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Water Quality Assessment of Bertam River and its Tributaries in Cameron Highlands, Malaysia

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Abstract: The expansion of the urban population within Bertam river catchment in Cameron Highlands increased the input of organic matter to the river system. It originates from sewage and fertilizers, through point sources and non-point sources of pollution. This organic pollution causes very severe bio-contamination with bacteria and viruses, which can cause some serious diseases. On the other hand, it is apparent that an assessment of water quality cannot focus on chemical indicators alone, but must instead focus on indicators that integrate the effects of physical, chemical and biological contaminations. Therefore, in this research the pH, EC, TDS, COD, Total Nitrogen, Total Phosphor and *E.coli* at four points (SP1 to SP4) of Bertam river and five points (SP5 to SP9) of its tributaries were measured during average and high water flow to determine and specify the level of pollution in the river. Results show water quality of the Bertam river deteriorates and continues just after its origin at SP1 as huge increase of total solids up to 4000 mg/L was observed during high water flow at SP2 while it was around 5 mg/L at SP1 in same period. Also the high concentrations of Total Nitrogen and Phosphorus was observed at SP2 (17 mg/L N and 14 mg/L P) and SP5 (9.7 mg/L N and 8.7 mg/L P) during high water flow. Finally, the presence of *E.coli* of more than 200 MPN/100ml was found at SP2, SP3 and SP7.

Key words: Water quality · Bertam river · Cameron Highlands

INTRODUCTION

Cameron Highlands is a highland region located about 121 km east of Ipoh and about 214 km north of Kuala Lumpur, in Pahang, Malaysia. At 1500 m above sea level it is the highest area on the mainland. It enjoys a cool climate, with temperatures no higher than 25°C and rarely falls below 12°C year-round. Cameron Highlands is actually a district in the state of Pahang although the road entrances are via Tapah and Simpang Pulai in the state of Perak. Cameron Highlands district is bordered by Lipis district on the south-east, Kelantan on the north and Perak on the west [1]. Originally, the rivers and small streams of the Cameron Highlands can be categorized as fast flowing, cool, clean, and clear water with high oxygen content and supporting sensitive aquatic invertebrates [2]. The expansion of the urban population within the Upper-Bertam river catchment increased the input of organic matter to the river system. According to Department of Environment, Malaysia overall organic pollutants (mainly domestic sewage) are the largest pollutants in the Upper-Bertam river [3]. It originates from sewage and fertilizers (animal fertilizers as chicken manure), through point sources (hardly treated domestic sewage) and non-point sources as agricultural runoff [4]. Besides adding to nutrient-content of the water (leading to extreme enrichment of the Upper-Bertam), addition of some forms of Nitrogen and Phosphorus will increase BOD and COD. This organic pollution causes very severe bio-contamination with bacteria and viruses, which can cause diseases such as Cholera, Typhoid, Hepatitis A and virus infections [5] and [6]. Septic tanks are the main method of sewage treatment in the Upper-Bertam catchment. Latrine holes and direct releases into water courses are still practiced. Better treatment facilities such as Imhoff tank systems, oxidation ponds and packaged treatment schemes are used in private housing estates [4].

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It is important to understand the relationship between human induced disturbances and their affect on aquatic resources [5]. River-ecology disturbances from urban and agricultural development contribute to an overall decrease in the (biological) integrity of Bertam river (e.g., road building/construction activities, stream canalization, alteration of the stream's riparian zone and water pollution due to any of these factors) [7]. It is apparent that an assessment of water quality cannot focus on chemical indicators alone, but must instead focus on indicators that integrate the effects of physical, chemical and biological contaminations [8]. Proper management of river and stream systems must be based upon a comprehensive monitoring strategy that is able to detect degradation in streams water quality due to human disturbance.

In this study physical, chemical and biological water quality parameters of Bertam river and its tributaries were measured. The sampling was carried out during average water flow and high water flow to determine the level of pollution and its differences within these two periods.

