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Physicochemical analysis on water quality status of Bertam River in Cameron Highlands, Malaysia

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Abstract
Seasonal variation study of physicochemical analysis in Bertam River, Cameron Highlands was carried out in August - November 2012. The river water quality was studied at six selected stations to represent different localities with varying anthropogenic discharge. Physicochemical parameters of the samples were measured pH, temperature, electrical conductivity, total dissolved solids, dissolved oxygen, salinity, ammoniacal nitrogen, biochemical and chemical oxygen demand, suspended solids, nitrate and phosphate following standard methods. The mean values of the measured parameters were compared with Malaysian National Standard for Drinking Water Quality (NSDWQ) and Water Quality Index Department of Environment (DOE WQI). Present level concentration of ammoniacal nitrogen, biochemical and chemical oxygen demand were under the categorization of Class II and III while suspended solids were categorized in Class IV in wet season. Mean WQI for Bertam River in dry season (78 Class II) was slightly better than in wet season (74 Class III). Thus it was indicated at meteorological change such as rainfalls having significant negative influence on study site. Statistical analysis of one way ANOVA test indicates that all measured parameters are shown significant difference except for pH, DO, salinity, COD and ammoniacal nitrogen. In conclusion, present the water quality of Bertam River should be extensively monitored since deterioration of water quality was clearly observed. Therefore, some sort of integrated river water management and good practice agriculture scheme should be implemented.

Keywords: Water Quality, Cameron Highlands, Bertam River, Agriculture site, Rainfall

1. Introduction
Bertam River is one of three main river basins in Cameron Highlands, cover up 73 km^2 of an area and play significant key role in Cameron Highlands as sources of drinking water supply, irrigation water for local cultivation activities and hydroelectricity generation [1]. Bertam drain eastwards into the Pahang River prior subsequently stream flow into the South China Sea, eastern coast of the Peninsular Malaysia. This important river also flowing into the TNB Ringlet Reservoir or also called as Sultan Abu Bakar Dam was commissioned in 1965 [2].
Seven causes of main water problems had been address in previous studies which is included land use change either legal or illegal development, uncontrolled river water abstraction in upstream, poor solid waste management, low awareness of local community, unplanned development, and inefficient administration [3]. Indeed, an aggressively of land use change in recent year for agricultural activities, tourism and urban development in an area of Cameron Highlands which have been widely reported in previous studies [4, 5]. Furthermore, Bertam River also was heavily contaminated with sedimentation problems, especially after

passing through the settlement and agricultural areas. Active deforestation in recent years had affected the climate of Cameron Highlands or even gave negative impact on tourism industry in this area [6, 7].
As pollutant loading to Bertam River water continuously increases caused by anthropogenic activities, an ability to predict the resulting its impact is becoming more important for ecosystems of Cameron Highlands. Thus, the aim of this principle study is to assess present status of Bertam River water quality in different localities of anthropogenic impacts as well as to determine seasonal variation such as atmospheric precipitations influences on aquatic ecosystems. The location on map sampling site in Cameron Highlands as presented in Figure 1.

