ORIGINAL ARTICLE

Heavy Metals Contamination and Potential Health Risk in Highland River Watershed (Malaysia)

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ABSTRACT

Introduction: Extensive agriculture activities in the upstream area causes pollutants flow to the downstream area and contaminate the drinking water resources. **Methods:** Water samples were collected from 27 sampling points of Bertam River in Cameron Highlands, during wet season in September 2017 for physicochemical properties and heavy metals analyses. Potential health risk was calculated based on the heavy metals concentration detected. **Results:** The pH value of the river ranged from neutral to slightly acidic (6.15-7.01). The overall mean level of turbidity (109.94 ± 160.73 NTU), DO (7.86 ± 0.71 mg/L), E. coli (5191.00 ± 14937.42 CFU/100 mL), and NH3-N (0.85 ± 0.54 mg/L) were exceeded the National Standard for Drinking Water Quality (NSDWQ) (Ministry of Health Malaysia). The concentration of heavy metals were in the following order; Fe>Al>Cu>Zn>Pb>Cd. The overall mean concentration of Cd (0.015 ± 0.007 mg/L), Fe (0.442 ± 0.191 mg/L) and Pb (0.021 ± 0.005 mg/L) were exceeded the national standard (NSDWQ). The non-carcinogenic health risk for adult and children from daily water consumption was within an acceptable risk. There is a potential cancer risk through Cd exposure in the drinking water where the risk higher among children (4.92 x 10-3), followed by adult male (3.06 x 10-3) and adult female (2.98 x 10-3). **Conclusion:** Significant heavy metals contamination and health risk through water consumption were observed in the highland river watershed, possibly due to the anthropogenic activities.

Keywords: Water quality, Heavy metal, Cameron Highlands, Agriculture, Bertam River

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INTRODUCTION

The highland region in Peninsular Malaysia is associated with a complex network of river basins. The region includes the upper of Perak-Galas, Pergau, Kinta-Jelai, Jelai-Tahan, Selangor-Semantan, and Endau-Rompin (1). Among the highly developed highland areas in Malaysia are Bukit Fraser, Genting Highland and Cameron Highlands in Pahang, Lojing in Kelantan and Kundasang in the Malaysia Borneo Sabah. Cameron Highland is one of the most famous retreat locations in Malaysia that located in the high elevation of Titiwangsa Range, with the highest peak is Gunung Irau (2110 m). More than 74% of the total area has an elevation more than 1000 m with a cold climate and scenic landscape. The average temperature here is between 17°C to 20°C all year round. The areas that have elevation more than 1000 m are categorized as mountains, 100 to 1000 m as hills, and areas with an elevation of 30 to 100 m as developable land (2). About 18,226.4 ha or 26% of the area in Cameron Highland having steep slopes with a gradient greater than 25° and 2,039 ha or 3% with a gradient greater than 35° (3). Areas with steep slopes exceeding 25° have high risk of soil erosion and not suitable for development.

The main economic activity in Cameron Highland is agriculture and tourism. The net agriculture production in 2015 was reported as 808,592 Mt equivalents to USD 749,048 (4). The major concern arises and widely discussed is the risk of drinking water contamination in the area from the rampant agriculture and tourism activities. The river water source in the highland watershed is susceptible to pollution from the upstream (5). There are three main rivers that flow across Cameron Highland which are; Telom River (37 km) (north), Bertam River (20 km) (central region), and Lemoi River (16 km) (south). These rivers serve as freshwater sources, hydroelectricity generation under Cameron Highland hydroelectric power scheme, irrigation for agriculture purposes, and recreational activities (2).

Bertam River is the most affected area by the rampant development in Cameron Highland as it flows across the highly dense residential area and agriculture farm at the west part of Cameron Highland which comprises of the main town of Brinchang, Tanah Rata, Habu, Lembah Bertam, and Ringlet. Additionally, there are three water treatment plants (WTP) in this area located at Kuala Terla, Brinchang and Habu. The Bertam River tributary name as Ulong River is the raw water supply for Habu. This river merge and form a main river network downstream and eventually a raw drinking water supply for the area of Pahang, Kelantan and Perak (1).

The contamination of rivers located in the upstream may cause the contaminants influx toward the downstream that mainly a source of raw water for the WTP. This creates health risk to the population at the downstream area, such as at district Lipis, Jerantut, Temerloh, Maran, and Pekan (6). Thus, it is crucial to conduct the health risk assessment especially for population that utilize the downstream river as sources of raw water for WTP. The importance of health risk assessment is to distinguish the potential health risk associated with toxic pollution in water such as heavy metals, through ingestion by estimation the risk through Chronic Daily Intake (CDI), hazard quotient (HQ) and hazard index (HI) calculation. Rampant and unplanned development for agriculture, urbanization, deforestation, hotels and residential areas create stress on the environment especially in river system and water bodies (1, 7-8). Land encroachment on river reserve areas with the agriculture, residential and infrastructures have increased the sedimentation load and particles from the surrounding land washed into the water bodies, which in turn deteriorates water quality. The instability of the land slopes can trigger the soil erosion and landslides in the highland areas, thus give the main reason why the areas are classified as fragile and sensitive ecosystems (1-2, 9-12).

