Scientific Research Publishing

Journal of Environmental Protection, 2024, 15, 934-947
https://www.scirp.org/journal/jep
ISSN Online: 2152-2219
ISSN Print: 2152-2197

Effects of Effluent from a Dumpsite on the Physicochemical Properties of River Achichum in Bamendakwe, Northwest Cameroon

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How to cite this paper: Alakeh, M.N., Francois, K.T., Biosengazeh, N.F., Chunkang, M.C. and Tamungang, N.E.B. (2024) Effects of Effluent from a Dumpsite on the Physicochemical Properties of River Achichum in Bamendakwe, Northwest Cameroon. *Journal of Environmental Protection*, **15**, 934-947.
https://doi.org/10.4236/jep.2024.159054

Received: July 3, 2024
Accepted: September 17, 2024
Published: September 20, 2024

Abstract

This study was aimed to assess the effects of effluent from a dumpsite on the physicochemical properties of river Achichum in Bamendakwe in the Bamenda I municipality, Northwest Region of Cameroon. The quality of water used for domestic purposes by the population of this area is mostly appreciated through its organoleptic assessment while no attention is paid to the physicochemical and microbiological properties. Samples (upstream, effluent, and downstream) were collected in the months of September 2022 and February 2023 and examined for organoleptic, physicochemical and bacteriological characteristics using standard methods. The river was contaminated to different extents by nitrates (28.56 - 149.91 mg/L), sulphates (246.89 - 725.42 mg/L) and heavy metals (0.01 - 0.04 mg/L for lead and 0.98 - 2.15 mg/L for aluminum). This contamination could be due to an inflow of the untreated effluent into the river. The river contained a high pollution level of lead and aluminum. Bacteriological investigations revealed that all the analyzed samples from the river contained indicators of faecal pollution such as *Enterobacteria* spp., *E. coli*, *Streptococcus* spp., *Salmonella* spp., *Shigella* spp., *Staphylococcus* spp. and *Vibrio* spp. Consequently, its utilization exposes consumers to health risks. Thus, water from the river should be treated prior to consumption.

Keywords

Effluent, Upstream, Downstream, Water Quality, Faecal Contamination,

Bamendakwe

1. Introduction

Safe and affordable supply of potable water is a basic human need. The quality of water has a great impact on public health, as poor microbiological quality of water is likely to lead to the outbreak of infectious water borne diseases [1]. Monitoring the quality of river water is necessary in the present-day society, especially rivers affected by urban effluents. Studies on water quality in the aquatic environment are still popular in the evaluation and management of river ecosystems in many countries [2]. This is due to the changes in water chemistry of rivers and drainages, and can be the result of domestic, industrial, or agricultural discharges which may in tend lead to aquatic ecosystem degradation. Therefore, the determination of physicochemical and bacteriological parameters of water samples can serve as indicators of water pollution due to both natural and anthropogenic inputs [3]. According to Tahri *et al.* [4], the importance of the provision of potable water supply in any nation cannot be over emphasized. Generally, as population, wealth and economic activities increase, there is an accelerated pace of industrialization [3], with corresponding global increase in demand for water supply [5].