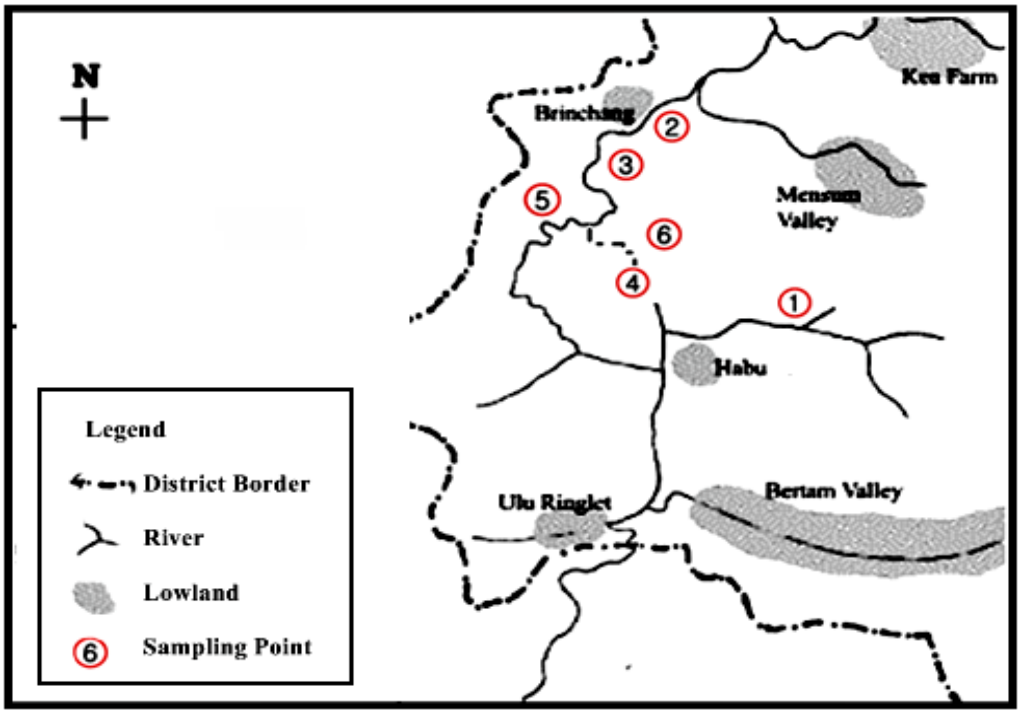

Figure 1 Location on map sampling site, Bertam River in Cameron Highlands

2. Materials and methods

2.1 Sampling Activity

Water samples were collected bimonthly from six selected stations located along the Bertam River from August - September (dry) till October - November (wet) 2012. River water samples were collected about 10 cm below the water surface using 1 liter HDPE and glass bottles. Samples were stored in a cool box filled ice packs at temperature approximately of 4ºC before transferring to Centre for Water Research and Analysis (ALIR Laboratory) for further laboratory analysis. All sampling, preservative and samples handling technique were in accordance with APHA 1998 for Examination of Water and Wastewater (20th Edition) [8]. Portable GPS was used to determine the coordinate each sampling station on location as presented in Table 1.

Table 1 Description of Bertam River sampling location in Cameron Highlands

Station	Latitude	Longitude	Depth (m)	
			Dry	Wet
1A Bertam River (Tea Plantations)	04°21.334 N	101°22.676 E	0.7	0.9
2A Bertam River (Golf Course)	04°26.561 N	101°23.279 E	0.5	0.6
3A Bertam River (Slim Camp)	04°28.928 N	101°22.821 E	0.3	0.4
4A Bertam River (FAMA Office)	04°28.914 N	101°22.825 E	0.3	0.5
5A Bertam River (Strawberry Farm)	04°26.531 N	101°23.820 E	0.4	0.5
6A Parit Waterfall	04°28.914 N	101°22.828 E	0.3	0.3

2.2 In-situ measurement
Physical water quality was measured in situ using YSI model 550 multi sensor probe consist of pH, temperature, dissolved solids, electrical conductivity and dissolved oxygen. Depth level of each sampling station was measured using depth meter echosounder. Calibration of YSI model 550 probes was conducted in the laboratory before field sampling and once again after sampling progress work was done.

2.3 Rainfall Data
Monthly rainfall data of Cameron Highlands within period Jan - Nov 2012 was acquired from Malaysian Meteorological Department as presented in Figure 2. During dry season (Aug to Sept 2012) time of sampling, 99.6 - 206.8 mm of total rainfall was recorded in Cameron Highlands with the mean value of 38 mm. Meanwhile, 224.2 - 411.2 mm of total rainfall was recorded during wet season (Oct to Nov 2012) with the mean value of 47 mm. The total number of raining days for both season were 28 (dry) and 52 (wet) respectively.

