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Full Length Research Paper

Water quality assessment of Ruguti River in Meru South, Kenya

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Physicochemical and microbiological analyses were carried out on water and sediment samples from Ruguti River in Meru South, to ascertain the water quality. The mean of the results obtained were compared with WHO (2011) standards for drinking water .The physicochemical parameters such as temperature, electrical conductivity, total dissolved solids, total alkalinity, total hardness, sulphates, chlorides, fluorides were in compliance with the WHO (2011) standards. Turbidity, nitrite and nitrates levels were above WHO (2011) standards. The concentration of phosphorous was below detection limit of the analytical method used. The mean values for all trace metals at all the sampling sites of the water samples were below the WHO (2011) standards for drinking water except Fe, Mn and Al. The results of sediment samples indicates that silicate, iron, calcium and aluminium are present in major quantities while other minerals are present in trace amounts. Sediments has lower carbonaceous matter and higher mineral contents. The concentration of the Cd in the sediment was below its detection limit. Total coliform bacteria/100 ml are greater than 2420 while *E. coli*/100 ml varied from 1203 to 1986. These results reveal that the Ruguti River is contaminated and use of the water for domestic purposes by the inhabitants could lead to hazardous side effects.

Key words: Water quality, microbiological parameters, physicochemical parameters, surface water, coliforms.

INTRODUCTION

Water quality is commonly defined by its physical, chemical, biological and aesthetic characteristics (Abdul, 2010; Arvind et al., 2011; Sukhdev, 2012; Agbaire et al., 2009; Shalom et al., 2011). A healthy environment is one in which the water quality supports a rich and varied community of organisms and protects public health (Adekoyeni and Salako, 2012; Afejuwon and Adelakun, 2012). Majority of water pollutants are however in the form of chemicals which remain dissolved or suspended in water and give an environmental response which is not acceptable (Krishna and Mohini, 2012; Hagan et al., 2011; Yisa and Jimoh, 2010).

Sometimes physical and biological factors also act as pollutants (Shrivaraju, 2012; Karikari and Ansa-Asare, 2006). Among the physical factors, heat and radiation are important which have marked effects on organisms (Kousar et al., 2010). Certain microorganisms present in water especially pathogenic species, cause diseases of man and animals and can be referred to as bio-pollutants (Chetna et al., 2006; Oladele et al., 2011; Romulus et al., 2012; Adejuwon and Adelakun, 2012; Ibiene et al., 2012; Prakash and Somashekar, 2006). The greatest microbial risks are associated with ingestion of water that is contaminated with feaces from human feaces from humans and birds (Ivana et al., 2012). Feaces can be a source of pathogenic bacteria, viruses, protozoa and helminthes which causes water borne diseases (WHO, 2011; Momba et al., 2006). Changes in normal appearance, taste or odor of a drinking water supply may signal changes in the quality of the raw water source or deficiencies in the treatment (WHO, 2011; Singth, 2007).

Pollution of rivers is mostly experienced as a result of industrial discharge, municipal waste disposal and surface run off (Chuima et al., 2009; Taiwo et al., 2012). Indiscriminate and uncontrolled discharges of wastes into rivers impact negatively on river, ecosystems and human health (Oladele et al., 2011). In effect, physicochemical and microbiological pollution parameters of the Ruguti River in Meru South District are lacking. It was therefore, necessary to investigate physicochemical and microbiological

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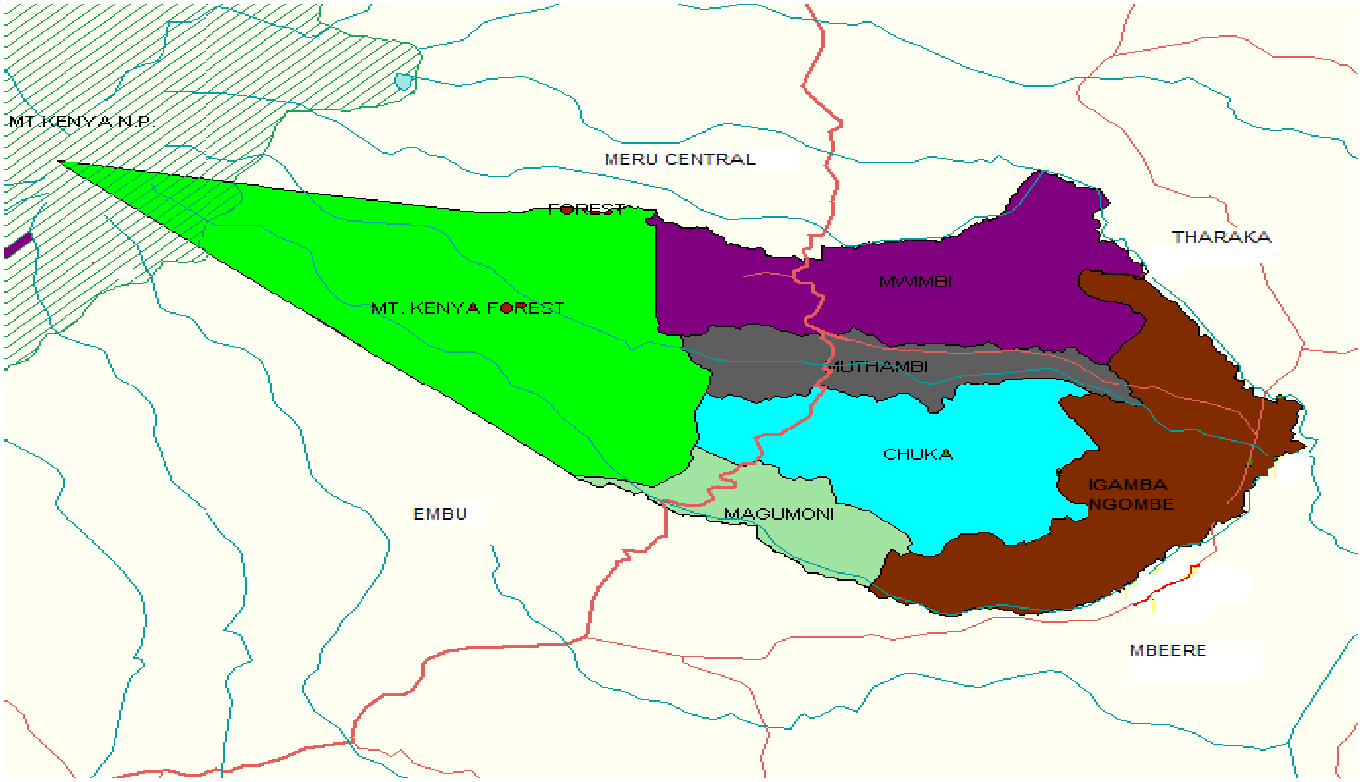


