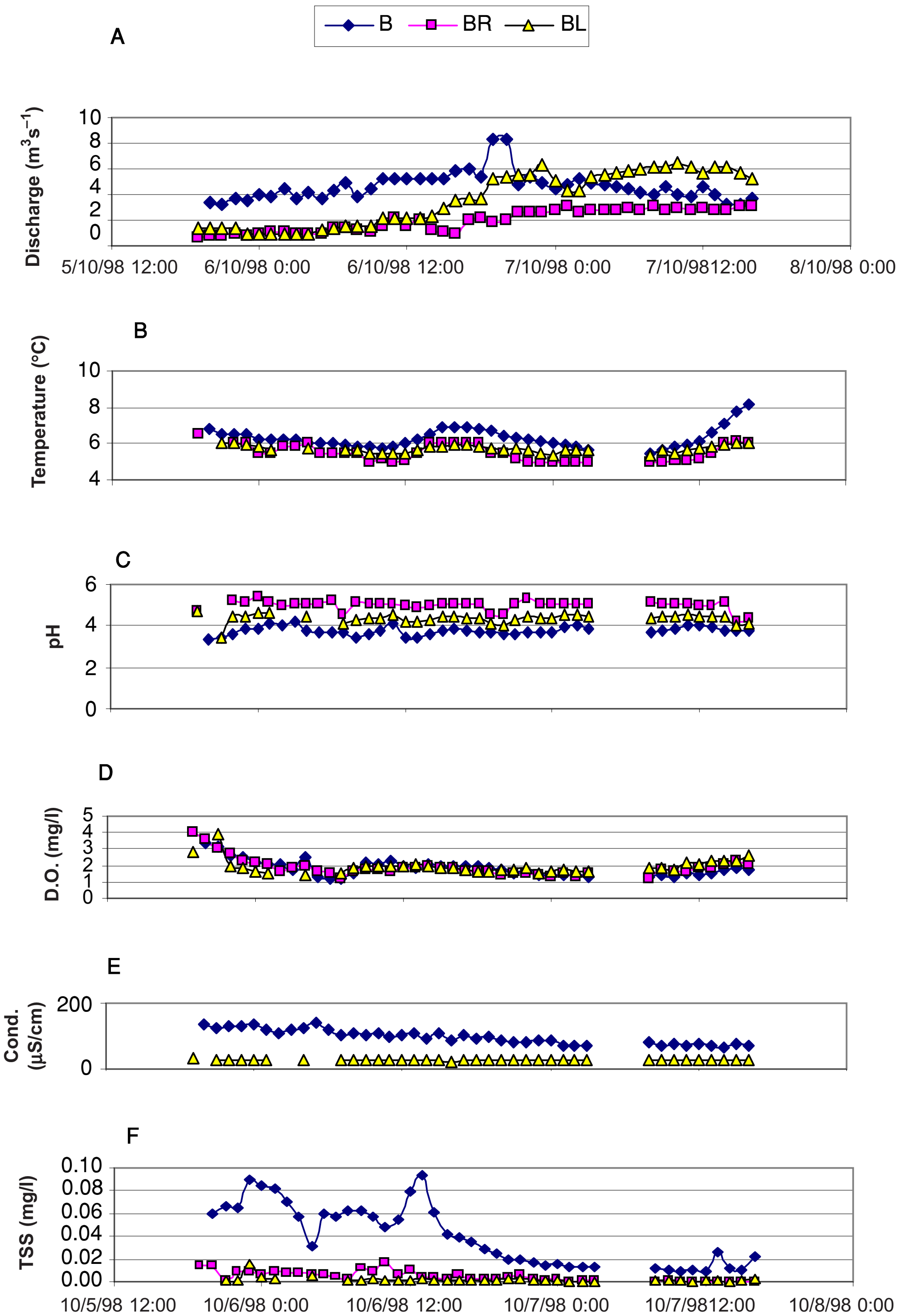

Figure 6 Physical parameters during intensive 48-hours sampling

BR than that at BL (Table 2). The pH during intensive sampling was slightly acidic at the outlet (3.76 ± 0.2) but less acidic at the inlet with values of 4.99 ± 0.3 at BR and 5.16 ± 0.09 at BL (Table 2). Generally, pH at BR is higher than BL and B and stays almost constant with slight variations from time to time during the intensive sampling (Figure 6C).