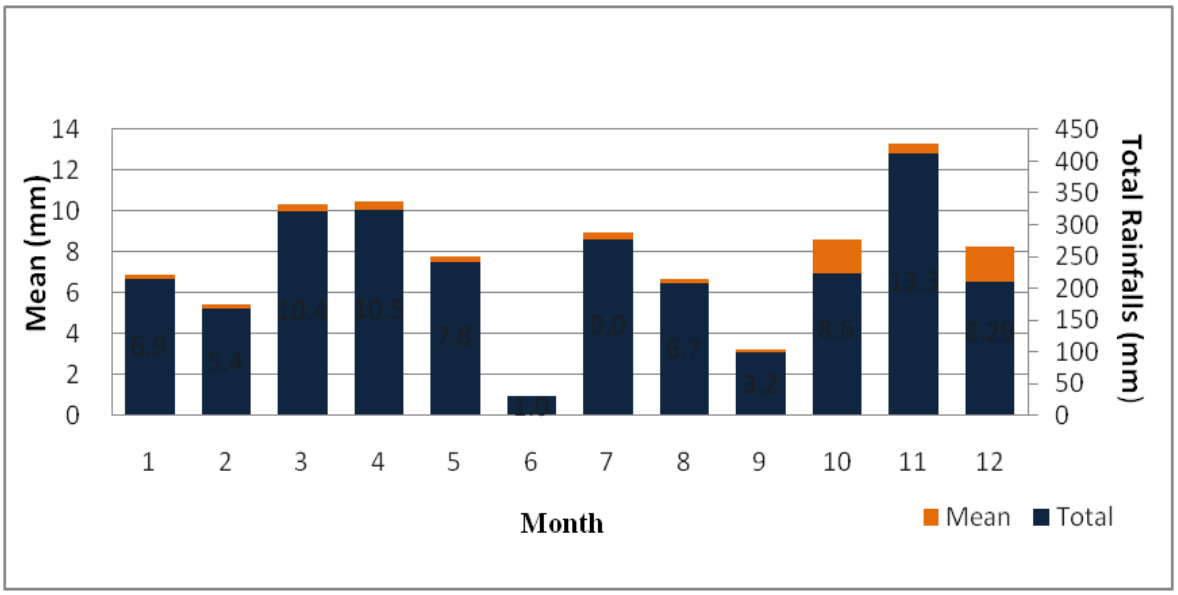

Figure 2 Meteorological Data of Rainfalls in Cameron Highlands

2.4 Laboratory Analysis
Standard methods that were used in this chemical study analysis are Ammoniacal-Nitrogen (Salicylate Method), Biochemical Oxygen Demand (Incubation Method as BOD_5), Chemical Oxygen Demand (Reactor Digestion and Colorimetric Determination), Suspended Solids (Gravimetric Method), Nitrate (Cadmium Reduction Method) and Phosphate (Ascorbic Acid Method). Ammoniacal-N, Chemical Oxygen Demand, Nitrate and Phosphate were determined by using a spectrophotometer Model HACH DR 2400 at a specified wavelength [8].

2.5 Statistical Analysis
Statistical analysis of the present data were interpreted using single factor analysis of variance (one way – ANOVA, $p<0.05$) to measure significant differences between sampling stations. Pearson correlation (r) test was analyzed to identify the association between pairs of variables for sampling stations.

3. Results and discussion

3.1 In-situ Measurement
Mean value of pH in this study were 6.54 (dry) and 7.26 (wet) was obtained within National Drinking Water Standard for Malaysian (7.0 - 8.5) and WHO (6.5 - 8.5) [9]. Highest value of pH was recorded for both seasons at station tea plantations (1A). Higher values of the pH at this station as consequence of acid-forming substances such as sulphate, phosphate, nitrates release into the river basin. These substances as abundance in

fertilizer usage might have altered the acid-base equilibria, resulted in the reduced acid-neutralizing capacity and hence raising the value of pH [10]. The physical characteristics of Bertam River water during the period of study were presented in Table 2.

Table 2 The physical characteristics of Bertam River water along different seasonal period

Parameter	**Dry**		**Wet**	
	Range	**Mean (SD)**	**Range**	**Mean (SD)**
pH	6.50 - 7.76	6.54 (0.15)	6.92 - 7.54	7.26 (1.21)
Temperature (°C)	15.37 - 19.41	18.19 (0.91)	15.29 - 17.62	15.95 (2.65)
Conductivity (μScm^{-1})	38 - 80	58.33 (9.19)	25 - 324	107.67 (17.94)
Dissolved Oxygen (mgL^{-1})	4.61 - 8.18	6.31 (1.87)	6.06 - 7.32	7.03 (0.08)
Dissolved Solids (mgL^{-1})	28 - 52	43.33 (7.31)	65 - 72	68 (11.33)
Salinity (ppt)	0.01 - 0.02	0.01 (0.002)	0.02 - 0.03	0.02 (0.021)

Mean value of temperature in this study were 18.19 (dry) and 15.95 (wet) °C season respectively. Lowest value of temperature was recorded for both seasons at station Parit waterfall (6A). This condition was highly expected since this station was in the vicinity of forest, none agriculture and low human anthropogenic activity during time of sampling. Furthermore, present status of temperature in Bertam River were not much differ with atmospheric condition since Cameron Highlands was considered having cool climate, with temperatures no higher than 25°C during day time [4].