Figure 1. Meru South district map showing divisional /district boundaries.

parameters of this river in order to evaluate how the water supply may influence infection and disease health implications.

Study area

Meru South district (Figure 1) is situated between longitudes 37°18'37'' and 37°28'33'' east and latitude 007'23'' and 0026'19'' south. Altitude of Meru South is from 5200 m above sea level at the peak of Mt. Kenya to 600 m in the lower areas. The topography of the district is influenced by the volcanic activity of Mt. Kenya (Figure 2). Numerous rivers which originate from Mt. Kenya forest transverse the district and flow eastwards as tributaries of Tana River, which discharge its water into the Indian Ocean. The district has bi-modal rainfall pattern with rains falling during the months of late March to early June and October to December. The highest amount of rainfall ranges from 2200 to 500 mm.

MATERIALS AND METHODS

Ninety-six grab water samples were collected in the middle part of the River Ruguti from the six sampling sites (Figure 3) during the period which covered early rainy season to early dry season. The samples were taken into 1-L sterilized glass bottles for bacteriological analysis and 2-L polythethylene containers for physicochemical analysis which were opened at depths of 15 to 20 cm below the water surface after rinsing the containers with the first sets of samples. The samples were given the treatment at the field as per standard methods (APHA, 2005). The bacteriological analysis was done using the standard methods (APHA, 2012).

Parameters with extremely low stability such as pH, electrical conductivity, turbidity and temperature, were measured on the field using temperature kit (Electronic India, model 16E). The rest of the characteristics of water samples were measured in the laboratory after transportation in a cool box at a very low temperature using standard procedures (APHA, 2005). To ensure accuracy, analysis was done in triplicates and mean value was taken into consideration. The standard reagents used in analysis were prepared using double distilled water.

Similarly sediments were also taken in the same sampling sites as water from depths of 5 to 10 cm below the river bed using a plastic trowel and pre-cleaned polyethylene bags. AAS (Varian Spectr-AA-10-Model) and XRF (Minipal QC Model) were used for determination of trace metals in sediments. The certified standard reference material IAEA 356 from the National Institute of Standards and Technology, USA was used for the validation of the atomic absorption spectrophotometric method. The specific methods employed under this investigation have been summarized in Table 1 (APHA, 2005; Arvind et al., 2011).