d) Dissolved oxygen

There was a significant difference ($p<0.05$) in dissolved oxygen (D.O) between biweekly and the intensive sampling and between inlets and outlets station. However, there was no significant difference ($p>0.05$) between the inlets of BL and BR. The readings were slightly lower during the intensive sampling periods (Table 2, Figure 6D). Higher DO (mean = 1.21 mg l^{-1}) was observed at outlet B, compared to inlets at BR (mean = 2.14 mg l^{-1}) and BL (mean = 2.11 mg l^{-1}).

Dissolved oxygen fall gradually at the start of sampling from 4 mg l^{-1} to 1.5 mg l^{-1} and increased at the end of the sampling programme in the wet season. The values for intensive sampling were higher at the start of sampling (3 mg l^{-1}), falling to nearly 1 mg l^{-1} in the morning of the 6th, peaked again at noon and fell again in the morning of the 7th, and rose to about 2 mg l^{-1} when sampling was completed.

e) Conductivity and total dissolved solids (TDS)

There was no significant difference ($p>0.05$) in conductivity between the inlet waters at BR and BL. However, the conductivity was higher at the outlet than at BR and BL (range: 45.48 - 140 µS cm^{-1}) which was double during the biweekly sampling and 4 to 5 times higher during the intensive survey. The same situation was also observed for total dissolved solids (TDS)(Table 2). Conductivity was higher at the outlet (B) compared to the inlet by as much as 6 times at the beginning of sampling, and decreased to about 3 times at the end of sampling. The average TDS concentration at BR was 14.8 ± 7.4 mg l^{-1} and 15.1 ± 7.4 mg l^{-1} at BL during the fortnightly sampling. A slightly lower mean concentration (12.2 mg l^{-1} ± 0.93) was observed at BL during intensive sampling but was not significantly different ($p>0.05$) from BR. TDS were higher at the outlet (B) by as much as 2 times the input (Table 2).

f) Total suspended solids (TSS)

The TSS was low in these waters, especially at the inlets. No significant difference ($p>0.05$) in TSS was observed between biweekly and intensive sampling at the inlets of BR and BL (Table 2, Figure 6F). However, there was a statistically significant different ($p<0.05$) at the outlet between the fortnightly and the intensive sampling, and was also higher at the outlet (2-6 times) than the input values. TSS was below 0.02 mg l^{-1} throughout the intensive sampling period at BR and BL. At the outlet, TSS were always higher ranging from just above 0.01 mg l^{-1} and reaching 0.09 mg l^{-1} at noon on the 6.10.98. There was a slight increase in TSS in the swamp.

Table 2 Mean and standard deviation of fornightly water quality parameters (n=11) and an intensive sampling (n=48) at Beriah Kanan river, Beriah Kiri river and Beriah river

