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National Institute of Ecology
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For details, contact:

Delhi Office: 366 Metro Apartments, DDA flats, Jahangirpuri, New Delhi 110033, India

Email: secretary@nieindia.org OR nieindia@gmail.com

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Effects of Anthropogenic Impact on Water Quality in Bertam Catchment, Cameron Highlands, Malaysia

M.G. RASUL[1], MIR SUJAUL ISLAM[1*], F. M. YAHAYA[1], LUBNA ALAM[2], MAZLIN BIN MOKTHAR[2]

[1] *Faculty of Civil Engineering and Earth Resources, University Malaysia Pahang (UMP), LebuhrayaTunRazak, 26300, Gambang Kuantan, Pahang, Malaysia*
[M.G. Rasul <grasulgeo@yahoo.com>; F.M. Yahaya <fadzil@ump.edu.my>]
[2] *Institute for Environment and Development (LESTARI), University Kebangsaan Malaysia (UKM), Bangi, 43600, Selongor, Malaysia* [Lubna Alam <lubna_762120@yahoo.com>; Mazlin bin Mokthar <mazlin@ukm.edu.my>]
*Corresponding author: E-mail: *sujaul@ump.edu.my*

ABSTRACT

Along the Bertam Catchment, Cameron Highlands, Malaysia, a study was conducted based on water sampling from different points. The study was done to investigate the spatial variability of the physico-chemical parameters with reference to varying anthropogenic activities. A total of sixteen water quality parameters were analyzed. Analytical results showed that electrical conductivity and total dissolved solids exhibited similar spatial variations and were higher in Lower Bertam than Upper. Total suspended solids concentrations ranged widely and were much higher than standards, due to higher soil erosion and sedimentation. Nutrient variables showed significance spatial variations influenced by anthropogenic activities. Among the tributaries, Sungai Jasar showed higher variations in almost all parameters than others. This study demonstrates that the water quality at stations around urban and agricultural areas is becoming deteriorated. Improvement of domestic waste treatment methods, agricultural practices and unplanned land clearing is pre-requisite to preserve the water quality from further deterioration.

Key Words: Bertam Catchment; Tributaries; Physico-chemical Parameters; Water Quality; Anthropogenic Activities.

INTRODUCTION

Quality of surface water varies over space and time. It performs an important role in the health of aquatic ecosystems and human beings. In any region, it is influenced by both natural processes and anthropogenic changes through alteration of its hydrochemistry. Hence, the assessment of water quality is one of the most important aspects in water resource studies that provide significant information for sustainable development and water resources management (Bu et al. 2010, Chen et al. 2012)

With intensive agricultural development, land clearing for agriculture and excessive utilization of commercial inorganic fertilizers has become a major issue and lead to increase erosion and nutrient additions. The subsequent siltation and nutrient losses to river water have caused water quality degradation around the world (Carpenter et al. 1998, Wu and Chen 2013, Kibena, et al. 2013, Glavan et al. 2013 and Bu et al. 2014). Besides, urban or residential areas with increased population, municipal sewage and industrial wastewater as well as land development are also the other sources of anthropogenic changes that import pollutant loads to the river water thus changing the water quality parameters (Mouri et al. 2013, Kibena, et al. 2013).

The Bertam River in the study area is one of the three main rivers in Cameron Highlands, Malaysia. The river system with a number of tributaries within theupper catchment areas play a vital role in Cameron Highlands as sources of water for freshwater supply, irrigation water for agricultural activities and for hydroelectricity generation and recreational activities (Gasim et al.

2009a). The river system receives agricultural runoff directly and also through tributaries, as well as domestic and municipal raw waste waters from the main urban areas. Extensive deforestation and earth bulldozing in the Highlands area for agriculture and housing development has resulted in wide spread soil erosion over the land surface (Eisakhani et al. 2009). Increasing urban population also increased the input of organic matter to the river system (Eisakhani and Malakahmad 2009). Uncontrolled sewage treatment plants and leachate from garbage dumps are also the main causes of water pollution (Gasim et al. 2009a).

Previously, the research studies on the water quality mainly concentrated in the upper Bertam region. Eisakhani and Malakahmad (2009) studied the temporal variation of water quality parameters in upper Bertam during average and high water flow period. Khalik et al (2013) studied the seasonal variation of physicochemical parameters in Bertam River and showed that the water quality has degraded with seasonal changes. There is no detailed study on the water quality of the whole Bertam catchment. Therefore, the main aim of this study is to evaluate the present status of water quality of Bertam catchment with special emphasizes on spatial variation along with its anthropogenic impacts.

MATERIALS AND METHODS

Study Area

Cameron Highlands is of the largest hill resorts in Malaysia and well known for its' agricultural and tourism activities. It is the smallest district located at west-south of Pahang State in Peninsular Malaysia and shares its boundary to Kelantan state at the northern part and Perak State at east-south part (Figure 1). The Bertam River is one of the three main rivers in Cameron Highlands playing significant key role as a source for drinking, irrigation and hydroelectricity generation.

The Bertam river catchment, the study area, has a total area of about 293.7 km^2 and is drained by a complicated river network influenced by hilly and undulating terrain system. Bertam is the main river flowing from GunungBrinchang at the upstream, through Brinchang town, Tanah Rata, Habu and into the Ringlet reservoir. Bertam River then flows to Telomriver about 24 km downstream of reservoir. The main tributaries in Upper Bertam namely SungaiBurung, Sungai Ruil, Sungai Jasar, Sungai Uluh and Sungai BatuPipih joint with the main course of Upper Bertam River at different locations before flowing into Ringlet reservoir. This study was carried out for upper part of BertamRiver and Lower Bertam until about 10 km downstream of the reservoir as all the urbanized and agricultural areas of the catchment are located within this area of interest. The study area lies between 101° 20' 00" to 101° 27' 30" E longitude and 4° 23' 30" to 4° 31' 30" N latitude (Figure 1).

The topography of the study area is an undulating mountainous landscape. The elevation of the area ranges from 2021.7m to 896.4m at above mean sea level. Temperatures are mild with the characteristics of 24^{0}C in the daytime and 14 ^{0}C at night. The average annual rainfall is 2660 mm having two peaks in May and October. The cold and temperate weather makes the area most suitable for many agricultural products. Agriculture is the second largest land use pattern followed by forest, producing vegetables, tea, flowers, fruit and other crops in the area (Aminuddin et al. 2005, Gasim et al. 2009b).

Sampling Program

Sampling program was conducted during January to June 2014 to collect water sample from selected 12 stations. Criteria for selection of sampling points were based on land use pattern, major river network and location for potential point and non-point pollution sources. A portable Global Positioning System (Garmin 76Cx) was used for determining the definite coordinate positions and elevations of the sampling stations. The sampling stations were designated based on their locations at Upper Bertam (UB-1, UB-2, UB-3 UB-4 and UB-5), Lower Bertam (LB-1 and LB-2) and the tributaries of Upper Bertam (TB-1, TB-2, TB-3, TB-4 and TB-5). Sampling stations along with their coordinate, elevation and selection criteria are presented in Table 1.