Moreover, the highlands topography causes the continuous flow of pollutants from upstream to downstream of the river. The soil stability of highland area is low and prone to soil erosion and landslide which eventually introduce into water bodies and increase the siltation and sedimentation rate (11). The highland slope also intensified the transportation of the contaminants from agricultural soils into the river system (13). Unsustainable usage of Phosphate fertilizers in agriculture farms that contain a trace amount of heavy metals such as As, Cd, Cr, Hg, Ni, Pb, and V may contaminate the river water and sediment (14).

This study has measured the heavy metals contamination and the water quality of the Bertam River. Through heavy metals concentration, the potential health risk of the population in the highland river watershed of Bertam, Cameron Highland via consumption of drinking water was determined. The results of this study help the environmental agencies to plan for mitigation measures for the area to reduce the impact to public health.

MATERIALS AND METHODS

Study area

This study was conducted in a highland area of Cameron Highlands, located to the north-west of Pahang, Malaysia with an area of 71, 218 ha (Figure 1). Most of the areas located in the elevation between 1,070 m until 1,830 m from sea level. There are three main rivers that flow across Cameron Highlands which are; Telom River (37 km) at the north, Bertam River (20 km) at the middle, and Lemoi River (16 km) at the south of the district. All these rivers flow eastward and merge to form Jelai River (3).

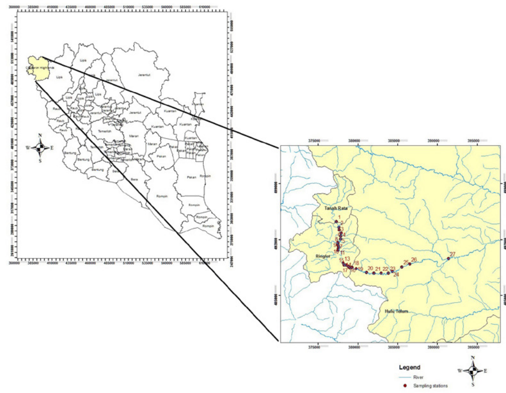

Figure 1: The map of Cameron Highland, Pahang and 27 sampling stations located along Bertam River. Cameron Highlands is the smallest district in Pahang, bordered by Perak at the west. The total area of Cameron Highlands is approximately 71, 225 ha and comprises of three main sub-district; Hulu Telom, Ringlet and Tanah Rata. Bertam River is one of the main river in Cameron Highlands with length 20Km. It flow through Brinchang, Tanah Rata, Ringlet and Lembah Bertam.

Water sampling and storage

Sampling was conducted during wet season in September 2017 (Figure I). This study has identified 27 sampling stations along the main Bertam River (excluding the tributaries) (Table I). Sampling started at the downstream sampling station (station 27) and moved way up to station 1 at the upstream. This is to reduce the tendency of sediment stir and disturbance that may affect the water condition (15). Among parameters that measured were the physical parameters (temperature, pH, Dissolved Oxygen (DO), Electric Conductivity (EC), salinity, turbidity, Total Dissolved Solids (TDS), depth), chemical parameters (Ammoniacal-Nitrogen (NH_3-N), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS)) and biological parameter (*Escherichia coli* (*E. coli*). Heavy metals elements tested were Al, As, Cd, Cu, Fe, Ni, Pb, and Zn. These parameters were selected based on its association with agricultural activities and

Table I: The description of each sampling point along Bertam River.

Catchment	Point	Latitude	Longitude	Elevation (m)	Location	Sampling point description	Water condition
Bertam Upstream	1	4.5054	101.3878	1623	Brinchang	Forest area and source point of the river	Very Clear
	2	4.4917	101.3867	1483	Brinchang	Residential areas and hotels	Very clear
	3	4.4898	101.3872	1484	Brinchang	Iris Hotel and residential areas	Clear, sludge and bad odor
	4	4.4889	101.3867	1477	Brinchang	Titiwangsa Hotel and residential area	Clear, sludge and bad odor
	5	4.4870	101.3844	1462	Tanah Rata	Golf course-main road	Clear
	6	4.4815	101.3803	1455	Tanah Rata	SLIM Camp-Golf course, and hotel construction	Clear
	7	4.4793	101.3817	1448	Tanah Rata	Kg. Sedia and strawberry agro-homestay	Clear
	8	4.4747	101.3839	1434	Tanah Rata	Taman Eko Rimba Parit Fall	Clear
	9	4.4712	101.3811	1426	Tanah Rata	Persiaran Dayang Indah, Century Pines Resort, Taman Pertabalan, and residential area	Slightly turbid and light brown
	10	4.4698	101.3814	1424	Tanah Rata	Persiaran Dayang Indah and MDCH field	Slightly turbid and light brown
	11	4.4676	101.3844	1407	Tanah Rata	Persiaran Dayang Indah and Taman Agroteknologi MARDI	Highly turbid and brown colour
	12	4.4659	101.3858	1392	Tanah Rata	Before entering Robinson Falls	Slightly turbid and light brown
	13	4.4540	101.3911	1140	Habu	Jalan Boh and intensive vegetable farming	Slightly turbid and clear
	14	4.4513	101.3914	1127	Habu	Jalan Boh and intensive vegetable farming	Clear
	15	4.4474	101.3914	1111	Habu	Jalan Boh and intensive vegetable farming	Clear
	16	4.4444	101.3908	1096	Habu	Jalan Boh and intensive vegetable farming	Clear
	17	4.4427	101.3878	1097	Habu	Near main road, TNB hydro-electric power station, intensive vegetable farming	Slightly turbid and clear
	18	4.4384	101.3889	1105	Habu	Habu Lake, and sand dredging activities	Highly turbid and brown colour
Bertam Downstream	19	4.4172	101.3975	1032	Lembah Bertam	Near town, below the road bridge and residential area	Slightly cloudy and clear
	20	4.4121	101.4117	1009	Lembah Bertam	Intensive vegetable farming and near soil/fertilizers pile	Slightly turbid and light brown
	21	4.4086	101.4206	989	Lembah Bertam	Intensive vegetable farming and the drains introduce effluent directly into river	Slightly turbid and light brown
	22	4.4081	101.4303	959	Lembah Bertam	Intensive vegetable farming and the drains introduce effluent directly into river	Turbid and brown colour
	23	4.4072	101.4386	946	Lembah Bertam	Bushes and opposite local indigenous residential area	Turbid and red-brown colour
	24	4.4073	101.4433	934	Lembah Bertam	Intensive vegetable farming	Turbid and red-brown colour
	25	4.4111	101.4553	912	Lembah Bertam	Intensive vegetable farming and below the road bridge	Turbid and brown colour
	26	4.4163	101.4647	850	Lembah Bertam	After intensive farming and bushes	Turbid and brown colour
	27	4.4236	101.5125	592	Lembah Bertam	Pile of sand for construction	Turbid and brown colour