Parameter	Beriah Kanan (BR)		Beriah Kiri (BL)		Beriah (B)	
	Fortnightly	**Intensive**	**Fortnightly**	**Intensive**	**Fortnightly**	**Intensive**
Discharge, Q (m^3 s^{-1})	1.27 + 0.97	1.95 + 0.85	2.27 + 1.69	3.64 + 2.06	4.32 + 1.95	4.63 + 1.08
Temperature (°C)	26.9 + 0.68	25.5 + 0.43	26.7 + 0.78	25.7 + 0.18	27.8 + 1.13	26.3 + 0.56
Dissolved oxygen (mg/l)	2.14 + 0.58	1.83 + 0.56	2.11 + 0.43	1.91 + 0.33	1.21 + 0.64	1.90 + 0.58
Specific conductance (µS/cm)	29.0 + 14.9	30 + 15	30.04 + 14	25.87 + 1.22	70.19 + 26.1	108.9 + 32.9
pH	4.77 + 0.37	4.99 + 0.3	4.87 + 0.33	5.16 + 0.09	4.29 + 0.34	3.76 + 0.2
TSS (µg/l)	3.3 + 4.0	4.5 + 4.3	1.2 + 1	1.85 + 2.5	7.7 + 0.4	40.4 + 26.5
TDS (mg/l)	14.8 + 7.4	14.4 + 0.6	15.1 + 7.4	12.2 + 0.93	35.7 + 13.24	48.3 + 11.00
NO_3-N (mg/l)	2.59 + 2.6	1.48 + 1.04	2.79 + 5.0	1.04 + 0.3	2.71 + 2.63	4.46 + 1.64
NH_3-N (mg/l)	0.078 + 0.04	n.a	0.051 + 0.02	n.a	0.075 + 0.04	n.a
Soluble reactive phosphate (µg/l)	0.65 + 0.15	0.6 + 0.3	0.43 + 0.15	0.44 + 0.15	1.5 + 0.62	1.4 + 0.7

4.2 Nutrients

The average SRP concentration during fortnightly sampling was highest at outlet B (1.5 ± 0.62 μg l^{-1}) compared to the inlets BR (0.65 ± 0.15 μg l^{-1}) and BL (0.43 ± 0.15 μg l^{-1}). There was no significant difference ($p>0.05$) between SRP during the biweekly and the intensive samplings programme for all stations (Table 2). The SRP concentrations were lower than the maximum values recommended by ecosystem target for SRP in upland UK rivers of 20 μg P-PO_4/l [16].

Ammoniacal-N (NH_3-N) was highest at BR (mean = 0.078 ± 0.04 mg l^{-1}) ranging from a minimum of 0.043 mg l^{-1} for medium to high flow rates and a maximum of 0.16 mg l^{-1} during low flow. At BL, NH_3-N was slightly lower (mean = 0.051 ± 0.02 mg l^{-1}) at medium flow and peaked at 0.083 mg l^{-1} at highest flow conditions. At the outlet B, the concentration of NH_3-N was slightly lower than or comparable to BR at 0.075 ± 0.04 mg l^{-1} with a minimum value of 0.042 mg l^{-1} at medium flow rate and a maximum value of 0.157 mg l^{-1} at low flow (Table 2). No measurements of NH_3-N were carried out during the intensive sampling in October 1998.

Nitrate was highest at BL with a mean concentration of 2.79 ± 5.0 mg l^{-1} (Table 2). The minimum value was 0.19 mg l^{-1} which was recorded during medium flow condition, and the maximum value of 17.35 mg l^{-1} observed during medium to high flow condition. This maximum value is greater than the interim water quality standards (INWQS) limit for Malaysian waters of 10 mg l^{-1} [17, 18]. During intensive sampling, the concentration was almost 60% lower than the fortnightly sampling at the inlet. However, there was an increase in the amount of nitrate at the outlet during the intensive sampling by as much as 60% compared to the inlets. All other nitrate values, except the maximum, are within the INWQS limit for Malaysian waters of 10 mg l^{-1} but greater than the threshold level for eutrophication of 0.3 mg l^{-1} [17, 18].

