Rainwater Quality Assessment In The Tamale Municipality.

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Abstract:-The study on the rainwater quality was carried out in Tamale Municipality in Ghana which is poorly endowed with natural water bodies that dries up during the dry season. Rainwater samples were analyzed for pH, turbidity, electrical conductivity and total dissolved solids and major ions (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, Cl^{-}, NO_3^{-}, H_2CO_3, CO_3, silica and SO_4^{2-}). pH levels ranged from 5.02 to 9.0 pH units with a mean of 7.18 ±0.72 pH units. The low pH found in some samples indicates high presence of CO_2 in the atmosphere as a result of excessive bush burning within the environs. This can also be attributed to the increased use of fossil fuel which emits high amounts of SO_2, NO_2 (vehicular movement) and particulate matter (smoke, dust, suspended soot) in the air. Turbidity levels of rainwater during the four year ranged from 0.4 to 12.4 NTU with a mean of 2.6±2.5 NTU compared to WHO limit of 5 NTU. The high levels of turbidity of rainwater recorded may be due to the presents of particulate matter in the atmospheric air. pH showed good correlation with K^{+} which indicates that the rampant annual bush burning is the common source of atmospheric pollution in the metropolis. The rainwater quality in the study area is influenced by local activities such as bush burning and particulate matter or dust.

Key words: Ghana, Tamale Municipality, Rainwater quality, Major ions, Particulate matter.

1 INTRODUCTION

The quality and quantity of available drinking water in the Tamale municipality during March-April where the temperature is relatively high with hot climatic environment, has being a critical factor in determining the well-being of the citizenry. The water supply systems and drinking water inaccessibility in the developing countries is a global concern which calls for immediate action. Currently, 884 million people in the world still do not get their drinking water from improved sources, almost all of them in developing regions [1]. Providing quality drinking water to all citizens of the world who are deprived access to water will serve as the breaking point of poverty alleviation in most developing countries especially in Africa, where substantial amount of national budgets are used to treat preventable waterborne diseases. Anyone of the UN Millennium Development Goals, from the halving of the number of people living in poverty to better education, and improved healthcare requires access to water as a necessary prerequisite and therefore, water is a key to Sustainable Development.

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The amount of annual rainfall recorded annually in the Northern region of Ghana varies between 750 mm and 1050 mm. The dry season starts in November and ends in March/ April with maximum temperatures occurring towards the end of the dry season (March – April) and minimum temperatures in December and January. Many rural communities in Ghana during the rainy seasons rely on traditional technologies such as temporal rainwater harvesting from the rooftop of their buildings for domestic use and digging of dugouts for the storage of rains and/or runoff water for use in the dry season. Fourteen (14) of such dugouts in five districts of Northern region of Ghana were all found to contained coliform bacteria [2], which make them unwholesome for human consumption unless treated. This traditional way of storing rainwater by dugouts is predominant in the three Northern regions of Ghana where the climate is dusty and relatively dry. The water quality of rainwater can be affected by urbanization, vehicular pollution and transboundary pollution. Poor water quality can increase the risk of water-borne diseases such diarrhoea, cholera, typhoid fever and dysentery. Water scarcity can also lead to diseases such as trachoma. The quality of harvested rainwater so far appeared contradictious [3]. The process of storage of rainwater is a major source of microbial contamination [2]. It is equally true the implications and complications for drinking water above critical limit of physico-chemical parameters. Although there have been concerns about microbial quality issues associated with rainwater harvesting in Ghana and elsewhere, this present research focuses only on the physico-chemical quality and content of collected rainwater in the Tamale Municipality between the year 2004 to 2008.

2. MATERIALS AND METHODS

2.1 Study area

The Tamale metropolis is the capital of the Northern region of Ghana. It is about 175 km east of longitude 1°W and latitude 9°N. It shares boundaries with the Savelugu/Nanton district to the north, Tolon/ Kumbungu district to the west, the East Gonja district to the south and the Yendi district to the east (Fig 1). The metropolis occupies approximately 750 km sq. which is about 13% of the total area of the Northern region.