The city of Bamenda, Northwest Cameroon, has witnessed an increase in population over the years, and this has resulted in large quantities of waste being dumped on farmlands, especially around water resources. In areas where human activity is concentrated, levels of environmental contaminants are also elevated [6]. The population growth, metal workshops, and use of metal appliances have experienced an increase in this city, which has resulted in the dumping of large quantities of waste around and in water resources. As the effluent from this waste flows into the water resources, there is possible contamination of the water resources with consequent health effects upon consumption by indigenes. The quality of the environment is of general importance as well as water quality assessment and treatment. Given the enormous impact water has on human health and the economic status of the population, the quality of water for drinking or domestic use has a powerful impact on public health. Hence, the effective monitoring and assessment of water systems is crucial to protecting the wellbeing of the public and to allow the implementation of a preventive approach to manage water quality. Bamenda, one of the emerging cities in Cameroon, has an estimated population of 614,809 inhabitants in 2024, with a growth rate of 3.53%. The Bamenda municipality has factories ranging from metallurgical, soap production, food processing, garage works, oil exchange services, to traffic releases, which generate huge amounts of wastes. Findings show that Bamenda city generates 120 - 160 tons of municipal solid waste daily (0.40 - 0.54 kg per capita), 76% of which is biodegradable and 24% non-biodegradable. About 90% of the solid waste comes from households [7] and the waste is deposited on soils or into water systems that supply the wetlands. As the effluent from the waste flows into water resources, there is the possibility of potential pollution of a water resource by this effluent. This contaminated water will have adverse effects on the health of the local population that uses such water for domestic purposes. Though the link between environmental pollution and domestic and industrial activities is recognized as a problem, information surrounding such contamination, its risk management, and concepts are not well documented. Hence, the need for proper environmental quality assessment in some areas. The main objective of this research was to assess the pollution load of the river into which untreated effluent from a dumpsite flows with reference to World Health Organization (WHO) guidelines for drinking water quality and the Cameroun Standards and Quality Agency (ANOR) guidelines. Collected water samples were therefore analysed for organoleptic, physicochemical, and bacteriological properties and recommendations were made based on the findings obtained.

2. Materials and Methods

2.1. Description of Sampling Site

The study was carried out in Bamendakwe found in the Bamenda I subdivision, situated Southeast of Mezam division, one of the seven divisions of the Northwest region of Cameroon. It is located within latitude 5˚51' to 5˚58' north of the equator and longitude 10˚8' to 10˚17' east of the Greenwich meridian. It falls within the humid tropical climatic zone and covers a total surface area of about 110 km^2 with one main village (Bamendakwe) comprising 13 quarters, namely, Abangoh, Achichum, Alahnting, Aningdoh, Banche, Nkar, Ayaba, Ntanche, Ntafebuh, Nta'afi, Moyo, Keneleri, and Abumuchi. This municipality is oriented 366 km Northwest of the Cameroon capital with an altitudinal range from about 1269 to 2606 m above sea level. The Bamenda I municipality is bounded to the north by Bamenda III subdivision, to the south by Santa, to the east by Tubah and Balikumbat, and to the west by Bamenda II subdivision [7]. It is connected to the national territory by the national road No 6. Its geographical location falls within the Guinean climate type. The climate is marked by two distinct seasons which are the dry and rainy season. The rainy season is usually from around mid-March to mid-October and sometimes extends to November. The rainfall ranges between 2000 and 2500 mm per annum and highest amounts are recorded in July and August.

2.2. Description of Sampling Points

The source types, sample codes, and their geographical coordinates as well as Pictures of the sampling sites are presented in **Table 1** and **Figure 1** below respectively:

Table 1. Source, sample code and geographical coordinates of sampling points.

Source	Sample code	Coordinates
River upstream	RNKW1	5˚57.3240'N 10˚11.5990'E
Effluent from dumpsite	RNKW2	5˚57.3610'N 10˚11.5010'E
River downstream	RNKW3	5˚57.3670'N 10˚11.4970'E

(A)

(B) (C)

Figure 1. Dumpsite besides the river (A), Effluent flowing into river (B), Section of river (C).

2.3. Sample Collection and Preservation

A total of twelve (12) water samples were collected from three (03) sampling points in September 2022 (wet season samples) and February 2023 (dry season samples). Two (02) samples were collected at each sampling point in clean and labelled polyethylene containers of 500 mL capacity each. The containers and caps were thoroughly rinsed with water to be sampled before collection. Collections were done very early in the morning before sunrise and the samples packaged in a cooler containing ice in order to maintain the temperature close to 4˚C to minimize physicochemical changes [1]. The samples were finally transported to the Research Unit of Animal Physiology and Microbiology and the Research Unit of Soil Analysis and Environmental Chemistry of the University of Dschang for preservation and analyses. A global positioning system (G.P.S) Garmin Etrex Vista was used to determine the coordinates of the sampling points. The sampling points are indicated on Figure 2.