RESULTS AND DISCUSSION

Physico chemical parameters

Analytical results for the various parameters have been

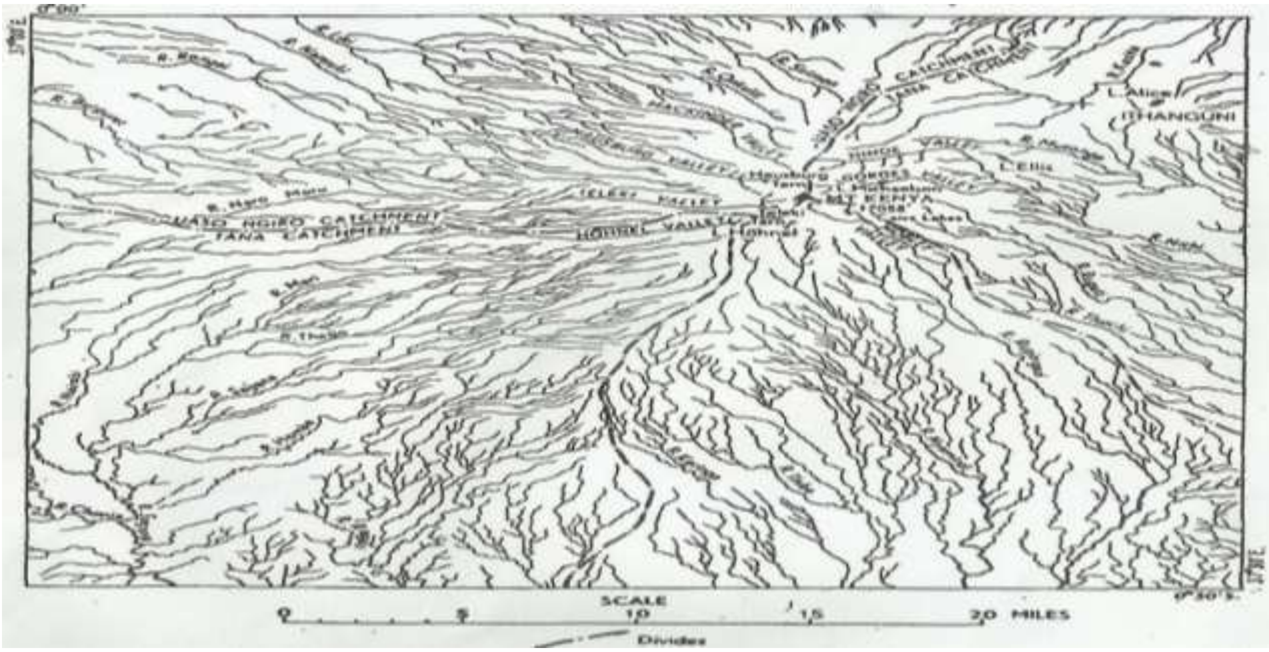


Figure 2. Drainage pattern in the Mt. Kenya area.

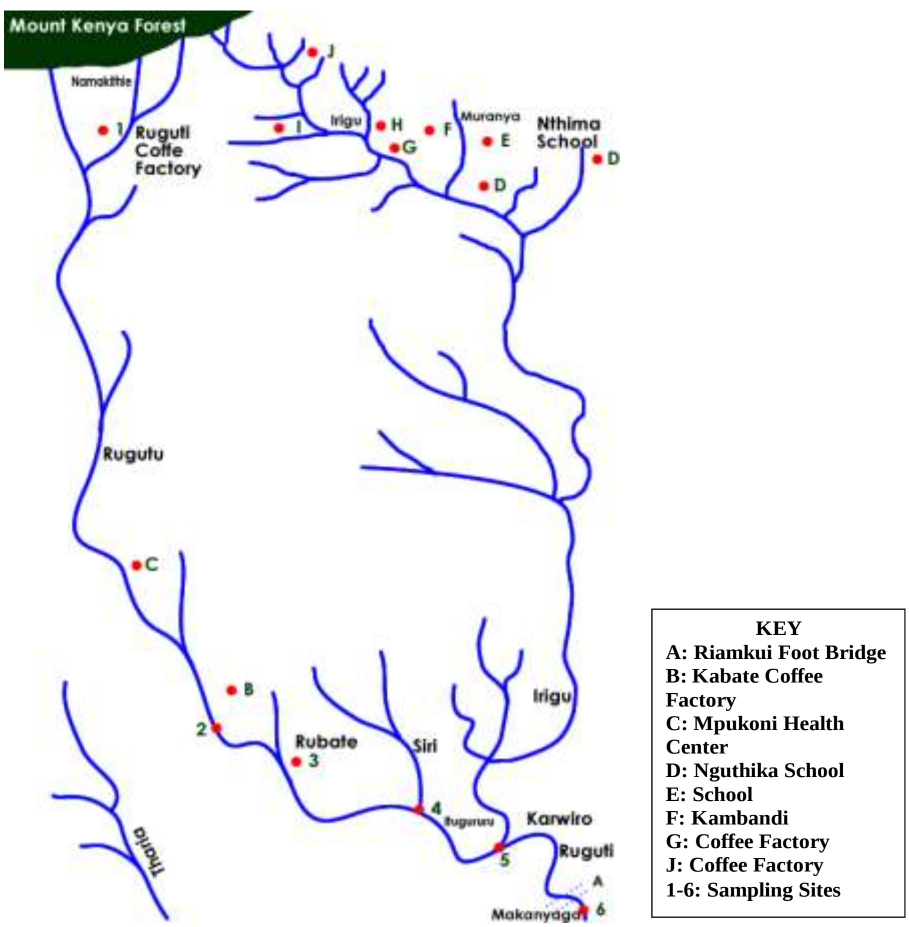


Figure 3. Sampling sites.

Table 1. Water quality test method.

Parameter	Test method
Temperature	Thermometric
pH	Potentiometric
Electrical conductivity	Conductometric
Turbidity	Nephelometric
Total dissolved solids	Gravimetric
Total suspended solids	Gravimetric
Total alkalinity	Titrimetric
Total acidity	Titrimetric
Total hardness	EDTA titrimetric
Sulphates	Turbidimetric
Ammonia	Nessierization spectrophotometric
Nitrates	Ultraviolet spectrophotometric
Nitrites	Spectrophotometric
Chloride	Argentometric
Fluoride	Ion-selective electrode
Phosphorous	Spectrophotometric
Metals	Atomic absorption spectrophotometric
MPN of coliforms organisms/100 ml	IDEXX Quanti-Tray/2000

shown in Table 2. The temperature ranged between 19.10 to 23.40°C. This is one of the most important parameters for it has an impact on the acceptability of a number of inorganic constituents and chemical contaminants that may affect taste. High water temperature enhances growth of microorganisms and may increase problems related to taste, odour, colour and corrosion. High temperature observed during rain season can be attributed to the insulating effect of increased nutrient loading resulting from surface run off and coffee factory discharge. In general, the entire Ruguti River system surface water samples temperature values are within the limit.