Water sample were collected at 15 cm depth from the surface of river water following the grab method. Three replicate samples were collected at each sampling points. Sample was collected using 1L HDPE bottles for physico-chemical analysis and 300mL amber glass bottles for BOD test. All samples were stored in a cooler box filled with ice packs to keep the temperature below 4^{0}C before transferring to the laboratory where the water samples were stored in a cold room at temperature below 4^{0}C, without adding chemical preservatives until analysis. APHA and HACH standard procedures were followed during sampling, sample transportation and preservation (APHA 2005, HACH 2012).

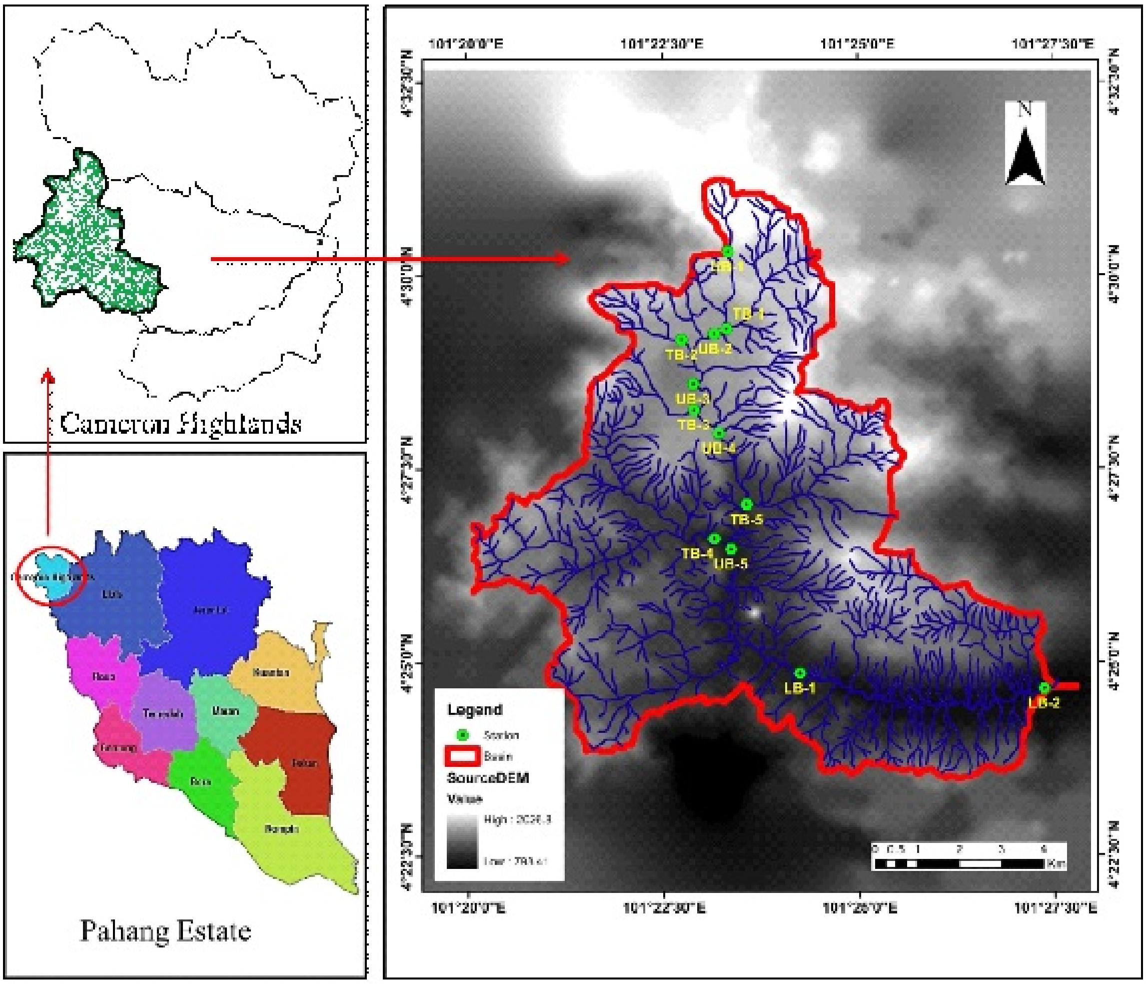

Figure 1. Location map and sampling stations in the study area

Table 1. Description of sampling locations in Bertam Catchment area

Catchment	Station	Latitude	Longitude	Elevation, m	Station Description and Selection Criteria
Upper Bertam (Main River)	UB-1	04°30'18.4"	101°23'19.9"	1635	Sloppy mountainous and forest area. Source area of the river.
	UB-2	04°29'15.0"	101°23'09.3"	1463	Adjacent to Brinchang town and after confluence of Sungai Burung (tributary)
	UB-3	04°28'36.0"	101°22'53.1"	1450	Adjacent to Taman Sedia residential area and after confluence of Sungai Ruil (tributary)
	UB-4	04°27'57.6"	101°23'12.7"	1443	After Tanah Rata town and confluence of Sungai Jasar.
	UB-5	04°26'27.9"	101°23'21.8"	1079	Before Ringlet Reservoir, after confluences of SungaiBatuh Pipih and Sungai Uluh.
Upper Bertam (Tributaries)	TB-1	04°29'18.8"	101°23'18.8"	1469	Sungai Burung; farming and residential area.
	TB-2	04°29'10.3"	101°22'44.3"	1459	Sungai Ruil; village area.
	TB-3	04°28'15.7"	101°22'53.6"	1428	Sungai Jasar; impact of residential area and sewage treatment plant
	TB-4	04°26'36.0"	101°23'09.0"	1125	Sungai BatuhPipih; around tea plantation and agricultural area
	TB-5	04°27'02.3"	101°23'33.8"	1087	Sungai Uluh; around tea and farming area
Lower Bertam	LB-1	04°24'51.3"	101°24'14.5"	1019	Intensive farming and residential area
	LB-2	04°24'39.1"	101°27'21.9"	915	Farming area

Physico-chemical parameters of water quality were measured in situ for temperature, pH, dissolved oxygen, conductivity, total dissolved solids, salinity and turbidity using portable YSI (model 6600-M) multisensor probe. The probes of the YSI model 6600-M were calibrated in the laboratory before each sampling program.

Laboratory Analysis

Different chemical parameters of the collected samples were analyzed following the standard methods of analysis (APHA 2012). All parameters were finally measured using HACH DR 5000 spectrophotometer. COD measurement was analyzed using reactor digestion and colorimetric determination method whereas BOD was done by 5 days incubator method as BOD_5 by keeping the samples in incubator at 20^0C temperature for 5 days. Total Suspended Solid (TSS) was determined using gravimetric method.