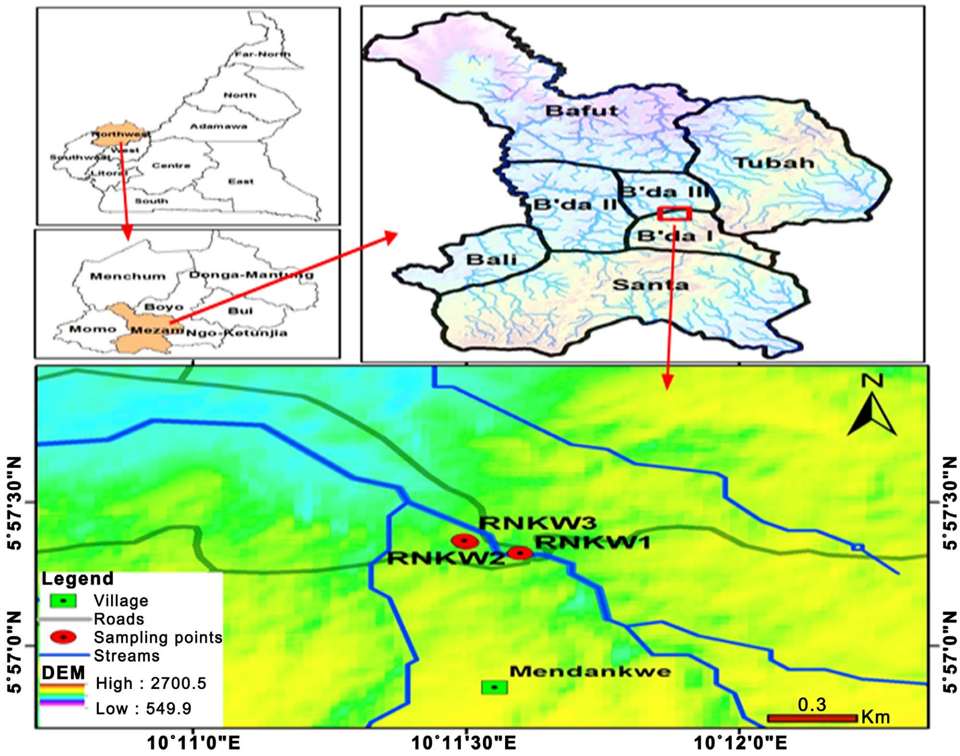

Figure 2. Location of sampling points in Bamendakwe.

2.4. Laboratory Analyses

2.4.1. Organoleptic and Physicochemical Analyses

The water and effluent samples were observed with naked eyes for gross appearance and examined for offensive odour through personal organoleptic assessment. Temperature, pH, electrical conductivity, and total dissolved solids were measured in situ with the help of a calibrated multi pH meter (APERA). Turbidity was measured using a turbidimeter (Model DRT, 100B, MF scientific, Inc). Sodium and potassium ions were determined by flame spectrometry, Calcium and Magnesium ions, by complexometric titration, and Iron, lead, zinc and aluminium by colorimetry. Chloride content was determined by the argentometric method while Nitrate and ammonium were determined by Kjeldahl's distillation method. Phosphates were determined by UV-visible spectrophotometric analysis, Bicarbonates, by acid-base titration and sulphates by gravimetric analysis.

2.4.2. Bacteriological Analyses

The multiple tubes fermentation technique or most probable number (MPN) technique was used for the presumptive determination of total coliforms and the standard count plate technique was used for the determination of specific bacteria (total faecal *Coliform*, *Salmonella*, *Escherichia coli*, *Streptococcus* spp., *Staphylococcus* spp., *Shigella* spp., *Vibrio* spp. *and Enterobacteria*) as described by [8].

2.5. Statistical Analyses

Statistical analyses were done using the Statistical Package for Social Sciences

(SPSS) version 20.0. Precisely, paired t-test was used to verify if there exist any significant difference between the mean parameters and Pearson correlation was used to verify the relations existing between parameters. The Piper's diagram was used to determine the water types.