sewage/municipal wastewater as the possible pollutant sources (16).

Water samples were collected at 0-15 cm from the water surface using water sampler. One Liter HDPE bottles were used to collect and stored the water sample for COD, NH_3-N, TSS, and heavy metals analysis. Acid-washed bottles with 2 mL of nitric acid (HNO_3) for preservations were used to store water samples for heavy metals analysis. Thio bags were used to collect a water sample for *E. coli* analysis. The bottles and thio bags were labelled specifically including the three replicates (sampling point, date, time, and type of analysis). YSI multiprobe (model 6600-M) was used to measure the in situ parameters. In situ parameters that have been measured including temperature, pH, DO, EC, salinity, turbidity, and TDS. The multiprobe was calibrated in the laboratory before used in the field.

All the collected samples were placed and stored in cool boxes with ice packs and ices to maintain the temperature below 4°C for sample preservation until the samples arrived at the water quality laboratory.

Laboratory analysis

Standard methods for the examination of water and wastewater was used according to American Public Health Association (17). Chemical Oxygen Demand (COD) was analyzed via reactor digestion and colorimetric technique using In-House Test Method MKA TM 01-based on APHA 5220D. Ammoniacal-Nitrogen (NH_3-N) parameter was analyzed via In-House Test Method MKA TM 03-based on APHA 4500-NH_3B. Total Suspended Solid (TSS) was analyzed via gravimetric method using APHA 2540D. E. coli were determined via membrane filtration method using 100 mL of water samples and colony count as described by APHA 9000. The water sample for heavy metals analysis was preserved with HNO3 during the sample collection. Then, they were filtered through Whatman No.1 filter papers in the laboratory and kept into acid-washed polyethylene pillboxes. The pillboxes were stored at 4 °C until metal analysis according to APHA 3210B method (18). The analysis for Al, As, Cd, Cu, Fe, Ni, Pb, and Zn were done using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES), model Optima 8300, Perkin Elmer, United State. The software used to process the data was WibLab32 for ICP, version 5.5.0.0714.

Quality control and quality assurance (QA/QC)

Quality control and quality assurance were implemented to obtain analytical performance of the measurements. To ensure the quality control and assurance have been met during the sampling process, sampling equipment were cleaned prior of sampling for each sampling stations. The on-site field measurement instruments were calibrated before the sampling process. Pre-cleaned sampling containers were used to store the samples. Three replicates were taken for each parameter at every station. For water sample, the maximum storage time between sample collection and analysis was addressed carefully. All laboratory equipment used were washed with phosphate-free soap preferably De-Con 90. It was used to decontaminating glassware, ceramics, rubber, plastics, stainless steel, and ferrous metals. The equipment was doubled rinsed with distilled water and left in 10% of HNO_3 for 24 hours. Blank samples were prepared to ensure the chemicals used in the laboratory analysis were free from contamination. For heavy metals analysis, calibration curves were generated from the reading of standard solutions for each individual metals. A blank calibration solution was used for a zero point. The procedural blanks were analyzed after every 5-10 samples in order to check for the sample accuracy (15, 19-20).

Calculation of health risk associated with heavy metal in drinking water

The potential health risk associated with heavy metals, through ingestion was estimated through Chronic Daily Intake (CDI) calculation in equation 1;

CDI (mg/kg/day) = C x IR x EF x ED / BW x AT (1)

Where C is the metal concentration (mg/kg), IR is the ingestion rate of water (L/day), EF is the exposure frequency (days/year), ED is the exposure duration or life expectancy (years), BW is body weight (kg) and AT is the average time exposure (days / year).

The CDI value was used to determine the Hazard Quotient (HQ) of non-carcinogenic health risk in equation 2, where RfD is oral reference dose (mg/kg/day).

HQ = CDI / RfD (2)

The HQ value >1 indicates that the level of metals exposure are possible to cause health effects. The risk to human can be multiplied if the exposure of all metals being considered at the same time. Therefore, Hazard Index (HI) was calculated to estimate the health risk from combination of all metals exposure by considering the total HQ as in equation 3. The HI value >1 indicates the potential health risk.