Data Analysis

Graphical analyses (box and whisper plot, bar diagram and scatter plot) of the measured values of the water quality parameters were used to interpret the spatial variation among the parameters and its relation to source pollution. Statistical analysis was carried out to find out the descriptive summary and correlation matrix for the identification of relations among the parameters. IBM SPSS statistics software (version 20) was used for the statistical analysis.

RESULT AND DISCUSSION

Physico-chemical Parameters in Bertam Catchment

The basic statistical data (the range, mean value and standard deviation) of the collected water samples from twelve stations along the Bertam River and its main tributaries is briefly summarized in Table 2 and Table 3**.** In the data, the high spreading of standard deviation of measured variables indicates a strong spatial variability in the composition between the samples (Kilonzo et al. 2014).

Mean water temperature of Bertam River was 20.04 ºC with a range of 16.35ºC to 25.55 ºC during the study period (Table 2). There was no significance variation in water temperature among the sampling stations (Figure 2) and was within the acceptable limit of Malaysian Standard (DOE 2008). The slightly increasing trend of temperature was followed by the changing elevations toward the downstream except LB-1. This was due to higher concentrations of nutrients and EC values at the station. Correlation matrix also showed a strong correlation of temperature with EC and nutrients (Table 4). Furthermore, the present data of temperature is more or less similar to the atmospheric condition as Cameron Highland considered having cool climate during day time (Eisakhani and Malakahmad 2009).

The mean pH values of water at all sampling stations ranged from 6.51 to 7.24 with an average of 6.87 and did not show a significance variation (Figure 2). In the main Bertam River, the lowest mean pH value (6.51) was recorded at the station UB-1 located at the mountainous forest area in the Upper Bertam region, while the highest pH (7.24) was found at the station LB-1 in Lower Bertam region located near the urban and extensive farming area. Among the tributaries, Sungai BatuhPipih (TB-4) showed the lowest pH value (6.52) followed by Sungai Jasar (TB-3) and Sungai Uluh (TB-5) with pH values 6.82 and 6.88. The range of average pH values recorded at all stations in the study area was within the normal threshold range for Malaysian river water (DOE 2010).

The mean DO values ranged from 5.28 mg L^{-1} to 8.39 mg L^{-1} with an average of 7.08 mg L^{-1}. In the main Bertam, the average highest DO concentration (8.39 mg L^{-1}) was recorded at UB-5 followed by UB-1 with a concentration of 7.59 mg L^{-1}; while the lowest (5.28 mg L^{-1}) concentration was recorded at station LB-1. Among the tributaries, lowest concentration (5.40 mg L^{-1}) was recorded at Sungai Jasar (TB-3) while highest concentration (7.80 mg L^{-1}) was found at Sungai Uluh (TB-5) (Figure2). The lowest concentration of DO at station LB-1 might be due to the combined effect of urban and agricultural wastes and at station TB-3 was due to domestic waste of residential areas. Similar results were obtained by Mallin et al. (2009), Mallin and McIver (2012).

Table 2 shows that the EC values ranged from 1.67µS cm^{-1} to 170.33µS cm^{-1} with a mean value of 68.80 µS cm^{-1}. In the Bertam River, the lowest mean value was recorded at station UB-1 with a value of 11.67µS cm^{-1}, while the highest value (163.00 µS cm^{-1}) was found at station LB-1. The distribution of EC among the sample stations of main Bertam River showed spatial variability (Figure 2). On the other hand, TDS value in the studied area varied from 8.78 mg L^{-1} to 111.78 mg L^{-1} with an average mean value of 47.15 mg L^{-1}. The highest value

Table 2. Statistical summary of physical parameters for surface water samples in the Bertam Catchment area

Station		Temp (°C)	pH	DO (mg L^{-1})	EC (µS cm^{-1})	TDS (mg L^{-1})	Turbidity (NTU)	TSS (mg L^{-1})
Main River								
UB-1	Range	16.21-16.50	6.24-6.89	7.40-7.88	8.00-15.00	6.00-10.00	0.00-0.01	2.00-11.00
	Mean ± SD	16.35±0.12	6.51±0.24	7.59±0.18	11.67±2.60	8.78±1.86	0.01±0.00	5.67±3.20
UB-2	Range	17.91-18.53	6.69-8.06	7.14-7.30	31.00-78.00	24.00-58.00	6.80-56.10	11.00-86.00
	Mean ± SD	18.30±0.29	7.24±0.47	7.24±0.05	64.89±15.49	47.22±10.58	25.54±22.24	40.67±30.66
UB-3	Range	18.55-18.93	6.15-7.17	7.04-7.21	32.00-70.00	35.00-55.00	28.60-98.00	55.00-175.00
	Mean ± SD	18.74±0.16	6.80±0.45	7.10±0.06	56.00±11.64	42.89±6.97	67.67±28.97	124.33±49.88
UB-4	Range	18.66-20.18	6.17-7.94	6.30-6.58	57.00-71.00	38.00-53.00	33.70-86.00	50.00-110.00
	Mean ± SD	19.46±0.62	6.96±0.59	6.42±0.09	65.22±5.80	44.56±4.88	55.90±20.62	83.44±22.69
UB-5	Range	20.02-20.27	5.73-7.50	8.20-8.57	46.00-71.00	33.00-45.00	78.20-950.00	39.00-1299.00
	Mean ± SD	20.17±0.09	6.66±0.68	8.39±0.11	56.78±9.87	38.56±5.08	392.89±396.75	516.44±527.11
LB-1	Range	24.30-26.92	7.06-7.45	5.05-5.64	98.00-202.00	61.00-131.00	56.00-79.50	77.00-171.00
	Mean ± SD	25.55±0.99	7.23±0.11	5.28±0.17	170.33±35.20	111.78±23.82	69.07±8.13	109.00±35.11
LB-2	Range	22.66-24.81	6.35-6.92	7.20-7.33	69.00-163.00	48.00-106.00	55.40-194.00	94.00-244.00
	Mean ± SD	24.02±1.01	6.56±0.25	7.27±0.05	127.11±30.86	83.89±19.76	119.24±55.25	174.78±55.72
Tributaries								
TB-1	Range	17.23-18.12	6.27-8.12	7.47-7.66	35.00-95.00	22.00-46.00	5.00-87.20	13.00-132.00
	Mean ± SD	17.77±0.41	7.17±0.70	7.55±0.06	61.44±15.79	38.00±8.72	33.33±37.87	54.00±49.11
TB-2	Range	18.25-18.45	6.53-8.03	7.36-7.51	18.00-45.00	15.00-33.00	19.30-336.00	32.00-675.00
	Mean ± SD	18.32±0.08	7.11±0.45	7.43±0.06	36.67±10.04	26.78±6.72	158.00±125.25	285.25±241.75
TB-3	Range	20.27-21.64	6.30-7.70	4.57-5.96	40.00-119.00	30.00-70.00	43.10-153.00	53.00-165.00
	Mean ± SD	20.80±0.60	6.82±0.42	5.40±0.51	69.44±25.66	51.78±14.02	82.56±32.97	97.56±34.05
TB-4	Range	19.16-20.74	6.25-7.60	7.63-7.75	45.00-54.00	32.00-38.00	23.00-68.10	51.00-215.00
	Mean ± SD	20.09±0.71	688±0.45	7.71±0.04	50.56±3.71	34.33±3.73	41.22±19.00	118.67±57.84
TB-5	Range	20.09-21.75	5.63-7.48	7.45-7.65	49.00-59.00	33.00-42.00	8.30-35.30	4.00-47.00
	Mean ± SD	20.92±0.71	6.52±0.71	7.58±0.08	54.44±3.97	37.22±3.73	18.14±9.10	22.78±15.17
All	Average	20.04	6.87	7.08	68.80	47.15	88.63	136.05