3. Results and Discussion

3.1. Organoleptic Parameters

Organoleptic characteristics of sampled waters are summarized in Table 2 below:

Table 2. Organoleptic characteristics of sampled waters.

	Dry season			Rainy season			
Sample Code	**RNKW1**	**RNKW2**	**RNKW3**	**RNKW1**	**RNKW2**	**RNKW3**	**Control**
Appearance	Clear with tiny whitish debris	Cloudy with tiny whitish debris	Clear with tiny few dark debris	Clear with tiny dark debris	cloudy clear with tiny dark debris	Clear with tiny whitish debris	Clean and Clear
Colour	Colourless	Brown	Colourless	Colourless	Dark brown	Colourless	Colourless
Odour	Odourless	Perceptible odour	Odourless	Odourless	Perceptible odour	Odourless	Odourless

RNKW1 = River Upstream; RNKW2 = Effluent; RNKW3 = River Downstream.

Upstream and downstream samples (RNKW1 and RNKW3 respectively) were clear, colourless with some tiny debris and odourless while effluent sample (RNKW2) was brownish with tiny debris and had a perceptible odour. This could be due to the infiltration of wastewater from the dumpsite into the river. Equally, the presence of debris in all sampled waters could be justified by the fact that the river is exposed to dust particles in the dry season and exposed to floods in the rainy season. Thus, the water samples do not align with WHO standards for domestic water as far as organoleptic parameters are concerned and there require treatment before use. A similar observation was made by Biosengazeh *et al.* [9] in open ground water sources in the Baba I village in the Northwest region of Cameroon.

3.2. Physicochemical Parameters

The physicochemical properties of the water samples are summarized in Table 3.

Table 3. Physicochemical parameters in analysed samples.

	Rainy season			Dry season		
Parameter	**RNKW1**	**RNKW2**	**RNKW3**	**RNKW1**	**RNKW2**	**RNKW3**
pH	7.6	7.6	7.1	6.9	6.9	7.6
Turbidity (NTU)	1.9	8.2	1.8	2.1	10.8	3.5
EC (mS/cm)	0.02	0.2	0.02	0.09	0.41	0.10
Ca^{2+} (mg/L)	17.20	18.10	17.20	21.03	19.32	23.54
Mg^{2+} (mg/L)	1.94	3.41	2.43	10.12	5.68	7.82

Continued

K^+ (mg/L)	2.77	2.56	2.30	1.78	2.78	2.11
Na^+ (mg/L)	0.08	1.00	0.08	1.02	1.83	1.92
HCO_3^- (mg/L)	54.90	45.89	42.70	57.16	56.79	56.81
NO_3^- (mg/L)	28.56	33.76	149.91	16.17	74.43	43.23
NH_4^+ (mg/L)	3.49	5.12	4.41	3.14	5.63	2.44
Cl^- (mg/L)	8.40	96.72	11.95	7.15	116.22	14.82
Total iron (mg/L)	0.10	0.21	0.10	0.20	0.34	0.00
SO_4^{2-} (mg/L)	590.40	725.42	656.00	361.12	433.23	246.89
PO_4^{3-} (mg/L)	0.00	0.00	0.00	0.03	0.00	0.00

EC = Electrical conductivity.

The pH values of water samples in the wet season were significantly higher than those in the dry season ($p \leq 0.05$), with the highest value of 7.6 registered for various samples. Decrease in pH could be due to the rains resulting in the dissolution of carbon dioxide to yield carbonic acid as shown by Equation (1).

$$H_2O_{(l)} + CO_{2(g)} \rightleftarrows H_2CO_{3(aq)} \quad (1)$$

Acidic pH could equally be explained by the fact that leaching washes acidic cations H^+ and Al^{3+} from the soil into the river source [1]. However, all the pH values fell within the range of 6.5 - 8.6 prescribed by WHO [1] and 6.5 - 9 prescribed by ANOR [10].