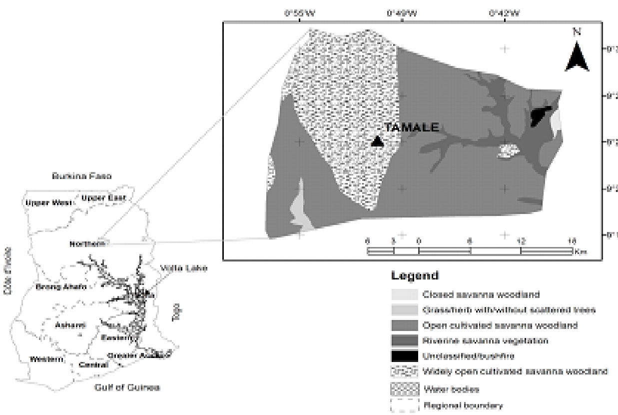

Fig 1: Map of Tamale Metropolis, Ghana.

The metropolis experiences one rainy season starting from April/May to September/October with peak season in July/August. Mean annual rainfall is about 1100 mm within 95 days of intense rain. Staple crop farming is highly restricted by the short rainfall duration. The dry season is usually from November to March. It is influenced by the dry North-easterly winds while the wet season is influenced by the moist south-westerly winds. The mean day temperatures range from 33°C to 39°C while mean night temperatures range from 20 – 22°C. The mean annual day sunshine is approximately 7.5 hours. The metropolis lies within the Guinea Savanna belt of Northern Ghana and it exhibits tall grasses interspersed with drought resistant trees such as neem, sheanut, dawadawa and mahogany [4]. During the rains the Metropolis becomes green making the vegetation more luxuriant. The Tamale Metropolitan area is underlaid by sandstone, mudstone and shale, which over time, have been weathered to different degrees [5]. The main soil types that have resulted from the above natural phenomenon include sand, clay and laterite ochrosols. These soil types are inadequately protected resulting in serious erosion during the rains. The metropolis is poorly endowed with water bodies. The only natural water systems are a few seasonal streams which have water during the rainy season and dry up during the dry season. Notable among these streams are the Pasam, Dirm-Nyogni and Kwaha. These streams have their headwaters in Tamale which is situated on a higher ground. Aside these streams, artificial dams and dugouts have been created to help in the provision of water throughout the year. Some of these artificial dams and dugouts are the Lamashegu, Buipella, Vittin and Nyohini dugouts.

2.2 Water sampling and analysis

The field and laboratory determinations were based on the Standard Methods for the Examination of Water and Wastewater [6]. Rainwater samples were collected manually in an open space from a height of 10 ± 2 meters above ground level, in clean acid-washed polyethylene bottles using glass funnels. The analysis were done within 24 hours after samples had being filtered and those that were not worked on immediately were refrigerated at 4ºC before all chemical parameters measured and ionic components determined. The temperature of rain water samples was readily measured using a mercury-in-glass thermometer and pH determined using portable pH meter. Conductivity was measured with Jenway model 4520 conductivity meter and turbidity with a Partech model DRT 100B Turbidimeter. Sodium and potassium were measured by flame emission photometry; calcium and magnesium by EDTA titration; sulphate by the turbidimetric method; colour by colour comparator and chloride by argentometric titration. Other analyses included alkalinity by strong acid titration method and silica by Molybdosilicate Method. Nitrate-nitrogen was analysed by hydrazine reduction and spectrophotometric determination at 520nm, and phosphate by reaction with ammonium molybdate and ascorbic acid, and measured at 880 nm. Fluoride by SPADNS method and total dissolved solids by the use of multipurpose Jenway 4520 conductivity meter. Statistical analysis was performed using SPSS version 16.0. The data was subjected to normality tests by fitting them with Normal and Lognormal distributions, on the premise that the observations were independent and identically distributed over the area and sampling period. The Lognormal distribution is capable of representing skewed environmental data, which are generally positively skewed. The Pearson's correlation significant was used to examine correlation between selected parameters; all tests were two tailed.