MATERIALS AND METHODS

Analytical Methods: pH, electrical conductivity (EC) and total dissolved solids (TDS) were measured with a Multi-meter and chemical oxygen demand (COD), Total Nitrogen and Total Phosphorus were determined according to the standard methods for water and wastewater examinations [9]. The study focuses on bacteria indicator as well since majority of sanitary regulations are based on the monitoring of this kind of indicator [10] and [11]. *Escherichia coli* (*E. coli*) was chosen because of its broad use as a tracer for fecal contamination and was sampled with precautions; i.e. samples taken in sterile conditions in special containers and cooled transport to the laboratory after sampling. The laboratory analyses were carried out at the environmental laboratories of Faculty of Social Sciences and Humanities and Faculty of Engineering, Universiti Kebangsaan Malaysia (UKM).

Sampling Locations: Samples were taken before addition of a side stream or possible change in water condition i.e. related to land use on riversides or sewage effluent into the river course. The dataset originates from 9 sampling stations along Bertam and its tributaries (Fig. 1). The value of each parameter after the change minus the value before the change gives the contribution of the land use or stream in the area. It takes a certain length of river course until both watercourses are mixed after a side stream is added to the main stream. This depends on the water rates and riverbed structure of the water streams. Samples were taken from the main watercourse after homogenizing the addition of (polluted) sources. Sampling points are specifically chosen on locations of the main river and its tributaries (Table 1).

Fig. 1: Map of the Sampling Stations in the Bertam river and its Tributaries

Table 1: Sampling Points

Sample location	Reason of selection
SP1, at source, slope of Mt. Brinchang	Clean background concentration
SP2, at Brinchang golf course	After farming, addition of Burong river and sewage inflow of Brinchang town
SP3, near MARDI in Tanah Rata	After addition of Ruil river and Jasar river, inflow sewage of Tanah Rata town and farming
SP4, before flowing in Ringlet Reservoir	After addition of Ulung river and Batu Pipih river and extensive farming
SP5, Burong river, just before joining Bertam river	Length, flow and farming and urban use
SP6, Ruil river, before joining Bertam river	Length, high flow and farming and urban Use
SP7, Jasar river, before joining Bertam river	High flow and inflow Tanah Rata sewage
SP8, Ulung river, before joining Bertam river	Length, high flow and farming (tea plantations and agriculture)
SP9, Batu Pipih river, before joining Bertam river	Length, flow and very intensive farming and agriculture use

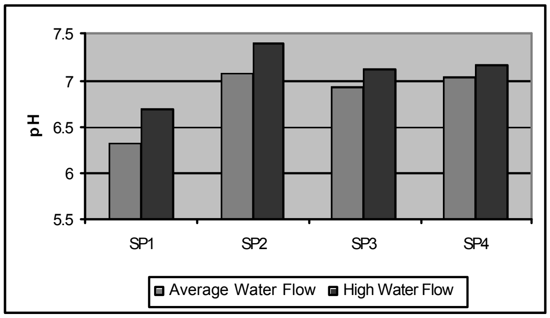
Sampling Time: In dryer periods with a few days of dry weather the river runs with relatively stable water rates. Within these periods riverbed erosion takes place delivering bonded compounds in the riverbed to the water stream. During rain or just after raining, the river is relatively unstable with rapidly increasing water rates with surface runoff of the surrounding land being added to the water stream. The water streams was then brown in color due to the silt and have a water rate much higher than the original water rate in dryer moments. To obtain results for both possible conditions a dry period with stable river flow and a wet period with high unstable river flow, was chosen through a year. Sampling took place on a monthly basis and the data were processed to give average values, whiles in order to achieve a more satisfactory representation of the complex datasets, a mean value was calculated for each parameter in each period.