$HI = \sum_{i=1}^{n} THQi$ (3)

The Lifetime Cancer Risk (LCR) was calculated for carcinogenic metal Cd and Pb by multiplying the CDI with the slope factor (SF) (mg/kg/day) as in equation 4.

LCR = CDI x SF (4)

The sum of carcinogenic risk caused by a combination of Cd and Pb is known as the total risk. The LCR value $<10^{-6}$ are clearly acceptable, 10^{-6} to 10^{-4} are range of generally acceptable risk and $>10^{-4}$ are clearly unacceptable.

Statistical analysis

The statistical test was conducted via IBM SPSS version 23. For statistically significant comparison between two independent groups sample means, independent samples T-test was used in the analysis while bivariate correlation test was performed to determine linear association or relationship of the continuous variables.

RESULTS

Physicochemical properties of river water

Table II present the physicochemical properties of the river water. Surface water temperature varied from

Table II The physicochemical properties of the river water samples (N=27)

Bertam Catchment	Point	Temp	Electric Cond.	Depth	pH	Turbidity	DO	Salinity	TDS	COD	NH_3-N	TSS	*E. coli*
	Unit	^{0}C	mS/cm	m	-	NTU	mg/L	ppt	g/L	mg/L	mg/L	mg/L	CFU/100mL
Upstream	1	17.36	0.02	-0.06	6.75	2.43	8.26	0.01	0.01	2.22	0.04	6.67	10
	2	19.14	0.05	0.07	6.78	2.38	7.99	0.02	0.03	4.30	0.17	6.33	500
	3	22.09	0.09	-0.05	6.62	10.64	6.59	0.04	0.06	10.79	2.06	11.33	50,000
	4	22.09	0.09	-0.03	6.63	14.40	5.33	0.04	0.06	10.94	1.62	12.00	575
	5	21.86	0.08	0.02	6.64	25.77	7.78	0.04	0.05	6.95	0.93	21.00	300
	6	21.41	0.07	0.08	6.58	10.72	7.48	0.03	0.05	6.90	0.68	13.00	150
	7	21.48	0.08	0.07	6.71	17.19	7.46	0.04	0.05	6.49	0.91	14.33	125
	8	21.74	0.07	0.14	6.68	16.46	7.83	0.03	0.05	5.41	0.88	17.33	100
	9	20.79	0.07	0.17	6.71	52.40	7.73	0.03	0.05	5.52	0.91	35.33	50
	10	20.57	0.07	0.03	6.78	75.27	7.90	0.03	0.05	5.35	0.95	51.67	100
	11	20.17	0.08	0.05	6.59	641.59	7.92	0.03	0.05	7.94	1.71	284.67	
	12	20.12	0.08	0.20	6.52	24.30	7.89	0.04	0.05	5.37	1.33	17.00	
	13	20.72	0.09	0.18	6.51	12.70	8.13	0.04	0.06	5.55	BDL	10.67	
	14	20.77	0.09	0.06	6.45	16.39	8.36	0.04	0.06	6.60	0.26	11.67	
	15	20.30	0.07	0.20	6.57	5.40	8.33	0.03	0.04	4.63	BDL	8.67	
	16	20.64	0.08	0.30	6.65	6.60	8.25	0.03	0.05	5.67	0.75	10.00	-
	17	20.30	0.09	0.15	6.42	13.40	8.42	0.04	0.06	5.61	0.21	15.67	
	18	19.30	0.00	-0.01	6.54	-	8.59	0.00	0.00	5.23	0.96	244.33	
Down-stream	19	21.32	0.19	-0.16	6.15	24.26	9.49	0.09	0.12	6.96	1.72	10.00	
	20	24.14	0.20	0.08	6.96	47.29	7.13	0.09	0.13	6.66	0.30	25.33	
	21	23.84	0.17	0.06	6.98	64.82	7.84	0.08	0.11	4.89	0.14	46.00	
	22	24.06	0.16	0.07	7.01	187.74	7.60	0.08	0.11	3.70	0.25	116.00	
	23	24.06	0.17	0.05	6.84	411.91	7.73	0.08	0.11	3.41	0.57	203.33	
	24	23.77	0.16	0.02	6.98	282.53	7.88	0.07	0.10	2.52	0.62	204.67	-
	25	23.54	0.12	0.07	6.91	271.79	7.90	0.06	0.08	2.92	0.98	247.33	
	26	23.64	0.11	0.13	6.94	259.90	8.14	0.05	0.07	3.03	1.21	229.67	
	27	22.77	0.06	0.04	6.59	360.18	8.32	0.03	0.04	2.35	1.02	340.33	
Overall upstream	Mean ± SD	20.60 ± 1.15	0.07 ± 0.02	0.09 ± 0.10	6.62 ± 0.10	55.77 ± 147.55	7.79 ± 0.75	0.03 ± 0.01	0.05 ± 0.02	6.19 ± 2.03	0.90 ± 0.55	43.98 ± 78.97	-
Overall down-stream	Mean ± SD	23.46 ± 0.85	0.15 ± 0.04	0.04 ± 0.08	6.82 ± 0.26	212.27 ± 132.24	8.00 ± 0.61	0.07 ± 0.02	0.10 ± 0.03	4.05 ± 1.64	0.76 ± 0.49	158.07 ± 107.71	-
Overall	Mean ± SD	21.56 ± 1.71	0.10 ± 0.05	0.07 ± 0.09	6.68 ± 0.20	109.94 ± 160.73	7.86 ± 0.71	0.04 ± 0.02	0.06 ± 0.03	5.48 ± 2.16	0.85 ± 0.54	82.01 ± 104.49	5191.00 ± 14937.42
Range		17.36-24.14	0.02-0.20	-0.01-0.30	6.15-7.01	2.38 -641.59	5.33-8.59	0.00-0.09	0.01-0.13	2.22-10.94	BDL-2.06	6.33-340.33	10-50,000
NSDWQ		NA	2.50[a]	NA	6.50-9.00	5.00	6.00[b]	NA	1.00	10.00[c]	0.20[c]	NA	0
p-value[d]		0.000*	0.000*	0.126	0.080	0.000*	0.485	0.000*	0.000*	0.006*	0.804	0.001*	-