The pH of the water samples in the study area ranged from 6.89 to 7.85 indicating it is within the range of 6.55 to 8.5 set by WHO. Thus, the pH of the river would not adversely affect its use for domestic and recreational purposes. It was observed that pH values are higher during dry season and may be due to increased photosynthesis blooms of cyanobacteria and other algae in River Ruguti resulting into the precipitation of carbonates from bicarbonate. A slight drop in pH value was observed at the sampling sites 1 and 2. This may be attributed to the influx of acidic waste entering the river from an adjacent coffee factory. pH has profound effects on water quality affecting the solubility of metals, alkalinity and hardness of water. The survival of aquatic organism is also greatly influenced by the pH of water bodies in which they are found. This is because most of their metabolic activities are pH dependent.

Electrical conductivity values of Ruguti River ranged from 0.18 to 19.36 μmho/cm. The results of electrical conductivity analyzed were higher in the wet season than in the dry season .This might be attributed to high temperature during this season. At various sampling sites, point sources waste waters were affecting the river water conductivity. The electrical conductivity of River Ruguti falls within the acceptable limit. The determination of electrical conductivity helps in estimating the concentration of electrolytes, thereby making it sour and unsuitable for drinking water. The total dissolved solids ranged between 0.10 and 12.10 mg/l. The correlation coefficient and probable error were found to be +0.87 and 0.07 respectively, which implies that the presence of the total dissolved solids is a major contributing factor to the conductivity of the river.

The total dissolved solids which show the nature of water quality was within permissible limits. Weathering of rocks depends upon the availability of bicarbonates into a given environment and soil beneath the water always contributes to the level of total dissolved solids in water. However, its contribution to Ruguti River was very low. The observed low concentration of dissolved solids in the surface water is a pointer to the fact that, there are less intense anthropogenic activities along the course of the river and runoff with low suspended matter content.

Turbidity is caused by suspended particles or colloidal matter that obstructs light transmission through the water.

Microorganisms (bacteria, viruses and protozoa) are typically attached to particulates, hence the more turbid the water, the greater the chances of water by WHO. The high values of turbidity are possibly due to effects of run off water and discharge from coffee factories borne disease. From results the turbidity of the water sample

Table 2. Mean of physicochemical qualities of the water samples.

Physicochemical parameter	Site 1		Site 2		Site 3		Site 4		Site 5		Site 6		WHO (2011)
	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	
Temperature(°C)	20.80	20.00	20.10	19.10	21.40	20.20	23.20	22.10	22.80	22.OO	23.40	22.00	
pH	6.89	7.34	6.90	7.28	7.20	7.85	7.25	7.65	7.81	8.50	7.19	7.34	6.5-7.5
Electrical conductivity (µmho/cm)	18.36	0.36	19.36	0.56	17.30	0.28	16.6	0.18	16.40	0.20	17.70	0.38	1500
Total dissolved solids(mg/l)	11.60	0.18	12.00	0.20	11.00	0.15	10.10	0.10	10.30	0.09	12.10	0.10	600-1000
Total suspended solids(mg/l)	8.20	0.03	8.00	0.03	3.00	0.03	3.60	0.02	3.20	0.02	1.80	0.05	NS
Total solids (mg/l)	19.80	0.21	20.00	0.23	14.00	0.18	13.70	0.12	13.50	0.11	13.90	0.15	NS
Turbidity (NTU)	48.49	7.02	52.83	6.32	43.00	7.81	42.50	7.32	31.50	6.35	22.1	7.45	5
Total alkalinity (mg/l)	4.00	2.00	3.00	1.00	2.00	1.0	1.00	0.50	2.00	1.30	1.00	0.60	120-600
Total acidity (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS
Total hardness (mg/l)	24.00	30.00	26.00	32.00	18.00	35.00	20.00	32.00	15.00	25.00	20.00	25.00	100-500
Sulphates (mg/l)	7.91	5.71	5.10	3.82	8.2	4.03	7.32	4.68	6.81	2.73	5.72	2.52	250
Ammonia (mg/l)	0.83	0.23	0.78	0.21	0.57	0.18	0.42	0.10	0.32	0.09	0.35	0.12	NS
Nitrates (mg/l)	107.97	3.11	100.1	72.32	62.51	0.18	83.12	0.20	64.11	0.52	52.33	0.90	50
Nitrites (mg/l)	6.17	0.07	5.72	90.05	5.11	0.03	6.81	0.02	5.15	0.04	6.10	0.05	3
Chloride (mg/l)	3.00	8.00	2.17	4.23	3.18	9.33	2.89	9.10	2.80	7.89	2.69	8.10	250
Fluoride (mg/l)	0.12	0.42	0.18	0.38	0.15	0.40	0.17	0.41	0.2O	0.46	0.23	0.45	1.5
Phosphorous (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS

Key: NS: Not specified, ND: Not detected.

ranged between 6.32 to 52.83 NTU. These values exceed the acceptable limits set which carries with them several compounds (bacteria, suspended solids, hydrocarbons and heavy metals). These compounds can impede the rays of light entering the River. This effect can influence the dissolved oxygen level in water bodies. This is possible because suspended particles absorb sunlight and increase the temperature of the water and this reduces the oxygen level of such water. The inhibited rays of sunlight by suspended particles can influence the rate of photosynthetic activity and thus reduce the dissolved oxygen level of water borne diseases.