(111.78 mg L^{-1}) was recorded at the station LB-1 and the lowest value of TDS was recorded at UB-1 which was similar as EC. Among the turbidities, the lowest EC and TDS value was observed in TB-2 (Sungai Ruil) while the highest EC and TDS value is observed in TB-3 (Sg. Jasar). As the station UB-1 is located at the mountainous forest, the water displayed a very low EC and TDS values. This is mainly due the origin of the river water from rain water. From this station to downward in the Upper Bertam, addition of the domestic wastewater from residential area increased their concentration in EC and TDS at station UB-2. The EC and TDS values slightly decreased at station UB-3 and UB-4 due to the addition of water from TB-2 (Sungai.Ruil) and later on TB-4 (Sungai BatuPipih) and TB-5(Sungai. Uluh) which containedless EC and TDS. Similar results were obtained by Eisakhani and Malakahmad (2009). The EC and TDS showed the similar spatial variability pattern among the sampling stations in the studied area (Figure 2). Moreover, correlation matrix showed a strong positive correlation among EC, TDS and nutrients variables (Table 4).

Regarding water clarity, the mean turbidity of Bertam River was 88.63 NTU, with a range of 0.01 to 392.89 NTU. The turbidity showed a wide range of variation among the stations (Figure 2). The highest turbidity found in water at station UB-4 located at the downward station of Upper Bertam, while the lowest value was recorded at station UB-1, near the forest area.

The mean concentration of TSS in water of Bertam River is 136.05 mg L^{-1}, with a maximum value of 516.44mg L^{-1} and minimum of 5.67 mg L^{-1}. The highest concentration was observed at station UB-4 and lowest concentration at UB-1. There was a noticeable increment of total solids in the Bertam River as a result of inputs of particulates in the river through the higher soil erosion and sediment transport due to anthropogenic activities in the study area.

Table 3. Statistical summary of chemical parameters for surface water samples in the Bertam Catchment area. All parameters are mg L^{-1}

Station		COD	BOD	TN	NH_3-N	NO_3-N	NO_2-N	TP	PO_4-P	SO_4
Main River										
UB-1	Range	09.00-19.00	0.35-5.95	0.20-1.00	0.02-0.06	0.01-0.20	0.00-0.00	0.12-0.48	0.12-0.40	0.00-2.00
	Mean± SD	13.56±3.09	3.45±2.02	0.40±0.27	0.40±0.01	0.08±0.06	0.00±0.00	0.32±0.11	0.20±0.09	0.44±0.73
UB-2	Range	16.00-38.00	8.05-11.05	1.90-3.90	0.86-2.12	0.04-0.90	0.03-0.15	0.79-2.01	0.50-1.03	0.00-4.00
	Mean±SD	20.78±7.22	9.89±1.08	2.89±0.70	1.37±0.56	0.43±0.31	0.06±0.04	1.07±0.39	0.80±0.17	1.11±1.69
UB-3	Range	8.00-35.00	5.50-11.85	2.50-3.50	0.76-2.20	0.40-0.88	0.04-0.76	0.53-1.30	0.48-0.93	2.00-7.00
	Mean±SD	19.44±7.70	8.42±2.45	2.97±0.31	1.28±0.54	0.66±0.17	0.22±0.29	1.01±0.25	0.74±0.15	3.67±1.58
UB-4	Range	13.00-41.00	5.95-13.95	2.50-7.30	0.55-1.36	0.50-1.20	0.13-0.20	0.66-1.21	0.34-0.76	0.00-10.00
	Mean± SD	23.00±7.95	9.33±3.44	4.00±1.45	0.90±0.32	0.76±0.24	0.16±0.063	0.94±0.17	0.50±0.16	3.67±3.87
UB-5	Range	8.00-40.00	1.25-10.45	2.00-6.90	0.23-1.94	0.60-1.20	0.03-0.05	0.42-2.10	0.33-1.52	1.00-14.00
	Mean± SD	21.44±13.00	5.87±3.64	4.24±1.66	0.99±0.73	0.81±0.20	0.04±0.01	1.22±0.75	0.81±0.32	3.78±4.09
LB-1	Range	16.00-41.00	5.85-21.45	3.80-10.9	0.89-1.95	1.90-3.70	0.11-0.18	1.46-2.80	0.52-1.51	7.00-13.0
	Mean± SD	27.44±7.50	11.31±5.56	6.19±2.11	1.38±0.40	2.83±0.63	0.15±0.03	2.02±0.48	1.09±0.35	10.22±2.49
LB-2	Range	11.00-22.00	2.10--7.35	3.20-6.80	0.28-1.23	2.80-3.70	0.03-0.09	0.95-2.35	0.93-1.77	4.00-15.00
	Mean± SD	15.11±4.04	4.60±2.15	4.91±1.10	0.55±0.31	3.18±0.30	0.05±0.02	1.63±0.51	1.28±0.26	7.56±3.32
Tributaries										
TB-1	Range	13.00-24.00	5.75-19.20	1.40-3.30	0.65-1.08	0.03-1.20	0.01-0.03	0.63-1.89	0.42-0.88	0.00-2.00
	Mean± SD	17.11±4.46	11.41±5.44	2.38±0.58	0.81±0.18	0.65±0.47	0.01±0.01	1.02±0.49	0.68±0.16	0.44±0.73
TB-2	Range	10.00-26.00	3.05-12.50	1.30-2.30	0.50-1.56	0.10-0.20	0.002-0.02	0.38-0.93	0.12-0.49	0.00-5.00
	Mean± SD	16.00±5.66	6.49±3.24	1.82±0.33	0.95±0.41	0.16±0.05	0.01±0.00	0.55±0.18	0.30±0.12	1.59±1.60
TB-3	Range	34.00-63.00	11.20-15.10	3.50-5.50	1.76-3.38	0.10-0.70	0.01-1.22	0.86-1.89	0.50-0.87	3.00-12.00
	Mean± SD	43.78±13.45	13.49±1.23	4.34±0.71	2.72±0.65	0.27±0.20	0.18±0.39	1.53±0.31	0.68±0.12	6.66±3.24
TB-4	Range	7.00-22.00	0.40-10.10	0.40-4.30	0.20-0.33	0.50-1.20	0.01-0.012	0.53-1.90	0.27-0.83	0.00-10.00
	Mean± SD	13.67±5.07	4.33±4.28	2.43±1.05	0.26±0.04	0.77±0.24	0.01±0.00	1.13±0.56	0.45±0.17	3.56±3.81
TB-5	Range	8.00-30.00	0.90-10.15	0.50-5.70	0.10-0.35	0.40-0.80	0.00-0.01	0.64-2.50	0.49-1.18	0.00-1.00
	Mean± SD	15.22±7.03	4.87±3.92	2.76±1.73	0.17±0.09	0.54±0.13	0.01±0.00	1.50±0.61	0.75±0.21	0.22±0.44
All	Average	20.55	7.79	3.28	0.95	0.93	0.07	1.16	0.69	3.56