RESULTS AND DISCUSSION

Water sampling in Bertam river and its tributary rivers was done in two events. First, in dryer period with a few days of dry weather the river runs with relatively stable flow rates. Within this period riverbed erosion takes place delivering bonded compounds in the riverbed to the water stream. Second, during rain or just after raining, the river is relatively unstable with rapidly increasing water rates with surface runoff of the surrounding land (with compounds bonded to the surface layers of i.e. agricultural land) being added to the water stream.

pH, EC and TSS: pH, EC (electrical conductivity) and TSS (total suspended solids) were measured with the portable multi-parameter instrument in the field during sampling. Although not definitive, pH of the aquatic systems is an important indicator of the water quality and the extent pollution in the watershed areas [12]. As illustrated in Fig. 2, the pH was found to be 6.32, 7.08, 6.93 and 7.04 during average water flow and 6.7, 7.41, 7.12 and 7.17 during high water flow for SP1 to SP4, respectively. As illustrated in Fig. 1 water at its origin at Bertam river (SP1) and also Ruli and Jasar rivers were more acidic than other stations. Chau and Jiang [13] have indicated that natural river water is slightly acidic because of its origin of rain water and because of tannin and leave acids released from the forest floors. Any increase in the pH is thus likely due anthropogenic influence, since also the host rock (granite) does not support buffering. Visible is the slight increase in pH going downstream, especially the steep increase at SP1 (forest stream) to SP2 after passing through Brinchang town. Chang [14] has mentioned that the increases in pH appear to be associated with increasing use of alkaline detergents in residential areas and alkaline material from wastewater in industrial areas. During high water flow this picture remains largely the same; except that more dilution of the main course occurs due the addition of the Batu Pipih and Ulung rivers; with lower pH.

As shown in Fig. 3 Electrical conductivity was found to be 9, 66, 63 and 47μS/cm during average water flow at SP1 to Sp4 respectively. While TSS amount was 6.4, 33, 30 and 25 mg/L during this time, which was low. The undisturbed and unpolluted rivers of the Cameron Highlands flowing through the forests display a very low EC and TSS at SP1. It can be supported by similar result in the research that was done by Hashim [7]. This is mainly due to the origin of the river water of rain water and due to the inert stream bank material (mainly granite). However especially domestic wastewater (sewage i.e.) has a very high EC and TSS [15], so addition of this wastewater will cause the EC and TSS to increase. This process is clearly visible in the observed amount. Where at SP1, the undisturbed and unpolluted part of the river a very low EC and TSS is found, however after flowing through Brinchang, both values dramatically increase



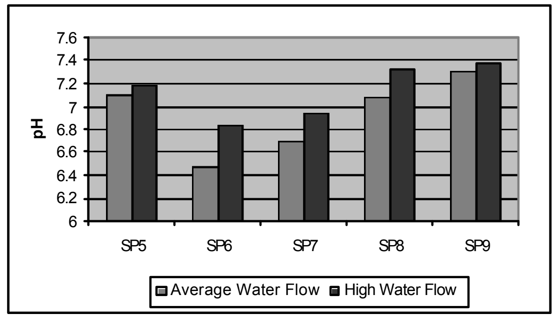
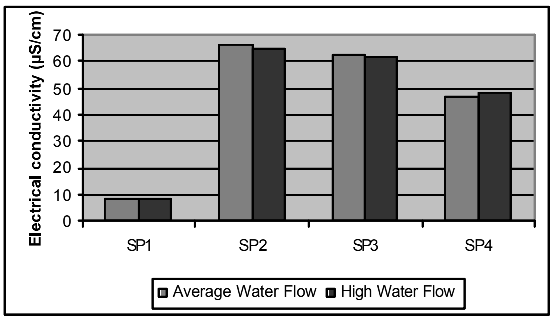