From the results the turbidity of the river sample ranged between 6.32-52.83 NTU. The high values of turbidity are possibly due to effects of run off water and discharge from coffee factories which carries with them several compounds (bacteria, suspended solids, hydrocarbons and heavy metals). These compounds can impede the rays of light entering the river. This effect can influence the dissolved oxygen level in water bodies. This is possible because suspended particles absorb sunlight and increase the temperature of the water and this reduces the oxygen level of such water. The inhibited rays of sunlight by suspended particles can influence the rate of photosynthetic activity and thus reduce the dissolved oxygen level of water. Turbidity in the study area was found exceeding the acceptable limits by WHO, hence might lead to health hazards..

The various ionic species contribute mainly to alkalinity includes bicarbonates, carbonates, hydroxides, phosphates, borates, silicates and organic acids. In some cases, ammonia is also accountable to the alkalinity. In the present study alkalinity ranged from 0.5 to 4.00 mg/l as $CaCO_3$ indicating slightly alkaline nature of water and it was within acceptable limit of WHO. The deviation from neutrality to alkalinity could be due to the bicarbonates, carbonates and silicates which dissolved in water from mineral rich soil. The high values of alkalinity observed during wet season could possibly result from some alkaline materials being washed into the different section of the river. The acidity of water was below the detection limit for the method used.

Hardness ranged from 15.00 to 35.00 mg/l as calcium carbonate .The value of hardness indicates that water is soft and is within the acceptable limits of WHO. The observed sulphate values ranged from 2.52 to 8.2 mg /l. The values were within acceptable range of WHO. The high values observed during wet season might be due to surface runoff. In the absence of dissolved oxygen, nitrate and sulphate serve as a source of oxygen for biochemical oxidation produced by anaerobic bacteria. Under anaerobic conditions, sulphate ion is reduced to sulphide which establishes equilibrium with hydrogen ion to form hydrogen sulphide. The presence of hydrogen sulphide leads to corrosion of pipes.

Nitrate levels ranged from 0.18 to 107.97 mg/l. The values observed during wet season were above the maximum allowable limit of 50 mg/l while during dry season the values were very low. The high concentration of nitrate during the wet season was probably as a result of high dissolved oxygen concentration in the river. This facilitates oxidation of ammonia to NO_3^-. The enrichment of nitrate could also be attributed to human and animal sewage, intense use of fertilizer and dust. These are washed in water bodies by rainfall. The high concentration of nitrate in drinking water causes methemoglobulinemia in infants, a disease characterized by blood changes. Also high nitrate levels lead to eutrophication.

The levels of nitrite ranged from 0.02 to 6.81 mg/l. The nitrite levels during wet season were above permissible limit and they were below the permissible limit during dry season. The high level of nitrite during wet season could be due to animal waste, fertilizer, natural deposits, septic tanks and sewage being washed into the river. The potential health effects from ingestion of water with a high level of nitrite is the possibility of having the disease called methemoglobulinemia.

Chlorides are leached from various rocks into the soil and water by weathering. The main source of chloride in surface water is due to atmospheric precipitation, animal feeds, septic tanks, use of inorganic fertilizers and landfills leachate. The observed range of chloride varied from 2.17 to 9.33 mg/l which was below the accepted WHO limit of 250 mg/l. Chlorides levels might be attributed to land fill leachate. The low levels of chloride during wet season might have been caused by dilution due to the high water levels. Fluoride levels ranged from 0.12 to 0.46 mg/l, and the levels are within the permitted limit. The main sources of fluoride in surface water are due to natural deposits, fertilizers, aluminium industries and water additive. The level of fluorides in this river could be due to natural deposits. The low level observed during wet season could be due to dilution. High levels of fluoride cause skeletal and dental flourosis. The concentration of phosphorous was below the detection limit for the analytical method used.

Trace metal concentration in water samples

The results of trace metal analysis in the water samples are presented in Table 3. The mean values for the elements at all the sampling sites of the river were below the WHO maximum guideline values for the respective elements in drinking water, except for Fe, Mn and Al.

The levels of Fe, which were above the WHO guideline value of 0.3 mg/l for drinking water, could be attributed to the geological weathering of parent rocks underlying the river basin and domestic effluents. Ferrous ion on exposure to the atmosphere is oxidized to ferric ion, giving an objectionable reddish brown colour to the water.

Iron also promotes the growth of “iron bacteria”, which derive their energy from the oxidation of ferrous iron to ferric iron and in the process deposit a slimy coating on the piping. At levels above 0.3 mg/l, iron stains laundry and plumbing fixtures.

At levels exceeding 0.1 mg/l, manganese in water supplies causes an undesirable taste in beverages and stains sanitary ware and laundry. It may also lead to the accumulation of deposit in the distribution system. The levels of Mn in both seasons in the present study were greater than 0.1 mg/l. This indicates that the river water is not suitable for domestic use.

The presence of aluminium at concentrations in excess of 0.1 to 0.2 mg/l often leads to consumer complaints as a result of deposition of aluminum hydroxide floc and the exacerbation of discoloration of water by iron. Al levels in the present investigation were higher than the permitted levels by WHO. The variations in concentrations of this metal from various sampling sites may be attributed to the nature of the catchments area, soil types and its composition, domestic wastes leaching of metal from garbage and geological weathering of rocks and atmospheric sources.

Trace metal concentration in sediment samples

Soil sediment enters a stream from eroding river banks, eroded soil from cleared land or exposed soil. It is of particular concern because many other pollutants, including bacteria, metals and some nutrients and toxins are carried along by soil particles. The results of trace metals analysis in the sediments are presented in Tables 4 and 5.