3. RESULTS AND DISCUSSIONS

Generally, most of the water quality parameters analyzed were within WHO recommended limit for potability (Table 1). pH levels ranged from 5.02 to 9.0 with a mean of 7.18 ±0.72. Of the 72 rainwater samples collected during the four year period 11.1% had pH in the range of 5.0-6.5, 31.9% in the range of 6.6-7.0, 43.1% in the range of 7.1- 7.9, 11.1% in the range of 8.0-8.9 and only one sample (1.4%) recorded a pH of 9. None of the samples analyzed recorded pH levels below 5.0 and above 9.0. pH of the rainwater recorded values less and some exceeded WHO limits for drinking water. The average pH was slightly higher compared with a similar study in Obuasi, a town in Ghana which recorded mean pH of value of 4.67 ± 0.47 [7]. The observed low pH of less ≥ 5.6 pH unit recorded in rainwater in the four year was acidic indicating high presence of CO_2 in atmosphere as result of excessive bush burning within the environs. This can also be attributed to the increased use of fossil fuel which emits high amounts of SO_2, NO_2 (vehicular movement) and particulate matter (smoke, dust, soot suspended) in the air. pH values lower than 5.5 are considered too acidic for human consumption and can cause health problems such as acidosis [8]. Turbidity levels of rainwater during the four year ranged from 0.4 to 12.4 NTU with a mean of 2.6±2.5 NTU compared to WHO limit of 5 NTU (table 1). The high levels of turbidity of rainwater recorded may be due to the presents of particulate matter in the atmospheric air within the metropolis. The turbidity values that exceed the 5 NTU has the tendency of causing treatment problems and harbouring of micro-organism. High level of turbidity can protect micro-organisms from the effect of disinfection, stimulate the growth of bacteria and give rise to significant chlorine demand [9]. The colour levels of rainwater recorded ranged from 2.5 to 10.0 Hz with a mean of 2.8±1.1 Hz compared to WHO guidelines of 15 Hz for drinking water (table 1). Colour is strongly influenced by the presence of iron and other metals, either as natural impurities or as corrosion products [10]. The conductivity values of rainwater recorded during the four year ranged from 2.03 to 102 µS/cm with a mean of 13.6±14.6 µS/cm. Electrical conductivity of rainwater reflects the impact of atmospheric particulate matter on the precipitation chemistry. This is lower than the average conductivity of precipitation at Nanping Mangdang Mountain in eastern China during spring and in other cities such as Beijing and Shenzhen [11], [12], [13]. Rainwater conductivity is mainly contributed by water-soluble ions, the value being related to the total sum of cations and anions in the rainwater. Low rainwater conductivity is an indicator of good atmospheric environmental quality. Total dissolved solids concentration recorded during the study ranged from 0.05 to 51 with a mean of 6.5±7.5 mg/L compared to WHO limit of 1000mg/L for drinking water (table 1). The total dissolved solids (TDS) in rainwater, originating from particulate matter suspended in the atmosphere usually range from 2 mg/l to 20 mg/l [14]. However, the study disagreed with the finding since total dissolved solids concentration has gone beyond the 20 m/l limit and probably due to the high concentration of particulate matter in the atmospheric air within the metropolis. The concentration of sodium ranged from <0.01to 0.05 mg/L with a mean of 0.06±0.1 mg/L compared to WHO limit of 200 mg/l for drinking water (table 1). Sodium (Na) is commonly taken as the best as the reference element for marine source [15]. However, it is reported that for individuals suffering from health problems such as heart disease or high blood pressure the maximum recommended sodium concentration in drinking water is 20 mg/l [16]. The potassium concentration during the four year ranged from <0.01 to 0.4 mg/L with a mean of 0.10±0.1 mg/L compared to WHO limit of 30 mg/l for drinking water (table 1). K^+ has been suggested as a chemical signature of biomass burning [17], [18]. This therefore revealed that the ongoing annual bush burning activity in the metropolis contributes to potassium concentration in the rainwater. The concentration of total hardness, calcium and magnesium of the rainwater compared to WHO recommended limits for drinking water (table 1). Total hardness concentration of the rainwater ranged from 2.0 to 74 mg/L with a mean of 10.64±11.5 mg/L, while calcium concentration ranged from 0.05 to 14.4 mg/L with a mean of 2.38±2.8 mg/L (table 1). The average mean recorded is extremely lower than value reported by similar study in Egypt [19]. However, it was much higher than the values ranged of 0.56 to 1.02 mg/l recorded in Obuasi, Ghana [7]. The Magnesium concentration of the rainwater ranged from 0.05 to 9.7 mg/L with a mean of 1.15±1.4 mg/L. However, the low concentrations of these minerals in rainwater have the tendency of causing health problems since water scarcity is compiling large number of the populace in the metropolis to patronise rainwater highly. Soft water (that is water low in calcium and magnesium), is associated with increased morbidity and mortality from cardiovascular diseases (CVDs) compared to hard water and water high in magnesium [20]. Recent studies also suggest that the intake of soft water may be associated with high risk of fracture in children [21]. A few months exposure may be sufficient consumption time effects from water that is low in magnesium and/or calcium [22]. Chloride concentration of the rainwater ranged from 0.1 to 13.9 mg/L with a mean of 3.56±2.3 mg/L compared to WHO limit of 250 mg/L for portable water. The average chloride concentration is slightly lower than that of rainwater in Egypt [19]. Chloride ion originates from human activities and refuse incineration, such as PVC, which produces HCl in gas phase [16]. The low chloride concentration of the rainwater recorded during the four year might be attributed to the low industrial emissions in the metropolis. The nitrate-N concentrations of the rainwater ranged from 0.01 to 6.5 mg/L with a mean of 1.58±1.8 mg/L compared to WHO limit of 10 mg/l (table 1). Nitrate-N of rain water is considered to be non-cumulative toxins. Sulphate concentration of rainwater ranged from 0.04 to 8.2 mg/L with a mean of 3.73±2.1 mg/L compared to WHO recommended limit of 400 mg/l for drinking water (table 1). It is generally accepted that sulphate is formed in the atmosphere by chemical conversion from SO2 [24], which is discharged into the atmosphere from natural and anthropogenic sources. SO_2 is gradually converted to aerosols matter by oxidation as it is carried by air currents downwind from its sources. However, the study recorded low sulphate concentrations that suggest that SO_2 discharged into the atmosphere from human activities in the metropolis could be moderate or insignificant. Phosphate concentration of the rainwater during the four years study ranged from <0.001 to 0.15 mg/L with a mean of 0.03±0.03 mg/L compared to WHO limit of 2.5 m/l for portable water. Total Alkalinity concentration of the rainwater during the study ranged from 2.0 to 40 mg/L with a mean of 8.16±6.5 mg/L compared to WHO limit of 1000 mg/l for drinking water. Bicarbonate concentration of the rainwater ranged from 2.4 to 43.9 mg/L with a mean of 9.41±7.6 mg/L. Water can dissolve carbon dioxide from the air, forming carbonic acid (H_2CO_3). The concentration is as result of the high presence of CO_2 in the atmospheric air due to the ongoing annual bush burning in the metropolis and its environs. Silica concentration of the rain water during the study ranged from 0.05-1.9 mg/L with a mean of 0.16±0.4 mg/L.