Turbidity values ranged from 1.8 to 8.2 NTU in the wet season and from 2.1 to 10.8 NTU in the dry season, falling within the limit prescribed by WHO (<5 NTU), except for the effluent samples (RNKW2) which had highest values in both seasons, with a maximum value of 10.8 NTU. High turbidity values in the effluent samples could be attributed to the presence of organic matter and high suspended particles content [11]. Such high values may indicate the presence of hazardous chemical and microbial contaminants. The slight increase in turbidity of samples downstream compared to upstream, though not statistically significant ($p > 0.05$), could be due to possible contamination by the effluent. As can be seen on **Table 3**, the turbidity values were significantly higher in the dry season than in the wet season ($p < 0.05$).

The values of the electrical conductivity of the various samples were significantly higher in the dry season than in the wet season, ($p \leq 0.05$) which could be due to the higher concentration of ions in the dry season, as the volume of water drops. These results are supported by a similar work done by Njoyim *et al.* [12]. The WHO standard is 1.5 mS/cm at 20˚C. Thus, the level of dissolved salts in the samples was low and hence does not present any risk of contamination.

Total dissolved solutes (TDS) ranged between 14.6 and 174 mg/L in September and between 16.6 and 74.4 mg/L in February. The lower values of TDS in February could be due to factors such as decrease in dilution, decaying organic matter (plants and animal matter) and colloids. These results are in agreement with the findings of Istifanus *et al.* [13] who carried out similar studies in the Bauchi State in Nigeria. The palatability of water with a TDS level less than 600 mg/L is generally considered to be good [1].

The concentrations of Na^+ and K^+ significantly dropped from September to February ($p < 0.05$). This could be as a result of the dilution factor associated with the rains. Also, the concentrations of sodium and potassium were higher in the samples downstream (RNKW3) than upstream (RNKW1), probably due to an inflow of the ions through the effluent. However, all the values obtained were far below the WHO and ANOR limits of 200 mg/L and 20 mg/L for Na^+ and K^+ respectively. Low sodium is probably due to low NaCl as well as low sodium and aluminium silicates at the dumpsite given that sodium in water generally results from the leaching of geological formations containing sodium chloride as well as rock salt decomposition like sodium and aluminium silicates [14]. Low K^+ ion concentration may be due to its low geochemical mobility. These results agree with those obtained by Temgoua [15] who analysed the chemical and bacteriological properties of drinking water from alternative sources in the Dschang Municipality, Cameroon.

Ca^{2+} and Mg^{2+} ions are responsible for water hardness. Generally, there was a significant increase in the concentrations of both ions in moving from the rainy to the dry season ($p < 0.05$). Higher concentrations in the dry season may be due to the higher temperature, which increases concentration of salts by excessive evaporation. Depletion of hardness in rainy season may be due to the dilution by rainwater. The increase in hardness can be attributed to the decrease in water volume and increase in the rate of evaporation at high temperature, high loading of organic substances, detergent, chloride, and other pollutants [16]. Similar results have been reported in the region by Nchofua *et al.* [17]. The concentrations of both ions were however lower than the WHO guideline values of 75 and 50 mg/L for Ca^{2+} and Mg^{2+} respectively. Hard water is good for drinking and cooking but not good for laundry, bathing and for use in the laboratory.

NH_4^+ found in the water sources was surely from biological breakdown of domestic and agricultural wastes and its presence was thus an indicator of bacterial, sewage, and animal wastes contaminations [18]. However, its low concentrations, with significant differences in seasons ($p < 0.05$) below the permissible limit of 30 mg/L prescribed by the WHO and ANOR, showed no associated health risk. This result was in accordance with the observation of Wirmvem *et al.* [19] who studied the hydrochemistry of shallow groundwater and surface water in the Ndop Plain, North West Cameroon.