XRF characterization was performed to know the chemical composition of the minerals that are present in the sediments (Figure 4). The data shows that silicate oxide, ferric oxide, calcium oxide and aluminium oxide are present in major quantities while other minerals are

Table 3. Elemental analysis of the water sample from River Ruguti.

Sampling site	Parameter / Season	Unit (mg/l)																		
		Na	Ca	Mg	Fe	Mn	Zn	Cu	K	Cr	Pb	Sb	Co	Cd	Mo	B	V	Si	Sr	Al
1	Wet	2.31	1.16	0.3	2.11	0.22	0.02	ND	1.55	ND	ND	ND	ND	ND	ND	ND	ND	5.2	ND	0.23
	Dry	3.4	1.20	0.60	2.51	0.29	0.23	ND	1.82	ND	ND	ND	ND	ND	ND	ND	ND	5.8	ND	0.29
2	Wet	2.30	1.14	0.39	2.13	0.23	0.021	ND	1.58	ND	ND	ND	ND	ND	ND	ND	ND	5.3	ND	0.24
	Dry	3.38	1.15	0.56	2.48	0.28	0.225	ND	1.78	ND	ND	ND	ND	ND	ND	ND	ND	5.5	ND	0.25
3	Wet	2.29	1.17	0.32	2.15	0.25	0.022	ND	1.59	ND	ND	ND	ND	ND	ND	ND	ND	5.4	ND	0.25
	Dry	3.35	1.18	0.45	2.47	0.28	0.22	ND	1.80	ND	ND	ND	ND	ND	ND	ND	ND	5.7	ND	0.28
4	Wet	2.38	1.155	0.31	2.17	0.24	0.022	ND	1.62	ND	ND	ND	ND	ND	ND	ND	ND	5.5	ND	0.26
	Dry	3.39	1.19	0.57	2.50	0.26	0.229	ND	1.73	ND	ND	ND	ND	ND	ND	ND	ND	5.8	ND	0.29
5	Wet	2.50	1.16	0.36	2.19	0.24	0.03	ND	1.68	ND	ND	ND	ND	ND	ND	ND	ND	5.6	ND	0.25
	Dry	3.36	1.18	0.59	2.49	0.28	0.18	ND	1.75	ND	ND	ND	ND	ND	ND	ND	ND	5.7	ND	0.27
6	Wet	2.38	1.17	0.34	2.15	0.26	0.05	ND	1.56	ND	ND	ND	ND	ND	ND	ND	ND	5.3	ND	0.26
	Dry	3.32	1.20	0.58	2.44	0.29	0.20	ND	1.80	ND	ND	ND	ND	ND	ND	ND	ND	5.6	ND	0.29
WHO (2011)		200	75	30	0.3	0.1	5	2.0	NS	0.05	0.01	0.02	NS	0.003	NS	2.4	NS	NS	NS	10.03

Key: NS: Not specified, ND: Not detected.

Table 4. Analysis of major oxides from sediment samples from River Ruguti.

Sampling site	Parameter / Season	Na_2O	CaO	MgO	Fe_2O_3	MnO	K_2O	SiO_2	Al_2O_3	TiO_2	LOI
1	Wet	3.08	4.96	1.3	11.3	0.19	0.82	50.59	16.10	3.16	5.01
	Dry	2.61	4.11	1.64	19.6	0.14	0.73	37.7	11.77	9.23	4.89
2	Wet	3.15	4.80	1.28	11.1	0.20	0.83	49.89	15.71	3.22	6.36
	Dry	2.46	4.10	1.73	20.2	0.17	0.69	38.96	11.68	10.1	6.27
3	Wet	2.98	3.00	1.41	11.98	0.11	0.73	49.38	17.1	3.02	5.71
	Dry	2.41	3.89	1.72	21.2	0.10	0.68	33.73	10.77	9.10	4.97

Table 4. Contd.

4	Wet	2.77	5.10	1.29	10.93	0.16	0.78	50.73	16.35	3.02	3.83
	Dry	2.35	4.76	1.57	17.12	0.11	0.63	51.32	12.01	9.81	2.22
5	Wet	2.93	4.38	1.25	11.43	0.18	0.77	47.79	15.89	3.20	7.13
	Dry	2.54	4.01	1.73	18.3	0.12	0.68	40.11	10.77	8.11	6.43
6	Wet	2.31	4.81	1.24	10.73	0.17	0.79	48.99	14.97	3.13	1.23
	Dry	2.21	3.89	1.58	19.58	0.12	0.68	46.7	10.77	8.13	1.17