Table 4. Correlation coefficient for water quality parameter in the Bertam Catchment area

Variables	Temp.	TDS	EC	TSS	Turbidity	TN	NO_3-N	NH_3-N	TP	PO_4-P
Temp	1									
TDS	0.844**	1								
EC	0.843**	0.953**	1							
TSS	0.057	-0.001	-0.018	1						
Turbidity	0.082	0.033	0.021	0.971**	1					
TN	0.679**	0.651**	0.640**	0.216*	0.237*	1				
NO_3-N	0.844**	0.813**	0.830**	0.068	0.077	0.582**	1			
NH_3-N	0.147	0.311**	0.242*	0.245*	0.281**	0.356**	-0.029	1		
TP	0.676**	0.680**	0.689**	0.205*	0.273**	0.644**	0.610**	0.427**	1	
PO_4-P	0.647**	0.679**	0.670**	-0.014	0.040	0.480**	0.671**	0.205*	0.734**	1

** Correlation is significant at the 0.01 level (2-tailed) * Correlation is significant at the 0.05 level (2-tailed).

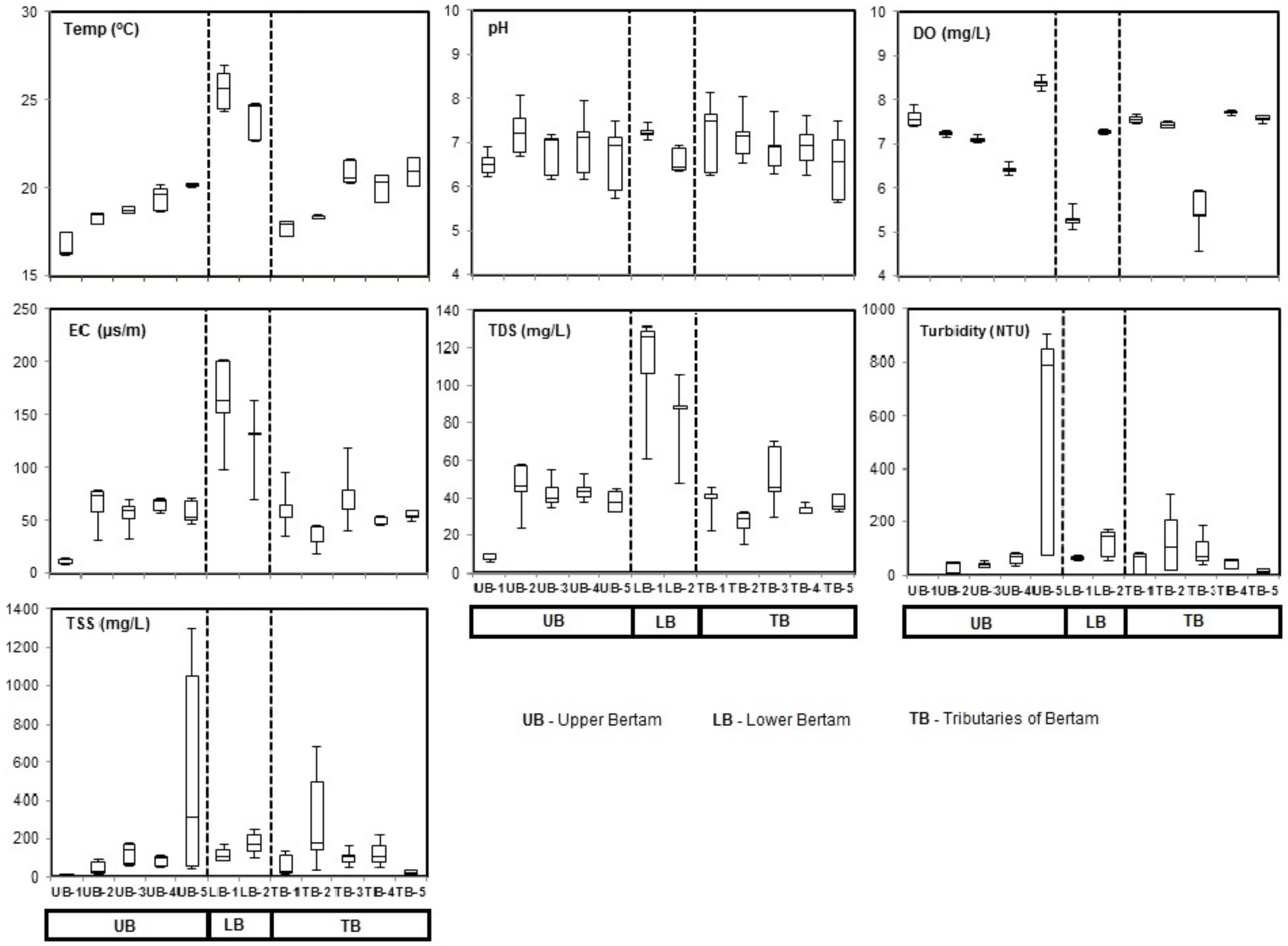

Figure 2. The spatial variations of physico-chemical parameters in Bertam Catchment area