Mean value of conductivity in Bertam River was obtained significantly increased during time of sampling for wet season. Highest conductivity recorded at station golf course (2A) caused by domestic effluent discharges and surface run-off from the golf fields directly into river basin thus might have increased the concentration of ions. Higher values of rainy season also possibly came off from precipitation ionic species that brings a lot of dissolved conducting minerals into river water. This problem was strength support by an increasing of dissolved solids concentration during period of study. Finding result was shown that present conductivity status much higher than previous data (9 - 66 μScm^{-1}) as recorded by Eisakhani and Malakahmad [4].

Mean concentration of dissolved oxygen in Bertam River was obtained slightly high during wet rather than in dry season. This condition was normally occurring since high precipitation will bring more stream flow higher than average water flow. The threshold range for Malaysian River is 3 - 5 mgL^{-1} [11]. Finding results was indicated that present status of dissolved oxygen in Bertam River water not much differ with previous data (4.49 - 8.23) mgL^{-1} as recorded by Redzuan et al. [12].

Mean concentration of total dissolved solid content in Bertam River indicated was higher in dry rather than in wet periods. Highest concentration of dissolved solids was obtained at station tea plantation (1A) for both seasonal periods. Poor vegetated riparian zone, highly active cultivation activity and precipitation are several factors that contribute much more soil loss runoff or leachate, thus brings pollutant from the farms with dissolved conducting minerals at this station. There is no defined trend in variation of mean value in salinity measurement among the all sampling station in both periods.

Statistical analysis of ANOVA ($p<0.05$) indicates that only temperature, conductivity and dissolved solids shown significance differences between sampling stations for *in-situ* measurement. Pearson correlation has shown good relationship between total rainfalls influence with parameters such as temperature (r=0.64) and dissolved oxygen(r=0.73). Thus, highly precipitations though a year would be lead deterioration of water quality. High correlation also were obtained between conductivity and dissolved solids (r=0.97) in water samples during monitoring period.

3.2 Laboratory Analysis

Chemical parameters that were analyzed in this study consist of suspended solid, biochemical and chemical oxygen demand, ammoniacal nitrogen, nitrate and phosphate. Each parameter was described individually in next section. Result of the analysis was also standardized with the Malaysian Department of Environment Water Quality Index Classification (DOE WQI) as presented in Table 3.

Mean concentration of suspended solids in this study was significantly higher in wet season. All sampling stations are being heavily exposed to increasing of particle pollutant in which highest value of suspended solids was recorded at station tea plantations (1A). Suspended solids were known abundance in range size

from 0.1 - 10 mm, typically composed of fine clay or silt particles, plankton, organic or inorganic compounds. Most of station those in the vicinity of agricultural site such as station 1A, 3A, and 5A were recorded more than 100 mgL^{-1} wet seasons thus would be lead to producing much more amounts of sediments in Bertam River basin.

Table 3 Classification of Malaysian Water Quality Index

Parameter (mgL^{-1})	Class				
	I	**II**	**III**	**IV**	**V**
pH	> 7	6 - 7	5 - 6	5	< 5
DO	> 7	5 - 7	3 - 5	1 - 3	< 1
BOD	< 1	1 - 3	3 - 6	6 - 12	> 12
COD	< 10	10 - 25	25 - 50	50 - 100	> 100
TSS	< 25	25 - 50	50 - 150	150 - 300	> 300
NH_3-N	< 0.1	0.1 - 0.3	0.3 - 0.9	0.9 - 2.7	> 2.7
WQI	> 92.7	76.5 - 92.7	51.9 - 76.6	31.0 - 51.9	< 31.0
Status	Clean	Slightly Polluted	Slightly Polluted	Polluted	Polluted

According to Malaysian Department of Environment [13], farming activities in Bertam Valley were clearly affected the concentration of turbidity and total suspended solids (TSS) of Bertam River. It was increased especially near Mensun Village although no precipitation recorded during monitoring study. In fact, Bertam River basin was obtained having high concentration of suspended sediments with the mean of 40.5 mgL^{-1} as compared with Telom River (6.3 mgL^{-1}) and Lemoi River (4.3 mgL^{-1}).

Finding results in this study was indicated that present status of suspended in Bertam River water have significantly increased as compared with previous data Eisakhani and Malakahmad [4] is 23.6 mgL^{-1} and Redzuan et al. [12] in the range of 0.15 - 354.90 mgL^{-1}. Malaysian DOE Water Quality Index was classified present mean concentration of suspended solid in Bertam River as Class I (dry season) and Class IV (wet season). The chemical characteristics of Bertam River water during the period of study were presented in Table 4.