Cl^- is mainly obtained from the dissolution of salts such as table salt (NaCl) and added through industrial sewage and seawater. The lowest value of Cl^- (8.4 mg/L) was recorded in the sample upstream and the highest (116.22 mg/L) recorded for effluent in the month of February. The moderately high chloride concentrations in the downstream sample were possibly due to contamination from the effluent. Seasonal changes influenced the concentration of Cl^- in the samples ($p < 0.05$), as the concentrations were higher in the dry season than in the wet season. This could be due to high dilution of the chloride because of high rainfall in the wet season. According to WHO and ANOR standards, the concentration of chloride should not exceed 250 mg/L. The Cl^- concentration was thus within the permissible limit set by WHO. Low chloride ions in the sampled waters could be because of low NaCl in the geological formations of the study area, as it is generally derived from the decomposition of rock salts like sodium and Aluminium silicates [20]. High Cl^- concentrations in water damages metallic pipes and structures, as well as harm growing plants.

3.3. Heavy Metals

The concentrations of heavy metals in analyzed samples are presented in Table 4 below:

Table 4. Total concentrations of heavy metals in analysed samples.

	Rainy season			Dry season			MAC
Parameter	RNKW1	RNKW2	RNKW3	RNKW1	RNKW2	RNKW3	MAC (WHO, 2022)
Pb^{2+} (mg/L)	0.01	0.01	0.02	0.02	0.02	0.04	**0.01**
Al^{3+} (mg/L)	1.52	1.87	0.98	1.85	2.15	1.32	**0.20**
Zn^{2+} (mg/L)	0.23	1.68	0.75	0.56	3.12	1.21	**3.00**
Fe (mg/L)	0.10	0.21	0.10	0.20	0.34	0.00	**0.30**

MAC: Maximum Allowable Concentrations.

The values recorded for lead ion (Pb^{2+}) ranged from 0.01 mg/L to 0.04 mg/L for both seasons, with a general increase in concentration in February (possibly due to leaching), which was statistically insignificant ($p > 0.05$). These values were above the WHO and ANOR standard of 0.01 mg/L. The highest value was registered for the sample downstream due to possible contamination from the effluent. Exposure to such high concentrations in pregnant women, could cause miscarriages, while in men could damage the organs responsible for sperm production [21].

The concentration of aluminium in the various samples ranged from 0.98 to 1.87 mg/L in September and 1.32 to 2.15 mg/L in February, with a general increase from September to February. All the values were above the WHO standard of 0.2 mg/L. Such levels of aluminium promote microbial growth in water systems which may lead to health complications.

The concentrations of Zinc ranged between 0.23 and 1.68 mg/L in September and between 0.56 and 3.12 mg/L in February with an increase in moving from September to February. These results were below the 3.0 mg/L guideline value prescribed by WHO, except for the effluent sample-RNKW2, which, in the month of February had a value of 3.12 mg/L. This could possibly be the reason for the greater values of the samples downstream (RNKW3) compared to those upstream

(RNKW1).

For Iron (Fe), the concentrations ranged from 0.1 - 0.21 mg/L in September and 0 - 0.34 mg/L in February without any significant changes with seasons ($p > 0.05$). All the results were below the 0.3 mg/L guideline value, except for the effluent sample which had a concentration of 0.34 mg/L in the month of February. Concentrations of iron above 1.0 mg/L could cause ill health such as gastrointestinal irritation [22].

Ouedraogo *et al.* [23] reported trace metals contamination of water resources in the community of Méguet, which was mainly due to Fe (3.78 - 11.12 mg/kg), Hg (0.03 - 0.29 mg/kg), As (0.01 - 6.31 mg/kg) and Pb (0.01 - 3.8 mg/kg) traced to effluents from mines located within that municipality. Nkobe *et al.* [24] evaluated four anthropogenic activity impacts on heavy metal quality of the Kumba river in the Southwest Region of Cameroon and found out anthropogenic activities greatly influenced the water quality.

3.4. Hydrochemical Facies

The concentrations of major anionic and cationic constituents of the water samples were plotted on a Piper trilinear diagram [25] to determine the water types. The diamond-shaped field between the two triangles is used to represent the composition of water with respect to both cations and anions. The plot of physicochemical data on the diamond shaped trilinear diagram (**Figure 3**) revealed that the analyzed water samples were calcium and magnesium bicarbonate type, thus making the water hard.