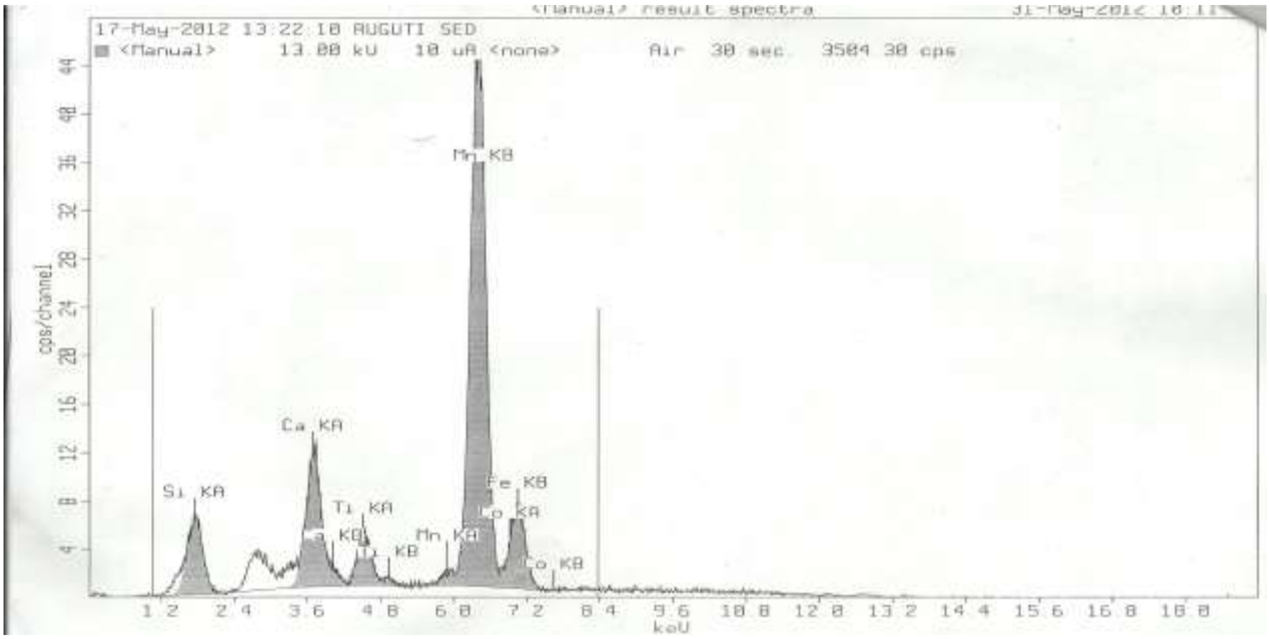
Table 5. Elemental analysis of the sediment samples from River Ruguti.

Sampling site	Parameter / Season	Unit (g/100 g)																	
		Na	Ca	Mg	Fe	Mn	Zn × 10^{-3}	Cu × 10^{-3}	K	Cr × 10^{-3}	Pb × 10^{-3}	Sb × 10^{-3}	Co × 10^{-3}	Cd	Mo × 10^{-3}	B × 10^{-3}	V × 10^{-3}	Sr × 10^{-3}	Al × 10^{-3}
1	Wet	0.041	0.267	0.113	1.45	0.0385	3.7	2.1	0.090	33	1.5	1.65	1.2	ND	11	155	1.6	1.3	1.6
	Dry	0.084	0.433	0.350	4.023	0.0368	5.3	3.2	0.131	5.1	3.5	3.17	7.3	ND	24	189	4.11	1.7	4.11
2	Wet	0.037	0.245	0.114	1.41	0.0372	3.2	2.8	0.089	3.0	1.1	1.55	1.0	ND	10	162	1.2	1.0	1.3
	Dry	0.073	0.427	0.360	4.23	0.0372	4.8	4.2	0.130	4.7	3.1	3.07	7.0	ND	20	197.2	3.2	1.5	3.8
3	Wet	0.036	0.258	0.110	1.45	0.036	2.8	1.5	0.078	2.8	1.4	1.50	9	ND	9	168	1.1	0.9	1.0
	Dry	0.076	0.478	0.352	4.520	0.035	3.9	2.7	0.119	4.1	3.4	3.00	6.5	ND	18	198.8	3.6	1.2	3.5
4	Wet	0.0387	0.297	0.117	1.42	0.0341	2.7	1.4	0.081	2.7	1.2	1.48	1.1	ND	8	172	1.4	1.1	1.7
	Dry	0.0830	0.483	0.382	4.19	0.032	3.8	2.5	0.128	3.7	3.1	2.98	7.1	ND	17	199.2	3.8	1.3	4.3
5	Wet	0.0287	0.283	0.121	1.44	0.028	3.1	1.1	0.078	2.4	0.9	1.32	8	ND	10	148	1.5	1.2	1.5
	Dry	0.0732	0.398	0.412	4.48	0.027	3.7	2.0	0.048	3.1	2.8	2.32	6.2	ND	21	187	3.2	1.6	3.5
6	Wet	0.038	0.255	0.110	1.38	0.029	3.5	1.5	0.082	2.2	1.0	1.55	1.0	ND	12	153	1.3	1.3	1.4
	Dry	0.082	0.366	0.348	4.36	0.027	4.9	2..1	0.0122	3.0	2.5	2.12	6.5	ND	26	177	1.72	2.0	3.8