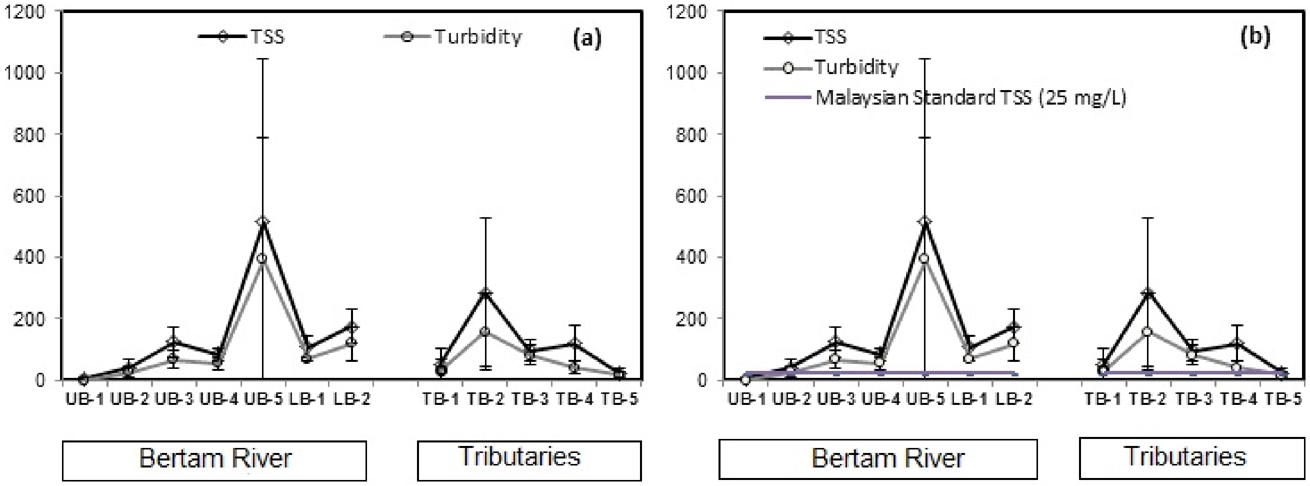

Figure 3. (a) Trend of TSS and Turbidity in the study area and (b) comparison with Malaysian Standard

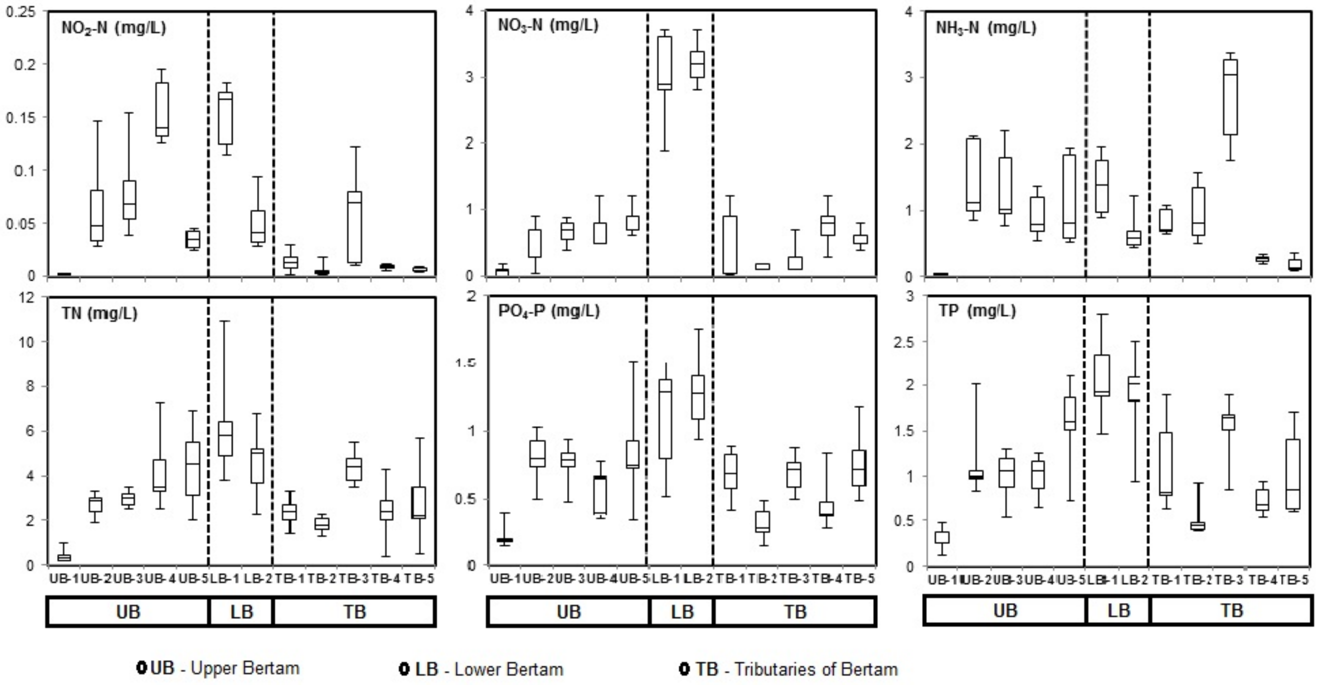

Figure 4. The spatial variations of nutrient variables in the Bertam River Catchment area

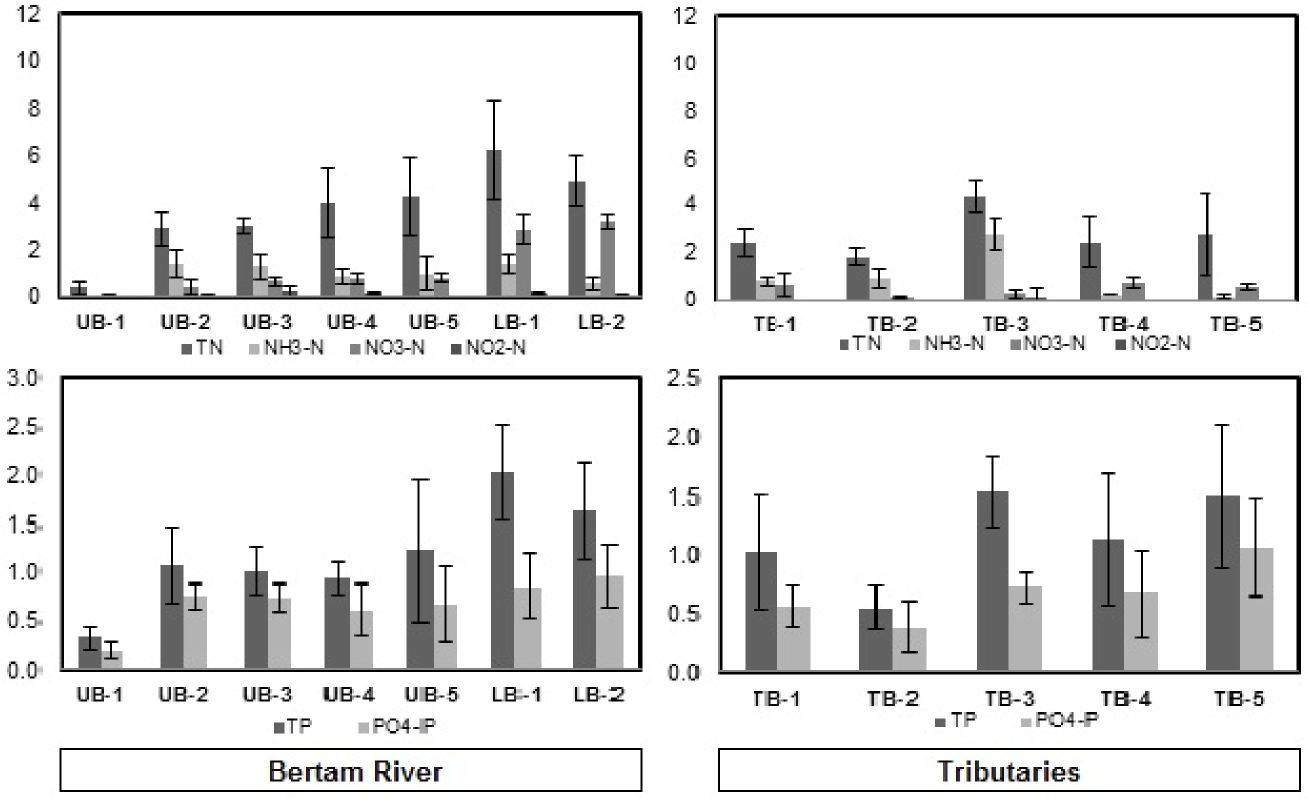

Figure 5. Changes of nutrient variables (TN, NO_3-N, NH_3-N, TP and PO_4-P) at different stations in the Bertam River Catchment area