Fig. 2: pH Variations in Bertam river and its Tributaries



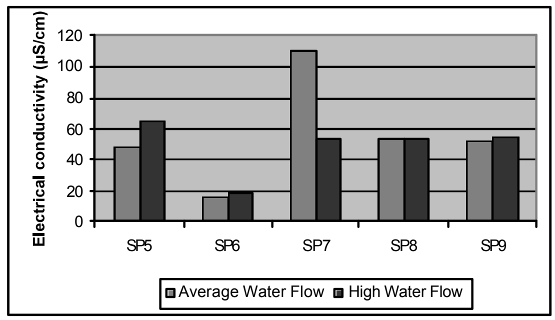
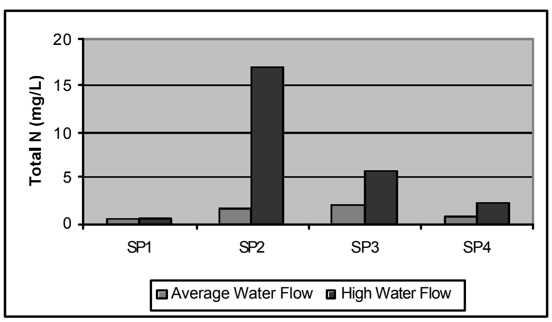


Fig. 3: Electrical Conductivity Variations in Bertam river and its Tributaries



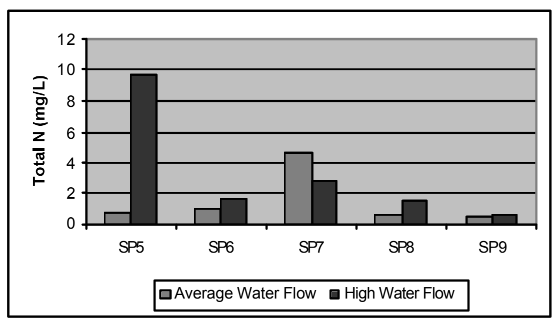
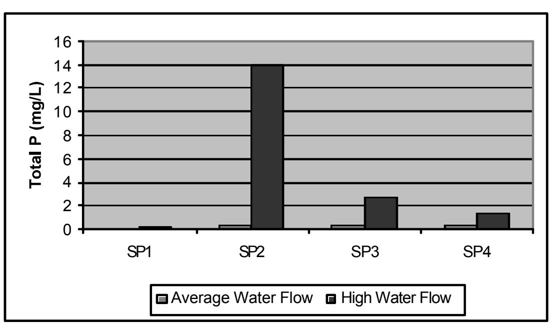