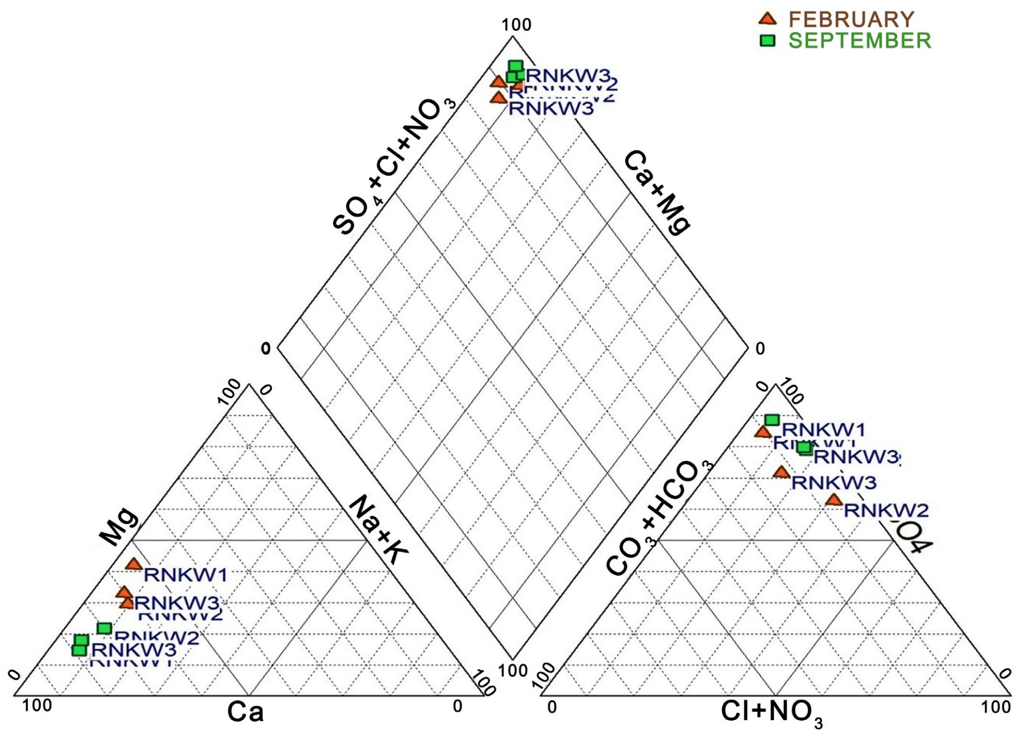

Figure 3. Piper's trilinear diagram of major ions showing water types.

3.5. Bacteriological Parameters

3.5.1. Most Probable Number of Coliforms in 100 mL of Water (MPN/100 mL)

Most probable number of coliforms in 100 mL of original water are presented in Table 5 below:

Table 5. Most probable number of coliforms in 100 mL of original water (MPN/100 mL).

	Rainy season			Dry season			
Sample Code	**RNKW1**	**RNKW2**	**RNKW3**	**RNKW1**	**RNKW2**	**RNKW3**	**Control**
Mean Count	160	170	165	43	180	160	0
Category	D-Grossly polluted (high risk	D-Grossly polluted (high risk)	D-Grossly polluted (high risk)	C-Not acceptable (high risk	D-Grossly polluted (high risk)	D-Grossly polluted (high risk)	A-excellent (no risk)

Analyses revealed the presence of faecal coliforms in all samples with most probable numbers ranging between 160 and 170 MPN/100mL in September 2022 and between 43 and 180 MPN/100mL in February 2023 (Table 5). With such high values, all the samples were thus classified under category D (grossly polluted) and not fit for consumption in both sampling sessions [8]. It was observed that MPN/100mL was higher downstream compared to upstream, a proof that the effluent is affecting the water quality downstream.