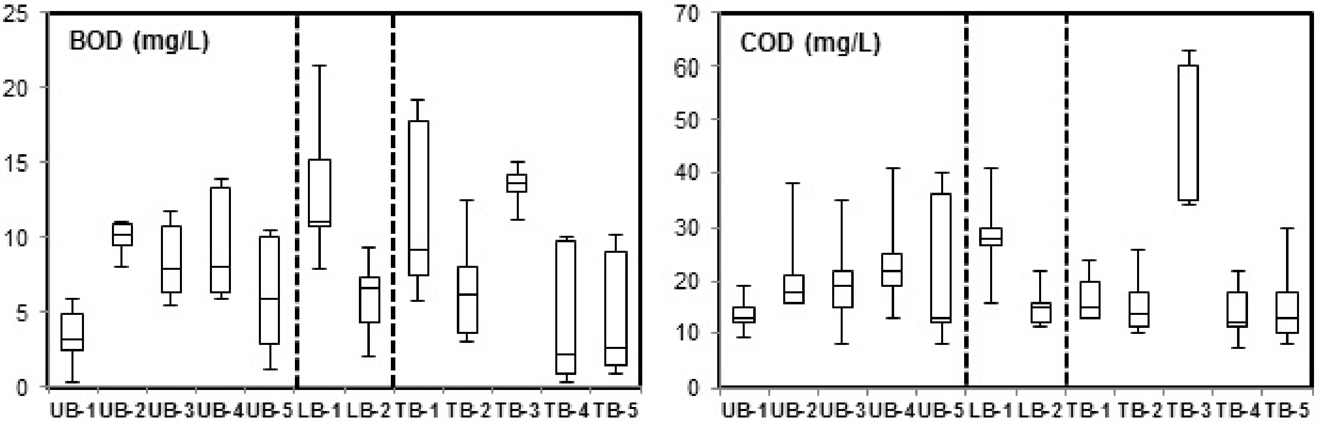

Figure 6. The spatial variation of BOD and COD values in the Bertam River and its tributaries.

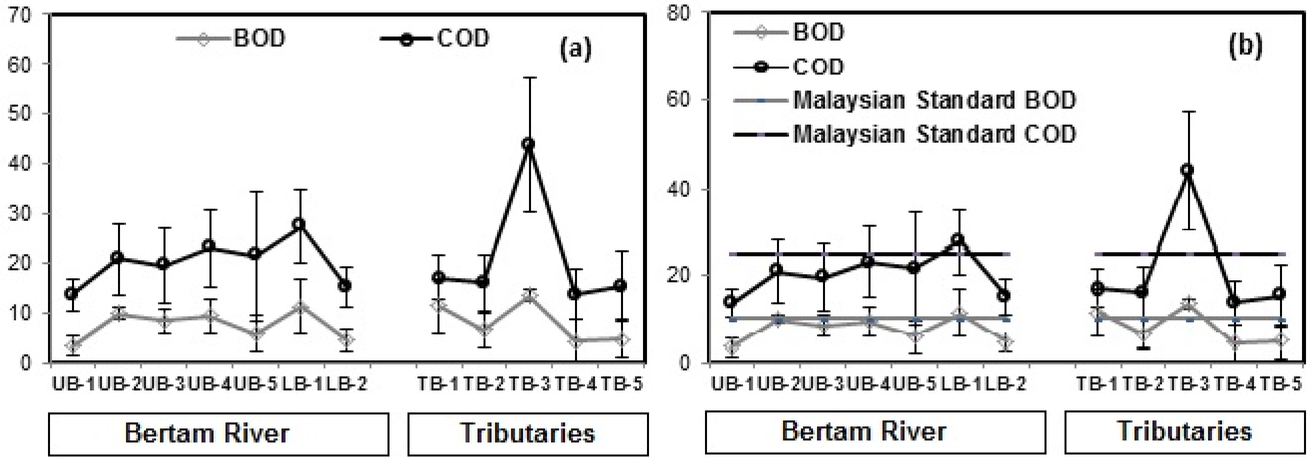

Figure 7. (a) The trend of BOD and COD concentration at different stations and (b) comparison with Malaysian Standard

Among the turbidities, station TB-2 (Sungai.Ruil) showed the highest TSS concentrations while station TB-1 (SungaiBurung) showed the lowest during the study period. There was the similar spatial variation pattern between turbidity and TSS among the sampling stations (Figures 2 and 3). Correlation matrix also showed a strong positive correlation between TSS and Turbidity (Table 4). The concentration of total solids at most of the stations of BertamRiver and its tributaries showed higher values than the limit of Malaysian Standard (Figure 3). The main reason was concluded by many researchers in their studies that the agricultural coverage and land pattern development strongly influenced the total suspended solids and sediments in the water (Kibena.et al. 2013, Mouri et al. 2013 and Glavan et al. 2013).

Variation of the Nutrient Variables

The mean value of nitrate-nitrogen (NO_3-N) ranged from 0.08mg L^{-1} to 3.18mg L^{-1} with a mean average of 0.93mg L^{-1} among the twelve stations of the study area (Table 3). The highest average concentration of NO_3-N was observed in the Lower Bertam region at station LB-2 followed by station LB-1(Figure 4). The lowest NO_3-N was observed at station UB-1 which is the point of origin of the BertamRiver at Upper Bertam region located at the mountainous area. The concentration of NO_3-N showed increasing spatial variation toward down to the Upper Bertam region from station UB-1 to UB-4. Among the tributaries, the highest concentration of NO_3-N was recorded at station TB-4 (Sungai BatuPipih) followed by station TB-1(Sungai Burung) and TB-5 (Sungai Uluh).

The stations (LB-1, LB-2, TB-4, TB-1 and TB-5) are located around the agricultural areas showed higher NO_3-N (Figure 5). This was attributed to the use of nitrogenous fertilizers in agriculture and vegetable farming areas (Shrestha and Kazama 2007). Ye et al. (2009) suggested that the agriculture sub-watershed has high concentration of NO_3-N and the forest dominated region has low concentration of most nutrient variables in Xiangxi basin, China.