4.3 Nutrient Balance

Based on a very limited sampling programme, an initial attempt to estimate the nutrient balance in topical wetland in Malaysia was carried out. Loadings of nutrients and suspended sediment between a time intervals was calculated by multiplying the discharge (Q) by concentration (C) over the time interval K, (in seconds) between samples. This is called an average sample load [19],

$$L = K\left(1/n\sum_{i=1}^{n} Q(i).C(i)\right).$$

The nutrient yield was obtained by dividing the loads with the size of the catchment area for a meaningful comparison between sites. A simple mass balance approach was used to calculate the nutrient budget and the results are tabulated (Table 3). The sampling frequency was very low and there could be large errors in calculating the

Table 3 A simple mass balance calculation of the total nutrient during the study period

Nutrient	Input at BR (kg/km^2)	Input at BL (kg/km^2)	Total input (kg/km^2)	Output at B (kg/km^2)	Input - Output	% retention
TDS	20324.04	17934.18	38258.22	22080.77	16177.45	42.3
TSS	5.69	1.54	7.23	5.57	1.66	23.0
NO_3-N	5070.39	5720.69	10791.08	2080.38	8710.70	80.7
NH_3-N	202.35	157.85	360.20	88.40	271.80	75.5
SRP	1.55	0.57	2.12	0.88	1.24	58.5

budget. However, this is the first attempt to produce a budget for a tropical wetland in Malaysia.

Despite limited data, we manage to see a temporal pattern of nutrient load every fortnightly. Figure 7 shows the variability of nutrient and suspended sediment budget with discharge. A positive budget indicates that material was retained in the swamp. Most SRP, NH_3-N, nitrate and TDS were retained in the swamp during the study period with fluctuations in the amount retained, depending upon the discharge and concentration. The TSS budget shows some fluctuations between retention (weeks 2, 3, 4, 7, 8, and 9) and flushing (weeks 1,5 6 and 10). The amount of nitrate retained in the swamps peaked to 3000-4000 kg km^{-2} in week 6 and 7, corresponding to a high discharge.

The TSS budgets indicate that suspended solids input was negligible as compared to the TDS loads. The sediment concentrations were low, thus resulting in low TSS loads. The net retention of TSS was 23.0%.

The dissolved solute load inputs were the highest with the total input of 20 324.0 kg km^{-2} at BR as compared to BL (17 934.2 kg km^{-2}). There was a net nutrient retention of dissolved solutes in the swamps of 42.3% (Table 3). Based on individual nutrients, it was observed that all nutrients and sediment are being trapped in the swamp. Phosphorus load was very low with total input of 2.11 kg km^{-2} as compared to the output of 0.88 kg km^{-2}, resulting in a net retention of almost 58.3%.

Generally with TDS (Figure 7D), dissolved solutes were retained in the wetland system even though discharge was fluctuating. For the TSS balance (Figure 7E), there was no direct correlation between sediment load and discharge. Even though discharge generally increased from sampling day 1, disturbance in the wetland itself created an alternating sequence of negative and positive balances. On sampling day 8 for example, a great retention of sediment was observed when the discharge decreased and was associated with lower sediment discharge and a reduction in velocity at the outlet.