Fig. 4: Total Nitrogen amounts in Bertam river and its Tributaries



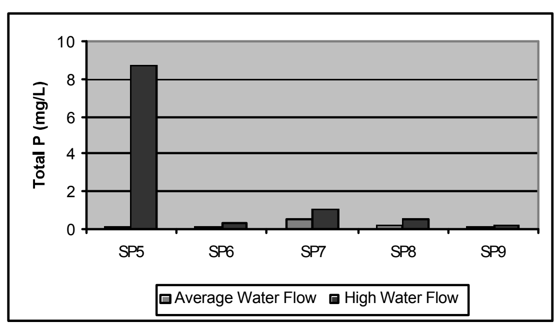


Fig. 5: Total Phosphorus amounts in Bertam river and its Tributaries

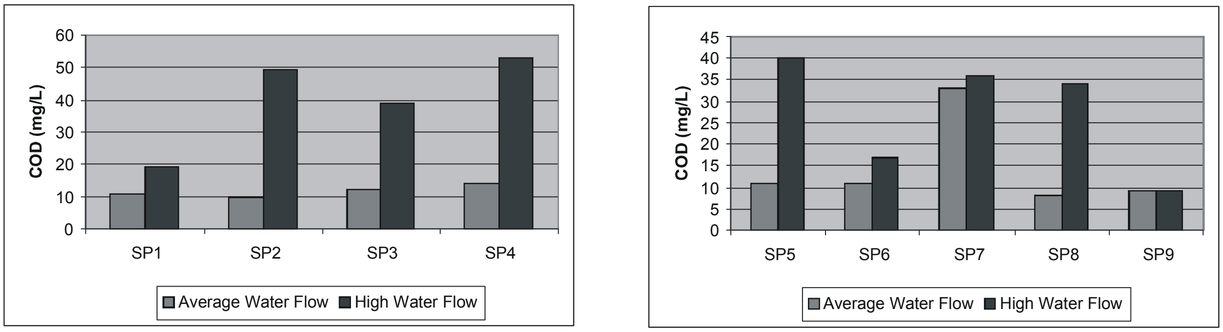


Fig. 6: Variations of COD in Bertam river and its Tributaries

SP2 and SP3). Although later on the town of Tanah Rata is passed (just before SP3) with addition of its wastewater, the EC and TSS slight decrease, this is very likely due to the increased flow of the main stream by addition of much cleaner streams as Ruil river and later on Batu Pipih river and Ulung river. Dilution of the salt concentration is making up the 2 values of EC and TSS. This last process is even more visible at the high water flow in Table 3; whereas this dilution is more significant because of the highly increased total flow; however the salt load can increase due to agricultural run off.

Nutrients (Total Nitrogen and Phosphorus): Phosphates and nitrates are important parameters to assess the water quality. Photosynthesis and respiration play an important role in the self-purification of natural water. The disturbance of the stationary state between photosynthesis and respiration leads to chemical and biological changes reflecting pollution. High levels of these species increase the growth of vegetation in water systems and increase the oxygen demand. The enrichment in nutrients and the enhancement of productivity and respiration leads to such imbalance [12]. Higher concentrations of nutrients were expected in high water flow because of agricultural runoff. During agricultural runoff; nutrients stored in the surface soil layers and then it is released (with rain) into the river during rainy time. The concentration of nutrient in average water flow is likely to be almost solely from domestic wastewater and will be more diluted in high water flow. Nitrates are considered better indicators in average water flow, due to their relatively good solubility and non-reactive behavior. Phosphate however is tightly bonded in the surface soil layers and to sediment and thus found in higher concentration during high water flow [7].

***Total Nitrogen*:** For total N (as Kjeldahl-Nitrogen) very low concentrations were found in the undisturbed tributaries. High to extremely high concentrations were found in the main stream and in some tributaries. Concentrations of 17 mg/L at SP2 (Bertam river) and 9.6 mg/L at SP5 (Burong river) are detected during HWF. The concentrations during AWF are significantly lower. SP3 (Bertam river) and SP7 (Jasar river) have shown high concentrations and thus severe eutrophication was observed. According to "Recommended Raw Water quality Criteria of the WHO" [10] Nitrogen concentrations are exceeded at almost all sampling points in ranges of 2 to 17 times during both AWF and HWF. Although during AWF much lower concentrations were found (Fig. 4). High level of nitrate at SP5 is most probably due to the extend use of pesticides and fertilizers at farming area near Burong river. Milovanovic 2007 explained that high level of nitrate indicate non-point pollution induced by agricultural runoff [6]. At SP2 as river passes through Tanah Rata domestic wastewater is the main cause of high nitrate.

***Total Phosphorus*:** Just as they do on land, phosphorus and other nutrients stimulate the growth of aquatic plants, including undesirable algae. Nutrient enrichment and stimulation of plant growth limits the potential use of the affected water and is a cost to the community. Agricultural production systems are one of the many contributors to the phosphorus found in streams and water storages [16]. As shown in Figure 5, Phosphorus concentrations (as Total P) were high (as for Total N) at the same sampling points especially at SP2 and SP5 during high water flow which indicate that agricultural runoff contains fertilizers is probably the major cause for high concentration of phosphorous at water streams [6] and [16]. It should be mentioned that phosphorus concentrations at SP3, SP4 and SP7 were high too that it causes severe eutrophication.