Table 1: Values of measured rainwater parameters in the Tamale metropolis

Parameters (N= 72)	Mean	SD	Min –Max	Skewness	Kurtosis	WHO
pH	7.18	0.72	5.02- 9.0	-0.03	1.4	6.5-8.5
Turbidity (NTU)	2.6	2.5	0.4-12.4	2.36	5.7	5
Colour (Hz)	2.8	1.1	2.5-10.0	4.30	23.0	15
Conductivity (µS/cm)	13.6	14.6	2.03-102	3.58	18.6	-
TDS	6.5	7.5	0.05-51	3.41	17.3	1000
Sodium	0.06	0.1	<0.01-0.05	7.5	58.4	200
Potassium	0.10	0.1	<0.01-0.4	1.5	1.2	30
Calcium	2.38	2.8	0.05-14.4	2.6	7.2	200
Magnesium	1.15	1.4	0.05-9.7	4.0	19.3	150
Chloride	3.56	2.3	0.1-13.9	2.0	5.6	250
Nitrate-N	1.58	1.8	0.01-6.5	1.4	1.0	10
Sulphate	3.73	2.1	0.04-8.2	0.1	-0.5	400
Phosphate	0.03	0.03	<0.001-0.15	1.5	2.3	2.5
Alkalinity	8.16	6.5	2.0-40	2.3	7.7	1000
Bicarbonate	9.41	7.6	2.4-43.9	2.1	5.9	
T. hardness	10.64	11.5	2.0-74	3.3	13.4	500
Ca. hardness	6.00	7.1	0.1-36	2.6	7.4	
Mg. hardness	4.64	6.0	0.1-39.9	4.0	19.1	
Silica	0.16	0.4	0.05-1.9	3.7	12.9	

Concentration (mg/L), unless otherwise stated.