Table 4 The chemical characteristics of Bertam River water along different seasonal period

Parameter (mgL^{-1})	Dry		Wet	
	Range	**Mean (SD)**	**Range**	**Mean (SD)**
Suspended Solids	9.13 - 26.22	15.08 (2.51)	42 - 512	177.67 (29.61)
Biochemical Oxygen Demand	2.17 - 3.21	2.64 (0.70)	0.42 - 1.75	1.25 (0.54)
Chemical Oxygen Demand	5 - 23	16.67 (2.77)	10 - 26	19.33 (3.22)
Ammonia Nitrogen	0.05 - 0.38	0.25 (0.04)	0.20 - 0.48	0.34 (0.15)
Nitrate	0.71 - 1.62	1.13 (0.64)	0.03 - 0.41	0.39 (0.06)
Phosphate	0.80 - 0.95	0.88 (0.10)	0.42 - 1.89	1.11 (0.18)

Mean concentration of Biochemical Oxygen Demand (BOD) in Bertam River was obtained slightly high during dry rather than in wet season. This phenomenon was considered normal in most freshwater system since dilution effect was occurring into water catchment. Highest concentration of this parameter was recorded at station tea plantations (1A) and golf course (2A) for dry and wet season respectively. Although none agriculture activities at station 2A, pollution loading due to chemical usage in fertilizer effluents from golf course was noted as possibly sources. Nevertheless, the mean values of BOD for both seasons found still far below than WHO limit (10 mgL^{-1}).

Finding results in this study also was indicated that present status of BOD in Bertam River have similarly trend as compared with previous data Redzuan et al. [12] in the range of 0.05 - 3.67 mgL^{-1}. Malaysian DOE Water Quality Index was classified the present mean concentration of BOD in Bertam River as Class II for both seasonal periods. Contrarily with BOD, mean concentration of Chemical Oxygen Demand (COD) in Bertam River water was obtained slightly high during wet season. There was fluctuated variation of data observed in this study where as station 1A (dry) and 3A (wet) seasons to be most contaminated area with chemical pollutant.

In this study, the present status of mean COD in Bertam River water have shown lower concentrations during time of sampling as compared with previous high water flow data [14] in the range of 34 - 49 mgL^{-1}. Although there were only slightly differ in COD concentrations, Malaysian DOE Water Quality Index was classified present mean concentration of COD in Bertam River as Class II for both seasonal periods.

Mean concentration of ammonia nitrogen in Bertam River was obtained no variation between sampling station during period of study but significantly increased along seasonal study. Highest concentration of this parameter was recorded at station tea plantations (1A) and golf course (2A) for dry and wet season respectively. This phenomenon was closely related to rapid conversion the oxides form of nitrogen compounds such as nitrate to ammonia in freshwater ecosystem with role of DO at low concentrations [15]. Meanwhile, lowest concentration of ammoniacal nitrogen was recorded at station 6A in both seasonal periods as expected clean than others since this placed as non agriculture site for Cameron Highlands region.

Finding results in this study also was indicated that present status of ammoniacal nitrogen concentration in Bertam River have significantly increased as compared with previous data Redzuan et al. [12] in the range of 0.01 - 1.66 mgL^{-1}. Malaysian DOE Water Quality Index was classified present mean concentration of ammoniacal nitrogen in Bertam River as Class II (dry) and Class III (wet) in seasonal periods of study.

Mean concentration of nitrate (NO_3) in Bertam River was obtained slightly high during dry rather than in wet season. As more land is converted into agricultural site, pollution nitrate was expected to be increased in recent years. Although, concentration of nitrate along wet season period much lower than dry period, higher concentration are still remain at those station in vicinity of agriculture such as station 1A (tea and cabbage cultivations), 4A (cabbage and others) and 5A (strawberry). This indicates that continuously applied the common N-P-K fertilizer or chicken dung [16] into agriculture scheme practice during early stage of cultivations will lead much more potential of being nitrate leached or surface runoff into the river.