Notes: NSDWQ= National Standard for Drinking Water Quality (Ministry of Health Malaysia) (30); NA= values not available because no guideline for drinking water is set due to the impracticality of controlling the parameters; [a] USEPA= United States Environmental Protection Agency (23); [b] Egyptian drinking water quality standards (31); [c] WHO= World Health Organization (32)**;** [d] Independent t-test to determine the differences between the means of upstream and downstream**,** * significant difference were obtained when p-value < 0.05

17.36°C to 24.14°C where the lowest temperature recorded at the upstream Bertam River. The temperature may influence the availability of dissolved oxygen (DO) in the water bodies. The DO value at the station with the lowest and highest temperature was 8.26 and 7.13 mg/L respectively. The overall mean of pH (6.68 ± 0.20) is within the acceptable range of 6.9-9.0 National Drinking Standard Water Quality (NDSWQ), Department of Environment Malaysia (32). The conductivity range from 0.02 to 0.20 mS/cm, which is below the USEPA standard value for drinking water (2.50 mS/cm). TDS in this study was ranged between 0.01 to 0.13 g/L. In average, the COD level (5.48 ± 2.16 mg/L) was below the WHO guideline for drinking water (6.00 mg/L) with the ranged of 2.22 to 10.94 mg/L. The NH_3-N was ranged from not detected to 2.06 mg/L and the mean value recorded was

0.85 ± 0.54 which exceed the WHO drinking water guideline (0.20 mg/L). The TSS value was significantly higher in the downstream (158.07 ± 107.71 mg/L) compared to the upstream (43.98 ± 78.97 mg/L) and the *E. coli* level exceeded the permissible value (10-50,000 CFU/100 mL) for Malaysia drinking water standard at all sampling stations. A very large distribution of *E. coli* value was obtained in all sampling stations while the highest level found at station 3 with the value of 50,000 CFU/100 mL.

The trend of turbidity in the river increases as it flows downstream. However, the highest turbidity value (641.59 NTU) was recorded at station 11 located at the upstream with muddy-brown colour water appearance. The location of this station near to MARDI Agro Technology Park, a major agriculture and cultivation for tourism and research purpose, possibly contribute to this. Value of the turbidity along the Bertam River varied from 2.38 to 641.59 NTU with a mean value of 109.94 ± 160.73. Most of the stations have turbidity exceeded the threshold value with the exception at the station 1 and 2 that located upstream due to minimal anthropogenic disturbance. Overall, the mean level of turbidity (109.94 ± 160.73), DO (7.86 ± 0.71), *E. coli* (5191.00 ± 14937.42), and NH_3-N (0.85 ± 0.54) exceeds the permissible value for drinking water.

The p-value < 0.05 stipulated that there is a significant difference between temperature, specific conductivity, turbidity, salinity, TDS, COD, and TSS in surface water between upstream and downstream of Bertam River.

Heavy metal contamination in river water

Table III shows the descriptive statistic of metal contamination in the Bertam River. The concentration of heavy metals were in the following sequence order; Fe > Al > Cu > Zn > Pb > Cd. Arsenic (As) and nickel (Ni) concentration was below than the detection limit which is <0.02 mg/L and <0.005 mg/L respectively. The mean concentration of Cd (0.015 ± 0.007 mg/L), and Pb (0.021 ± 0.005 mg/L) have slightly exceeded the guideline values. The value of Al in a few stations were slightly exceeded the NDSWQ acceptable value of 0.20 mg/L. The statistical analysis shows Al was significantly higher in the downstream compared to the upstream of Bertam River (p<0.05). The overall mean concentration of Fe in this study (0.442 ± 0.191 mg/L) exceeded the guideline value of 0.30 mg/L at almost all stations in the upstream. Cu and Zn were below than the NDSWQ maximum level.

The correlation test between physicochemical parameters have obtained strong positive relationship between water temperature with conductivity, pH, turbidity, salinity, TDS, and TSS. Meanwhile, conductivity has strong positive relationship with turbidity, salinity and TDS whereas turbidity has strong positive relationship with salinity, TDS and TSS. For the metal-physicochemical properties relationship, Al had a strong positive relationship with turbidity, TSS, conductivity, salinity and TDS. Cu has positive relationship with temperature and pH but negative relationship with COD (Table IV).