Table 2: *E.coli* values in Sampling Points

Sampling point	*E. coli* (MPN/100ml)
SP1 Bertam river	-
SP2 Bertam river	>200
SP3 Bertam river	>200
SP4 Bertam river	86
SP5 Burong river	65
SP6 Ruli river	52
SP7 Jasar river	>200
SP8 Ulung river	14
SP9 Batu Pipih river	59

Table 3: Amounts of Total Suspended Solids in Sampling Points

	TSS during AWF (mg/L)	TSS during HWF (mg/L)
SP1	6.4	5
SP2	33	4000
SP3	30	1800
SP4	25	930
SP5	13	3900
SP6	<2	51
SP7	12	870
SP8	4.8	150
SP9	18	67

Chemical Oxygen Demands: Chemical Oxygen Demand (COD) showed the same trend as total N and total P. SP2, SP4 and SP5 have shown particularly high COD with 49,53 and 40 mg/L, respectively during high water flow (Figure 6). Also COD at stations SP3, SP7 and SP8 were found to be high (39,36 and 34mg/L respectively). While much lower concentrations were determined during average water flow still SP7 has shown high COD level (33 mg/L) during average water flow. This indicates domestic wastewater discharge from residential area of Tanah Rata to Jasar river. Many researchers have mentioned that high COD pointing to a deterioration of the water quality likely caused by the discharge of municipal wastewater [17-19].

Based on achieved results for Total N, Total P and COD, it should be mentioned that huge decline in water quality could be observed during post-monsoon (HWF) at all stations which indicate non-point sources of pollution to have tremendous contributions to impacts on water quality.

Microbiological Observations. *E. coli* samples were taken during average water flow. The found values are illustrated in Table 2. As can be seen, except SP1 all sample points show extremely high presence of *E.coli*. One would expect successively increased values along the Bertam river the flow direction, but the addition of Ulung river and Batu Pipih river just before the sample point SP4, caused dilution of the *E.coli* load as well as some effects of degradation of the bacteria due to transport/oxygenation between SP3 and SP4 (over Robinson Waterfalls). *E.coli* and pathogens are typically found in domestic wastewater and chicken manure as applied in agriculture in the area. Birbir et al. indicated that untreated domestic wastewater discharged into a water body may carry millions of pathogenic microorganisms [20]. In another approach Lu et al have founded in agreement with others [21-26] that have demonstrated *E. coli* can survive and multiply in irrigation water, wastewater, subtropical sediments, and mineral water [27].

Total Suspended Solids (TSS):TSS represents the concentration of material in suspension in a liquid effluent [28]. TSS concentrations were found extremely high at some points during high water flow while it was almost negligible during average water flow (Table 3). The highest were at SP2 (Bertam river at Brinchang town) and at SP5 (Burong river) with 4000 mg/L and 3900 mg/L respectively. Land erosion is a major contributor of suspended sediments and siltation in the river in Cameron Highlands. Besides the severe pollution with organic compounds, siltation (increase of turbidity of the water) is the most significant factor causing water quality deterioration. Most important source of silt into the river course is agriculture, mostly on extremely steep slopes of Cameron Highlands.

CONCLUSIONS

Water quality of the Bertam river and its tributaries deteriorates because of the huge increase of suspended solids, the high concentrations of Nitrogen and Phosphorus compounds including COD, which cause very significant enrichment and eutrophication as well as presence of *E. coli* causing severe micro-biological contamination. Results show all above mentioned parameters are higher than those recommended by the Recommended WHO especially during high water flow; therefore this water resource is not adequate for human consumption or industrial purposes and needs to be purified. The main reasons for this water quality deterioration are agricultural activities which cause sediment transport, encroachment of nutrients as well as microbiological contamination due to the use of chicken manure which contains *E. coli* and urban areas with poorly treated or untreated sewage poured in the river cause nutrient enrichment and biological contamination.

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