Contrarily to nitrate status, mean concentration of phosphate (PO_4) in Bertam River was slightly increased during wet rather than in dry season. In this present study, poor vegetated at riparian zones make it could not react as a P trap along agricultural area such as ploughing activities was occur during time of sampling for dry season near station (1A). Thus, it will make possible soil loss as runoff was continuously high. Not only came off from fertilizer, manmade sources of phosphate in the environment include domestic and industrial discharges, or even changes in land use in areas where phosphorous is naturally abundant in the soil [17] would be lead much more possible sources of pollutant.

In this study, present of nitrate concentration in Bertam River still did not exceed the Malaysian National Drinking Water Quality Standard, NDWQS (10 mgL^{-1}) permissible safe limit for drinking purposed but otherwise phosphate concentration was exceed (0.2 mgL^{-1}) as recommended standard.

Statistical analysis of ANOVA ($p<0.05$) indicates that all measured parameters has shown significance difference except for COD and ammoniacal nitrogen. High correlation also were obtained between nitrate and phosphate ($r=0.96$), good correlation between suspended solid and nitrate ($r=0.63$), phosphate ($r=0.67$) and temperature ($r=0.68$) in water samples during monitoring period.

3.3 Water Quality Index

Water Quality Index (WQI) of Bertam River along differ seasonal periods of this study were determined by Malaysia Department of Environment formula based on six parameters as give by the following expression**:**

$$WQI = 0.22*S_IDO + 0.19*S_IBOD + 0.16*S_ICOD + 0.15*S_IAN + 0.16*S_ISS + 0.12*S_IpH$$

Whereby S_i is represent sub-index of each parameter, WQI was then classified based on Interim National Water Quality Standard Malaysia (INWQS) which categorized water quality into five classes namely class I (WQI > 92.7), class II (WQI 76.6 – 92.7), class III (WQI 51.9 – 76.5), class IV (WQI 31.0 – 51.9) and class V

(WQI < 31.0) based on beneficial use of the water [18]. The calculated values of WQI for all sampling stations in both seasons are shown as in Table 5.
In this study, WQI was in the ranges from 75 – 82 (dry season) and 68 – 80 (wet season), whereas all station was shown slightly decreased in wet season except for station 5A (Strawberry Farm). Therefore, the mean water quality index in wet season with values of 74 was slightly lower than mean water quality index for dry season with values of 78. Although the value of mean WQI was not much differ along seasonal study, present status of Bertam River must be concern since the index value was continuously introduced river as polluted status. This implies that meteorological compartment such as heavily rainfall does has significantly negative influenced on deterioration water quality especially carried out much more pollutants into river basins as clearly presented trend at station 1A.

Table 5 Mean WQI status of Bertam River, Cameron Highlands

Station	WQI	Dry		WQI	Wet	
		INWQS			INWQS	
		Class	Status		Class	Status
1A Bertam River (Tea Plantations)	82	II	SP	68	III	SP
2A Bertam River (Golf Course)	75	III	SP	73	III	SP
3A Bertam River (Camp Slim)	81	II	SP	72	III	SP
4A Bertam River (FAMA Office)	78	II	SP	74	III	SP
5A Bertam River (Strawberry Farm)	76	II	SP	80	II	SP
6A Parit Waterfall	78	II	SP	76	II	SP
Mean WQI	**78**	**II**	**SP**	**74**	**III**	**SP**

C; Clean, SP; Slightly Polluted

The present monitoring results clearly indicated that the water quality status of Bertam River seem to degrade significantly after heavy precipitations. Malaysian Environmental Quality Report [19, 20] has stated that the water quality of Bertam River was remained in class II over the last three years. Overall, deterioration water quality of Bertam River recorded as found in present study are in line with several recent reports of other rivers in Cameron Highlands such as Jelai (84 – class II), Habu (87 – class II), Telom (85 – class II), Tringkap (86 – class II) and Ringlet (84 – class II) [19].

Conclusion

It can be concluded that, present Bertam River water quality has degraded along seasonal change. This may have resulted from agricultural and domestic wastes either disposed directly or indirectly into the river. Atmospheric precipitations in this highlands was clearly observed bring much more negative influences since its play vital role in increasing several pollutant such as suspended solid and nutrient loss. An effective management of possible soil erosion from land use change of urban development, agriculture activities and domestic waste in the vicinity of the Bertam River should be planned and enforced. Moreover, good agriculture scheme practices like rain shelter cultivation, limitation of fertilizer and pesticide should be considered in this area. Therefore, main purposes of freshwater ecosystem such as drinking, irrigation and other domestic essential can be continuously contributed by Bertam River especially for Cameron Highland's population.

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