3.5.2. Specific Microbes Isolated (Colony Forming Units/mL)

Specific microbes isolated in colony forming units are presented in **Table 6** below:

Table 6. Results of specific microbes isolated (Colony Forming Units/mL).

	SEPTEMBER 2022			FEBRUARY 2023			
Sample code	**RNKW1**	**RNKW2**	**RNKW3**	**RNKW1**	**RNKW2**	**RNKW3**	**WHO/ANOR**
Total Coliform *Enterobacteria* spp.	240	410	280	160	320	180	0
Total faecal Coliform *E. coli*	140	170	160	50	180	160	0
Streptococcus spp.	3	10	5	5	15	10	0
Salmonella spp.	30	50	55	10	45	45	0
Shigella spp.	8	20	19	0	10	10	0
Staphylococcus spp.	27	2	5	14	0	5	0
Vibrio spp.	10	2	3	0	5	5	0

Faecal contamination is of global concern owing to the negative health effects associated with it. The samples were analysed for specific microbes which included *Enterobacteria* spp., *E. coli*, *Streptococcus* spp., *Salmonella* spp., *Shigella* spp., *Staphylococcus* spp. and *Vibrio* spp. Higher colony counts of pathogenic bacteria in the sample downstream (RNKW3) suggested their recent contamination by human or animal faeces and equally possible contamination from the effluent, both scenarios being indicators of poor hygiene and sanitation conditions for the inhabitants. Similar high coliform counts have been reported in other areas in Cameroon by Temgoua [15], Njoyim *et al.* [12], Mofor *et al.* [20], Biosengazeh *et al.* [9] and Mofor *et al.* [26].

4. Conclusion

This study focused on the effects of effluent from a dumpsite on a river by analysis of the organoleptic, physicochemical, and bacteriological properties of the river into which the effluent flew. This river serves as a source of domestic water in the Bamendakwe municipality in the Northwest region of Cameroon. Results of organoleptic and physical parameters showed that none of the samples were of good organoleptic properties, though they had acceptable pH limits ranging from moderately acidic to weakly basic and had high mineral contents (nitrates and sulphates). Regarding the chemical aspects, all the analyzed sulphate and nitrate ions amidst other ions were found to be higher than the WHO guideline limits and the water sources ranged from soft to moderately hard with lead and aluminum above the WHO guideline values in all the samples. The analyzed samples revealed that the river water was calcium and magnesium bicarbonate type, indicating shallow fresh ground waters. Low to high seasonal influences were observed in the variations of most of the parameters including pH and the concentrations of Na^+, K^+, Ca^{2+}, Mg^{2+}, NO_3^-, Cl^-, and NH_4^+. With respect to bacteriological quality, faecal coliforms and specific bacteria namely *Enterobacteria* spp. *E. coli*, *Streptococcus* spp., *Salmonella* spp., *Shigella* spp., *Staphylococcus* spp. *and Vibrio* spp., were identified in all the samples, especially the effluent from the dumpsite, suggesting recent contamination of the sources by human or animal faeces. Results also revealed that the water downstream has a high pollution load compared to the water upstream, which is clear evidence that the effluent from the dumpsite has a negative influence on the quality of water downstream. The river is thus unfit for domestic uses and thus, exposes the local population to water borne diseases such as typhoid, diarrhoea and dysentery. Therefore, home treatment methods such as chlorination, filtration, boiling and solar disinfection should be implemented prior to consumption.

Conflicts of Interest

The authors declare that there are no competing interests concerning the publication of this article.

Acknowledgements

The authors appreciate The Institute of International Education's Scholar Rescue Fund (IIE-SRF), for awarding a visiting scholar fellowship to the corresponding author, and Calvin Center for Christian Scholarship (CCCS), Calvin University, for the week of writing CO-OP that enabled the completion and revision of this manuscript. We are grateful to the technicians of Research Unit of Animal Physiology and Microbiology and the Research Unit of Soil Analysis and Environmental

Chemistry, of the University of Dschang, Cameroon for assisting in the laboratory analysis. Anonymous reviewers of this manuscript are highly appreciated.

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