Health Risk Assessment (HRA)

Calculation for carcinogenic and non-carcinogenic risk assessment from this study was summarized in Table V. The HQ value for all individual non-carcinogenic metals in the adult and children were less than 1. This explained that the risk of metals exposure posed by all the metal of interest from the daily consumption of water from Bertam River is within the designated level of consumption. The HI measured was less than 1 in all categories which stipulate there is acceptable level of health risk posed by the combination of all metals. As for cancer risk, the LCR values for Pb in all categories were within an acceptable risk. However, the LCR for Cd in male adult (3.06×10^{-3}), female adult (2.98×10^{-3}) and children (4.92×10^{-3}) were $>10^{-4}$ indicates not acceptable carcinogenic risk.

DISCUSSION

This study has monitored the level of water quality and heavy metal concentration of the highland watershed area of Bertam River in Cameron Highland. The analysis had determined low level of DO at the downstream of Bertam. This was possibly related to high domestic and agriculture waste disposed of directly and indirectly into the river (7). Similar result was obtained in Rasul et al., (2015), where the DO level was determined at similar ranged to the present study (7.86 ± 0.71 mg/L). The average pH value in this study was within the acceptable range of the Malaysian National Drinking Standard Water Quality (NDSWQ). It is very important to ensure that the pH value was within the safe range of 6.9 to 9.0 as pH governs the behaviour of other parameters such as ammonia content and metal solubility in water (34).

Electrical conductivity and TDS in this study were below than the USEPA drinking water standard value. Both of these parameters are important to define salt concentration in the water. High conductivity and TDS may increase water salinity especially in highly nutrient enrichment waterways (34). TDS in drinking water should not exceed 500 mg/L, although "water with a TDS content of up to 1000 mg/L is still acceptable. However, water is undrinkable in the 1000 to 2000 mg/L range of TDS. High salinity in water not pose a significant health risk to the general population. However, it could be impacts for those who need to limit their daily salt intake or to cases advice sought from a doctor. High salinity in water also has a great impact on aquatic life.

COD measure the amount of oxygen used to oxidize all organic and inorganic compound in the water. High COD value in this study indicates high pollution of organic matter and its component in the water (34).

Table III: Heavy metals concentration (mg/L) in the river water samples (N=27)

		Heavy metals (mg/L)					
Bertam Catchment	**Sampling Points**	**Al**	**Cd**	**Cu**	**Fe**	**Pb**	**Zn**
Upstream	1	0.113	BDL	0.016	BDL<0.2	BDL<0.01	BDL<0.01
	2	0.052	BDL	0.018	0.514	BDL<0.01	BDL<0.01
	3	0.102	BDL	0.028	0.520	BDL<0.01	BDL<0.01
	4	0.097	0.014	0.047	0.501	0.019	0.035
	5	0.193	BDL	0.013	0.355	BDL<0.01	BDL<0.01
	6	0.088	BDL	0.019	0.511	BDL<0.01	BDL<0.01
	7	0.115	0.014	0.051	0.513	0.018	0.028
	8	0.134	BDL	0.012	0.518	BDL<0.01	BDL<0.01
	9	0.154	BDL	0.017	0.477	BDL<0.01	BDL<0.01
	10	0.225	0.006	0.032	0.451	BDL<0.01	BDL<0.01
	11	0.416	BDL	0.024	0.425	BDL<0.01	BDL<0.01
	12	0.098	BDL	0.016	0.522	BDL<0.01	BDL<0.01
	13	0.187	BDL	0.015	0.379	BDL<0.01	BDL<0.01
	14	0.206	0.015	0.047	0.446	0.021	0.033
	15	0.121	BDL	0.023	BDL<0.2	BDL<0.01	BDL<0.01
	16	0.127	0.015	0.053	0.202	0.020	0.031
	17	0.170	BDL	0.025	0.328	BDL<0.01	BDL<0.01
	18	0.324	BDL	0.018	0.618	BDL<0.01	BDL<0.01
Downstream	19	0.147	0.024	0.037	1.187	0.021	0.030
	20	0.239	0.021	0.138	0.533	0.025	0.033
	21	0.400	0.007	0.060	0.459	BDL<0.01	BDL<0.01
	22	0.152	0.015	0.042	0.280	BDL<0.01	BDL<0.01
	23	0.185	0.028	0.065	0.299	0.027	0.044
	24	0.190	0.006	0.039	0.278	BDL<0.01	BDL<0.01
	25	0.222	BDL	0.024	0.214	BDL<0.01	BDL<0.01
	26	0.215	0.019	0.043	0.291	0.027	0.037
	27	0.244	0.007	0.035	0.230	0.010	0.023
Overall upstream	Mean ± SD	0.162 ± 0.087	0.013 ± 0.003	0.026 ± 0.013	0.455 ± 0.096	0.020 ± 0.001	0.032 ± 0.003
Overall downstream	Mean ± SD	0.222 ± 0.071	0.016 ± 0.008	0.054 ± 0.032	0.419 ± 0.289	0.022 ± 0.006	0.033 ± 0.007
Overall	Mean ± SD	0.182 ± 0.087	0.015 ± 0.007	0.035 ± 0.025	0.442 ± 0.191	0.021 ± 0.005	0.033 ± 0.006
Range		0.052-0.416	BDL-0.028	0.012-0.065	BDL-1.187	BDL-0.027	BDL-0.044
NSDWQ		0.20	0.003	1.00	0.30	0.01	3.00
p-value[a]		0.041*	0.345	0.057	0.829	0.103	0.925

Notes: NSDWQ = National Standard for Drinking Water Quality (Ministry of Health Malaysia); BDL= below detection limit, <0.005 mg/L; NA= values not available; a Independent t-test to determine the differences between the means of upstream and downstream; * significant difference were obtained when p-value < 0.05.