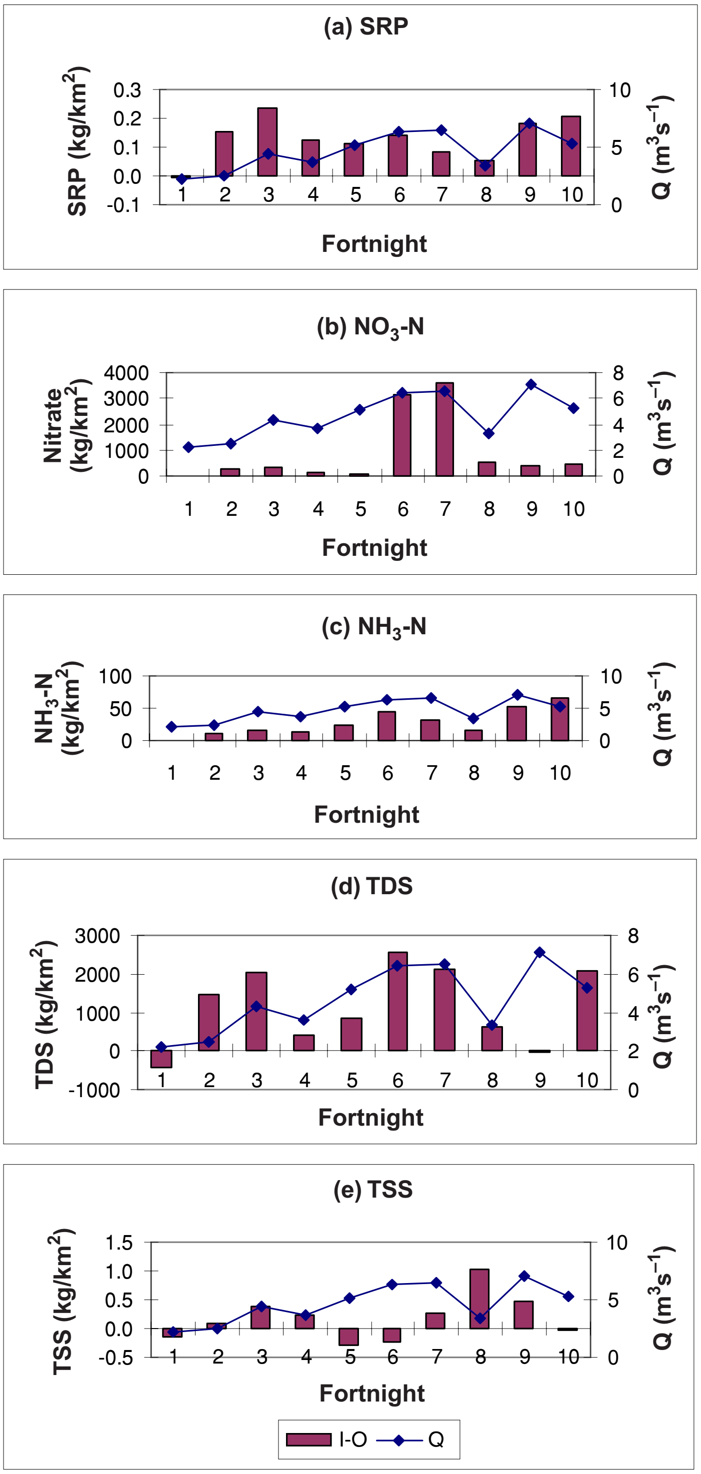

Figure 7 Variation in nutrient and sediment balance with average discharge at Beriah outlet

5.0 DISCUSSIONS

The water chemistry of wetlands is primarily a result of the geologic setting, water balance i.e relative proportion of inflow, outflow and storage, quality of inflowing water, types of soils and vegetation, and human activities within or near the wetland [20]. In general, this study showed that the water quality at the inlets was slightly better than at the outlet, showing the influence of human settlement, rubber and oil palm estates in the wetland affecting the water quality and nutrient. As the outflow is less than the combined flow of the inlets, this will effects the concentration of the nutrients. The evaporation of the wetlands could also have some impact on the concentration of the nutrients leaving the wetlands.

Runoff is slowed down upon entering a wetland. This phenomenon may be due to the spread of floodwater over a large area, its immobilization in low-lying basins and depressions or the moderating effects of the vegetation (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 materials [6, 8, 21, 22].

In this study, TSS was in low concentrations at the inlets but increased in concentration at the outlet. However, mass balance calculations (Table 3) showed that there was retention of suspended sediment by the swamp by almost 23%. Although this percentage is low, there still exist some form of retention. The dissolved components were higher, reaching up to almost 40 000 kg km^{-2} of input, but it is also being retained in the swamp. Individual evaluation of the nutrient shows both the nitrogenous components (nitrate and ammoniacal nitrogen) and phosphorus are retained in the wetland system (Table 3).

The trapping mechanism in Beriah swamp is efficient as has been observed elsewhere [23 - 25]. This study shows that retention of almost 80% of nitrate, 75.5% NH_3-N and 58% of SRP by the swamp. The retention of nitrogen and phosphorus found in this study is comparable to other studies. Johnston [26] for example, stated that the estimated mean retention of phosphorus by wetlands is 45%, and Hammer and Knight [27] found that natural wetlands could retained 77% nitrate as compared to only 44% by constructed wetlands.