The values of ammoniacal-nitrogen (NH_3-N) ranged from 0.04 to 2.72 mg L^{-1} with an average mean of 0.95 mg L^{-1}. In the Upper Bertam, the concentration of NH_3-N was extremely low (0.04 mg L^{-1}) at station UB-1, whereas the highest value was found just at the next station UB-2 (Figure 4).After that the values gradually decreased towards down stations due to the influences of different tributaries. The range of NH_3-N recorded at the stations of Lower Bertam showed lower values than the Upper Bertam. Among the tributaries, station TB-3 (Sungai Jasar) showed the highest concentration of NH_3-N (2.72 mg L^{-1}) followed by station TB-2 (Sungai Ruil). The reason behind the highest concentration was the waste water from residential area and the sewage treatment Plant. In the study area, the higher concentrations of NH_3-N were recorded mainly at the stations that were attached by urban domestic waste (UB-2, UB-3, TB-2 and TB-3) (Figure 5). This pollutant may originate from decomposition of nitrogen containing organic compounds such as proteins and urea occurring in municipal wastewater discharges (Vega et al.1998). The spatial distribution of Total nitrogen (TN) showed variation within ranges of 0.40 to 6.19 mg L^{-1} with an average mean of 3.28 mg L^{-1} among the stations. The highest TN was recorded at station LB-1 (6.19 mg L^{-1}) in the Lower Bertam. A spatial increasing variation was observed in the Upper Bertam from its starting point at station UB-1 (0.40 mg L^{-1}) to UB-4 (4.24 mg L^{-1}) (Fig 4).The highest value of TN was recorded at station TB-3 (Sungai Jasar) (2.73 mg L^{-1}) among the tributaries followed by station TB-4 (Sungai BatuhPipih) and station TB-5 (Sungai Uluh) (Figure 5).TN showed a similar trend asNO_3-N. The reason was behind the combined effect of non-point pollution from the agricultural fields and residential wastewater around the stations of the Bertam River and its tributaries. The diversification of the agriculture practices, involving the use of fertilizers on both cash crops and food crops was a potential source of high nitrogen concentrations (Kilonzo and Obando 2012, Kibena.et al. 2013).

The mean average concentration of phosphate-phosphorous (PO_4-P) was 0.69mg L^{-1} with a range of 0.20 to 1.28 mg L^{-1} among the sampling stations in the studied area (Table 3).The lowest concentration (0.20 mg L^{-1}) was observed at the station UB-1 while the highest average concentration (1.28 mg L^{-1}) was recorded in the Lower Bertam at station LB-2 followed by LB-1 (Figure 4). Among the tributaries, the highest concentration of PO_4-P was found at station TB-5 (Sungai Uluh) followed by TB-1(Sungai Burung) and TB-3 (Sungai Jasar). Similarly, Total phosphorous (TP) distribution showed same spatial trend to PO_4-P, with high values (2.02 mg L^{-1}) at station LB-2 and the low value (0.32 mg L^{-1}) at station UB-1. Higher concen-tration of PO_4-P and TP at stations LB-2, LB-1, TB-1and TB-3 indicated (Fig 5)that agricultural runoff containing fertilizers were probably the major causes for concen-tration of PO4-P and TP (Milovanovic 2007, Mouri et al. 2013) .On the other hand, the concentration at UB-2 and UB-3 may be due to the residential and municipal wastewater discharges (Vega et al. 1998).It was also observed that the phosphorous concentration followed the similar spatial trend as TN among the all sampling stations. TP and TN also showed a strong positive correlation (Table 4).

Variation of Organic Matter (As COD and BOD)

The mean average concentration of biological oxygen demand (BOD) ranged from 3.45 mg L^{-1} to 13.49 mg L^{-1} with a mean average of 7.79 mg L^{-1} (Table 3). The average values of BOD showed spatial variation among the stations. The highest BOD is found at station LB-1 while the lowest value was marked at station UB-1. Among the tributaries highest BOD value was recorded at station TB-3 (Sungai Jasar) while lowest value was found at station TB-4 (Sungai BatuPipih) (Figure 6). Chemical oxygen demand (COD) showed more or less similar trend as BOD among all the stations (Figure 7). The higher value of BOD and COD at station LB-1 (11.31 mg L^{-1} and 27.44 mg L^{-1} respectively) and TB-3 (13.49 mg L^{-1} and 43.78mg L^{-1} respectively) indicated that the domestic wastewater discharged from residential area into the river stream. Many researchers have mentioned that high COD value deteriorated water quality likely caused by the discharges of municipal wastewater (Kibena et al.,2013).

CONCLUSION

The analytical results obtained during this study have been evaluated to identify the spatial variation of measured variables and to interpret the reasons behind the possible contamination of the surface water in the Bertam catchment area. The distribution of EC and TDS showed similar trend of spatial variability pattern with a very low values at the point of origin in the forest area and gradually increased downward.Strong positive correlation was observed between turbidity and TSS and also showed same spatial variation pattern among the stations. The values gradually increased downward in the upper catchment and dropped in the lower catchment due to the effect of Ringlet reservoir. Noticeable increment of total suspended solids was found in most of the stations of the BertamRiver and its tributaries as a result of inputs of particulates through the higher soil erosion and sedimentation. Considerable ranges of nutrient parameters (TN, NO_3-N, NH_3-N, TP and PO_4-P) were found at different locations with relation to varying human activities. Higher concentration of total nitrogen, nitrogen-nitrate, total phosphorous and phosphate phosphorous were found in Lower Bertam region than Upper showed more or less increased spatial variation trend toward downward. Higher concentrations were mostly observed around the stations influenced by agricultural runoff within the agricultural zone. On the other hand, the concentration of NH_3-N is higher in stations of the Upper Bertam. The high NH_3-N concentrations were recorded mainly in the areas that were influenced by urban domestic waste water. The river received a higher organic loading (as BOD and COD) at some stations surrounded by urban and residential areas due to the discharge of domestic wastewater. Among the tributaries, Sungai Jasar found to be more polluted containing higher EC, TDS and NH_3-N due to the addition of untreated municipal wastewater from residential establishments. Alternatively, higher NO_3-N and PO_4-P were observed in Sungai BatuPipih and Sungai Burung due to effect of surrounding agricultural activities. From the analytical results, it was found that the water quality at the site near forest was much more clear and unpolluted in terms of all parameters. It could therefore be concluded that soil erosion and sediment transport due to poor agriculture practices and land clearing as well as nutrient enrichment due to agricultural activities and untreated domestic sewage discharge in residential areas were the main reasons behind the variation of affected water quality of Bertam River and its tributaries. It is therefore important to implement compatible policies and programs for improvement in domestic waste water treatment methods, in poor agriculture practices and in proper land use management for sustaining the water quality from further deterioration.

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