This was probably comes from the agriculture waste from the vegetables farm in this area. Another element that was higher in the upstream of Bertam was NH3-N. This was related to intensive usage of the untreated chicken manure to facilitate the growth of crop due to high nitrogen content by the farmers (35). Other factors could be due to sewage pollution and wastewater from residential areas that cause high NH_3-N at the sampling stations located upstream (36). A similar result also was obtained in Rasul et al., (2015) where high NH_3-N was detected.

There was a distinct fluctuation of the TSS value in this study as the value varied depending on the location of the sampling station. Sampling stations with TSS values more than 100 mg/L were mostly located at the downstream of the Bertam River. Similar results also was obtained from the previous studies as the level of TSS at most stations were exceeded the Malaysian Standard value (8, 36). The highlands area increases the tendency of carrying the pollutant as well as the suspended matters from upstream to downstream. The intensive agriculture and the sand dredging activities at these sampling stations may indicate the discharge of washings from soil and sandpits. High TSS value reduces the light penetration in the surface water and influence the elevation of turbidity level (34). It also may form deposits on the river bed which will increase the risk of sedimentation. Precipitation may elevate the TSS value in the river as indicated in the recent studies where the

Table IV: Pearson's correlation coefficients (r value) of the relationship between physicochemical properties and heavy metals concentration (N=27).

Correlation coefficient (r)	Temperature	Conductivity	Depth	pH	Turbidity	DO	Salinity	TDS	COD	NH_3-N	TSS	*E. coli*	Al	Cd	Cu	Fe	Pb
Conductivity	0.820**																
Depth	-0.365	-0.214															
pH	0.516**	0.197	-0.339														
Turbidity	0.674**	0.530**	-0.487*	0.399*													
DO	-0.288	-0.051	0.242	-0.301	0.045												
Salinity	0.840**	0.986**	-0.251	0.209	0.542**	-0.046											
TDS	0.834**	0.991**	-0.217	0.184	0.544**	-0.082	0.973**										
COD	-0.096	0.143	0.208	-0.455*	-0.329	-0.449*	0.080	0.182									
NH_3-N	0.245	0.265	0.010	-0.312	0.350	-0.208	0.235	0.313	0.421								
TSS	0.491**	0.381	-0.474*	0.428*	0.967**	0.118	0.394*	0.390*	-0.465	0.266							
E. coli	0.542	0.584	-0.509	-0.448	-0.033	-0.529	0.558	0.537	0.743*	0.577	-0.160						
Al	0.322	0.418*	-0.361	0.166	0.715**	0.269	0.414*	0.416*	-0.140	0.070	0.683**	-0.268					
Cd	0.484	0.556	-0.188	0.639	0.437	-0.402	0.614	0.586	-0.126	-0.031	0.342	NA	0.401				
Cu	0.468*	0.053	0.058	0.468*	0.316	-0.228	0.088	0.094	-0.497*	-0.025	0.310	-0.311	0.086	0.353			
Fe	-0.049	-0.216	0.012	0.069	-0.044	0.036	-0.188	-0.218	-0.234	0.281	0.062	-0.740	0.078	0.343	0.005		
Pb	0.668	0.310	0.188	0.649	0.697	0.032	0.312	0.248	-0.585	0.388	0.700	NA	0.291	0.691	0.738	0.157	
Zn	0.080	-0.049	-0.683	0.501	0.346	-0.295	-0.108	-0.029	0.132	0.206	0.256	NA	0.465	-0.088	0.258	-0.145	0.373

**Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed), NA – not available

Table V: Health Risk Assessment of heavy metals exposure through river water consumption among adult and children in the study area

Risk	Male Adult		Female Adult		Children	
Non-carcinogenic	CDI (mg/kg/day)	HQ	CDI (mg/kg/day)	HQ	CDI (mg/kg/day)	HQ
Al	5.88×10^{-3}	8.40×10^{-4}	5.73×10^{-3}	8.18×10^{-4}	9.46×10^{-3}	1.35×10^{-3}
Cu	1.13×10^{-3}	2.83×10^{-2}	1.10×10^{-3}	2.75×10^{-2}	1.82×10^{-3}	4.55×10^{-2}
Fe	1.43×10^{-2}	2.04×10^{-2}	1.39×10^{-2}	1.99×10^{-2}	2.30×10^{-2}	3.28×10^{-2}
Zn	1.07×10^{-3}	3.55×10^{-3}	1.04×10^{-3}	3.46×10^{-3}	1.72×10^{-3}	5.72×10^{-3}
HI (∑HQ)		5.31×10^{-2}		5.17×10^{-2}		8.54×10^{-2}
Carcinogenic	CDI (mg/kg/day)	LCR	CDI (mg/kg/day)	LCR	CDI (mg/kg/day)	LCR
Cd	4.85×10^{-4}	3.05×10^{-3}	4.72×10^{-4}	2.97×10^{-3}	7.80×10^{-4}	4.91×10^{-3}
Pb	6.78×10^{-4}	5.77×10^{-6}	6.61×10^{-4}	5.62×10^{-6}	1.09×10^{-3}	9.28×10^{-6}
Total risk		3.06×10^{-3}		2.98×10^{-3}		4.92×10^{-3}