5.1 The Temporal Variation of Nutrient Balance

The temporal variations of nutrient balance with discharge were shown in Figure 7. Examining the flux of individual components, SRP (Figure 7A) was flushed in the beginning of the study and then retained for a month peaking at sampling day 3 and starting to flush slowly, as shown by the slowly decreasing amount of retention. Some form of flushing was shown to happen at sampling day 8, and when the discharge started to increase. There was then an accumulation of phosphate until the end of the study. This could be associated with the dampening effects of the swamp on the oscillation of water and solutes [28].

There was a net total nitrogen retention by the swamp. The effects of dampening of the oscillation of discharge and solutes was also observed, where for the case of nitrate, the increase in discharge and nitrate retention at sampling day 6 and 7 total up to almost greater than 3000 kg km^{-2} in both cases (Figure 7B). Ammoniacal nitrogen flux (Figure 7C) was shown to behave closely with the outlet discharge.

The low ambient DO in the swamps observed in this study will influence both the rate of nitrification and denitrification (nitrogen removal) [29]. Nitrification is a biological process during which nitrifying bacteria convert toxic ammonia to less harmful nitrate. Denitrification on the other hand, has been observed even in the presence of dissolved oxygen [30], however, the net nitrogen retention observed in this study could be attributed to other factors favourable for, or much more dominant in favour of nitrification. There was a 60% increase in the amount of nitrate at the outlet during the intensive sampling carried out during high water conditions. High water could contribute to oxygenation of the water, sediment and the senesced plant community, promoting nitrification and reducing denitrification [31].

5.2 Nutrient Retention

The dampening effect of the vegetation in the swamp could have played an important role in helping the retention of nutrient and sediment. The dampening effect of the oscillation on discharge and solute loads was also observed during this short-term study, and was noted especially during high water, when the channel bank over flows occur due to increased flow resistance by the thick macrophytes. Impediment of water flows by macrophytes increase nutrient removal through sedimentation [32, 33]. Bottom shear stress is reduced when water is flowing through stocks of submerged plants, thus organic particles preferably settle within and in vicinity of macrophytes stands [34] thus acting as temporary nutrient sinks [35]. According to Reddy and D'Angelo [36] the amount of phosphate retained in wetland will depend on the concentration in the overlying water column and associated biogeochemical processes functioning in the soil. Inorganic P added at concentrations considerably greater than those present in the interstitial water of wetlands soils may be retained by oxides and hydrous oxides of iron, aluminum and calcium carbonate.

The effect of water and nutrient retention of swamp is shown by the nutrient of balance carried out by the swamp system. The percentages of retention were 81% for nitrate, 58% for phosphate, 23% for TSS and 42% for TDS. While the concentration of nutrient does not differ much between inlets and outlet, the retention of water by swamps reducing the velocity of water at the outlet affect the calculation of nutrient balance. This study agrees with other major wetland dynamic studies which shows that wetland are at least seasonal sinks for nutrients such as nitrogen and phosphorus [37, 38, 39, 40] and all types of wetlands are excellent sediment traps [25].

6.0 CONCLUSION

This study concludes that Beriah swamp, a tropical wetland ecosystem, works efficiently as a nutrient and sediment trap. The chemical mass balance approach was successfully used to determine the nutrient loading from non point sources of pollution using upstream-downstream sampling locations. Mass balance calculations indicated that nitrate and phosphate retention are 80.7% and 58.3%, respectively. The approach provides an account of the advantages of using upstream-downstream sampling locations to estimate the nutrient loading to the swamp and to detect changes in the water quality and constituents within the freshwater wetland system.

The results of this study could be utilized for the management of the catchment areas and freshwater wetlands in Malaysia. Further in-depth study is needed, where a more sophisticated equipment and instrumentation could be installed to give a much better and accurate estimation of the nutrient loading.

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