Correlation Analysis

Correlation analysis was performed to distinguish the possible common sources of ionic constituents and how some of the physical parameter influences their concentration. To determine the association among ionic constituents in rainfall, correlations among ions in precipitation were calculated and listed in table 2. As seen from table 2, pH showed good correlation with K^+ which indicates that wood combustion is the common source since the metropolis is engulf with bush burning during early dry season but it is insignificant statistically. It also showed good correlation with TDS, Na^+, Mg^{2+} and Cl^- at 5% indicating that particulate matter and CO_2 are common source of their concentration in the atmospheric air. Turbidity shows significant correlation at 5% and 1% with colour and Ca^{2+} respectively. This indicates that particulate matter is the common source that contributes to colour and calcium levels of the rainwater in the metropolis. Total dissolved solids at 1% showed significant correlation that was good with Na^+, Mg^{2+}, H_2CO_3, Ca^{2+} and Total hardness, confirming particulate matter as a common source that contribute to Na^+, Mg^{2+}, Ca^{2+} and Total hardness concentration in rainwater within the metropolis. However, the significant correlation between TDS and H_2CO_3 indicates that their common source of pollution is CO_2 in the atmosphere. Sodium at 1% showed significant correlation with Mg^{2+}, H_2CO_3, total hardness and Ca^{2+}. Potassium at 1% showed significant correlation with Cl^- and H_2CO_3 that shows that an increase in potassium concentration will decrease in their concentration and vice versa. Calcium at 1% shows significant correlation with SO_4 and H_2CO_3. This is in line with other studies that reported SO_4^{2+} correlated with Ca^{2+} and sea salt (Na^+ and Cl^-) [25], indicating that the major portion of SO_4^{2-} was in the form of salts with soil originated constituents. Magnesium at 1% showed significant correlation with silica, total hardness, H_2CO_3 and Cl^-. Chloride at 1% showed significant correlation with silica and H_2CO_3 and also a correlation with SO_4 that is not statistically significant. Phosphate showed significant correlation with H_2CO_3 and negative correlation with total alkalinity.

Table 2: correlation analysis of rainwater parameters

	pH	TURB	TDS	Na	Ca	Mg	Cl^-	SO_4	PO_4	HCO_3^-	SILICIA
	1	0.02	0.28*	0.31*	0.049	0.34**	0.24*	0.05	0.04	0.39**	0.25*
pH		0.86	0.02	0.01	0.79	0	0.05	0.67	0.73	0	0.04
		1	0.16	0.14	0.54**	-0.01	-0.04	0.28*	0.39**	-0.14	-0.02
TURB			0.17	0.26	0	0.94	0.77	0.02	0	0.25	0.9
			1	1**	0.01	0.62**	0.36**	-0.09	0.24*	0.60**	0.36**
TDS				6.16	0.94	4.8	0.003	0.48	0.05	2.87	0
				1	0.02	0.63**	0.35**	-0.12	0.26*	0.58**	0.35**
Na					0.94	1.93	0.01	0.35	0.04	3.78	0.01
					1	0.06	-0.05	0.72**	0.39*	0.14	-0.06
Ca						0.74	0.78	8.31	0.03	0.46	0.75
						1	0.54**	-0.16	0.08	0.73**	0.54**
Mg							3.13	0.2	0.53	3.55	2.1
							1	-0.18	0.03	0.50**	1**
Cl								0.14	0.82	0	5.19
								1	-0.22	-0.03	-0.2
SO_4									0.07	0.77	0.1
									1	0.19	0.03
PO_4										0.11	0.83
										1	0.44*
HCO_3^-											0
											1
SILICA											

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

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

4 Conclusion

The results of rainwater quality indicate pH values were lower and some values exceed WHO recommended limits for portability in the four year study period. pH levels ranged from 5.02 to 9.0 with a mean of 7.18 ±0.72 pH unit. The observed low pH of less ≥ 5.6 recorded showed that rainwater is acidic indicating high presence of CO_2 in atmosphere as result of excessive bush burning within the environs. This can also be attributed to the increased use of fossil fuel which emits high amounts of SO_2, NO_2 (vehicular movement) and particulate matter (smoke, dust, suspended soot) in the air. Turbidity levels of rainwater during the four year ranged from 0.4 to 12.4 NTU with a mean of 2.6±2.5 NTU compared to WHO limit of 5 NTU. This therefore poses a health threat to the indigenes in the metropolis that largely depends on rainwater as their major source of drinking water. The study recorded an average conductivity of 13.6µS/cm which indicates good atmospheric environmental quality in the metropolis. pH showed good correlation with K^+ which indicates that the rampant annual bush burning is the common source of atmospheric pollution in the metropolis. Therefore, the rainwater quality in the metropolis is influenced by local activities such as bush burning, exhaust from vehicles and particulate matter or dust.

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