Note: The health risk was calculated based on the following parameters;
IR adult male – 2.26 L/day, IR for adult female – 1.97 L/day, IR for children – 0.78 L/day (22-23);
EF = 365 days/year (23);
ED for adult = 74 years; ED for children = 6 years (24);
BW adult male – 69.95 kg; BW adult female – 62.59 kg; BW children – 15 kg (22-23);
AT for adult 27,010, AT for children 2,190 (23);
RfD (mg/kg/day) = Al: 70×10^{-1}; Cd: 5.0×10^{-4}; Cu: 4.0×10^{-2}; Fe: 7.0×10^{-1}; Pb: 3.5×10^{-3}; Zn: 3.0×10^{-1} (23, 25-27)
SF (mg/kg/day) = Pb: 8.5×10^{-3}; Cd: 6.30 (28-29)

mean value of TSS in the dry and wet season was 177.67 ± 29.61 mg/L and 15.08 ± 2.51 mg/L respectively (7, 37).

Bertam River is flowing through a highly dense residential housing area and is located very close to many hotels that possibly contribute to high *E. coli* in the water (38). The presence of bad odour and sludge at the bottom and riverside indicate the possibility of recent sewage and wastewater effluent from the housing and hotel area. This finding is consistent with what has been obtained in previous study (36). In addition, precipitation also increases the water flow rates and surface runoff that carried the compound-bounded soils from nearby surrounding land into the water bodies (7, 36). High precipitation, especially on the wet season, may reduce water quality (2, 7, 37). The influence of precipitation could intensify the turbidity and TSS values and also cause dilution of nutrient content (7). Clay, silt, organic and inorganic matter are another factors that increase the turbidity which was highly influenced by the land clearing for development and agriculture (39). Land clearing disrupted soil stability which eventually triggered erosion of soil into the water bodies.

Metal contamination in river water come from various sources such as from the metal-based pesticides, inorganic and organic fertilizers, industrial emission and transportation. Inorganic phosphate fertilizers may contain a trace amount of As, Cd, Ni, and Pb (40-42). High concentration of all metals was found at the downstream sampling stations in this study where most of the agriculture activities are here. The highest concentration of Cd, Cu, Pb, and Zn were recorded at the downstream station that possibly receive pollutants of nearby agriculture farms effluent and farm at the upstream area. Previous study has reported high level of Cd and Pb in the river water of the agriculture area was related to the application of phosphate fertilizers (20).

Result of this study also have determined high Fe in the Bertam River. In general, the soil composition has a high natural concentration of Fe and commonly does not enriched from anthropogenic sources (43). However, results in this study provide an indication of other factors that possibly contributing to the high Fe level in the water apart from intensive agriculture activities and soil erosion. Water pH plays an important role in metal solubility. Low water pH causes dissolved Fe concentrations in water become high (44). Since the upstream of Bertam River was slightly acidic (6.62 ± 0.10) compared to the downstream area (6.82 ± 0.26), this possibly triggered the release of Fe from the upland soil (45). The usage of alkaline detergents and material from residential and industrial wastewater in Bertam also influence the water pH as it flowing downstream (8, 36).

The routes of metals exposure can be through respiration/inhalation, absorption/dermal contact and ingestion/oral uptake. In comparison to ingestion, other pathways are considered negligible. Heavy metals generally are not removable even after being treated through water treatment plant, thus increase the risk of metal contamination via drinking water (46). Moreover, metals are prone to bind with organic matter in the sediment and the release of metals in sediment into the water may pose a serious burden to human health. The long-term exposure to metals may disrupt the normal function in body vital organs and systems (19, 33, 47). The tendency of metals to bio-accumulate in water pose health risk towards the human. Heavy metal contamination in drinking water was evaluated to determine the potential health risk assessment which comprises chronic and carcinogenic risk.

Since information on the heavy metal contamination in Bertam River is lacking, this study has comprehensively integrates the assessment of the physicochemical and metal pollution together with the health risk estimation. The health risk estimation calculation findings of this study is useful to serve as a data to elaborate the potential health risk through water drinking and work as baseline modelling for research in future. This finding also creates awareness about how good agricultural practice can contribute to the sustainability of agriculture activity and to human health. This is also can be an education and strategic urban plans undertaken by the authorities and policymakers in future. It is necessary for the conservation effort made involved of all levels in the society. Slowly but surely, the effort will be able to meet the 11th Malaysia Plan to improve water quality and protect the environment through an integrated river basin management plans.

Precipitation that occurs before and during the sampling process can be considered as the limitation of this study that possibly influences the degradation of water quality in the study area. However, the results manage to illustrate the impacts of the agriculture activities in this area towards river water quality degradation and heavy metals level. Therefore, the findings of this assessment suggested for continuous monitoring to be done as it is crucial to identify pollution influx in the river water bodies.

CONCLUSION

Rampant agriculture activity in Bertam River had caused some degradation pattern in water quality parameter such as turbidity, DO, *E. coli*, NH_3-N, and TSS of which they exceed the permissible levels in drinking water. Heavy metals were detected and Cd, Fe and Pb were exceeded the recommended standard for drinking water. Most of the water quality parameters and heavy metals were at the higher level in the downstream area of Bertam River compared to the upstream. Significant carcinogenic health risk was detected for Cd among adults and children through drinking water in this study. However, non-carcinogenic health risk of metals exposure through drinking water creates acceptable level of health risk.

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