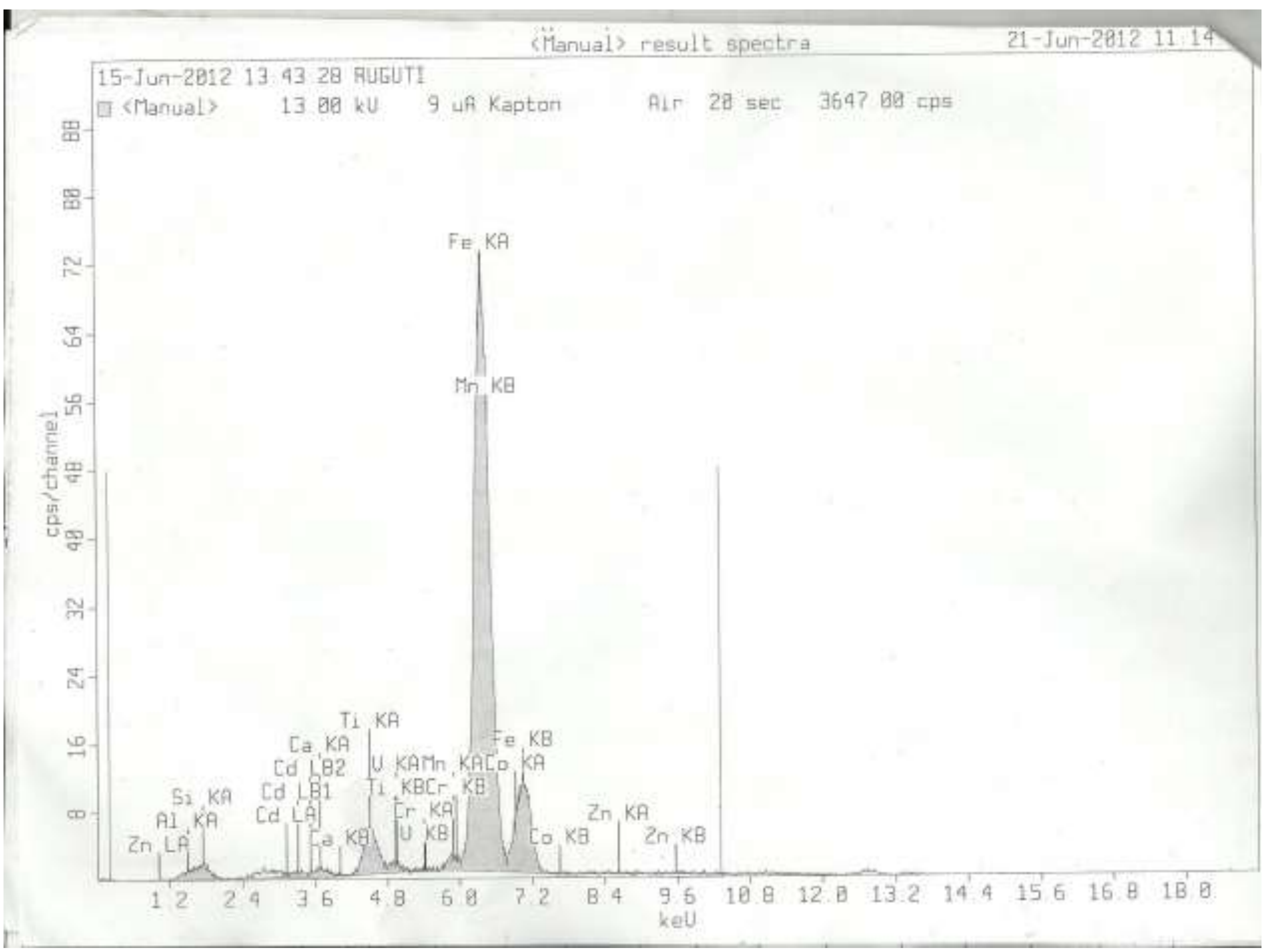
Key: NS: Not specified, ND: Not detected.

present in trace amounts. This was confirmed by carrying out full assay analysis. The loss on ignition values indicates that sediments have lower carbonaceous matter contents.

The concentration of Cd in the sediment samples was below its detection limit for the analytical method used. The levels of Fe, Al and Ca in both seasons were higher in comparison to other trace elements. The levels of Fe, Al and Ca ranged from 1.38 to 4.52%, 0.391 to 1.47%, and 0.245 to 0.483% respectively. The levels of other trace elements ranged from 0.00 to 0.199%. These levels could be attributed to both point and non point sources due to agriculture coffee factories, domestic effluents and sedimentation. The



(a)



(b)

Figure 4. A representative XRF spectra of River Ruguti during (a) wet season and (b) dry season.

Table 6. Bacteriological analysis of water samples.

Sampling site	Wet season		Dry season	
	Total coliform bacteria/100	*E. coli*	Total coliform bacteria/100	*E. coli*
1	>2420	1986	>2420	1414
2	>2420	1733	>2420	1414
3	>2420	1553	>2420	1203
4	>2420	1414	>2420	1300
5	>2420	1533	>2420	1203
6	>2420	1733	>2420	1300

correlation coefficient between the trace elements in sediments and water was found to be +0.55 and the probable error was 0.19. This indicates that correlation is not significant and the levels of trace elements in sediments are not a major contributor to the levels of trace elements in water.

Bacteriological analysis

The microbial analytical results obtained are shown in Table 6. *E. coli* /100 ml in the study area varied from 1203 to 1986 while total coliform bacterial /100 ml was found to be greater than 2420. These results indicate that water from Ruguti is heavily contaminated with both general coliform bacteria and *E. coli.* The factors that determine the type of bacteria and the number of bacteria in water are: temperature, light, organic matter, acidity, salinity, protozoa, rainfall and storage conditions. The presence of *E. coli* is an indication of contamination of water supplies. *E. coli* indicates feacal contamination of drinking water. E*. coli* being pathogenic bacteria cause four types of clinical syndromes namely, urinary tract infection, diarrhoea, pyrogenic infections and septicaemia. Hence it becomes necessary to ensure that the drinking water is free from bacteriological contamination. This can be attributed to the unhygienic conditions around the river. The result of bacteriological analysis indicates that Ruguti River is absolutely unfit for drinking and unhealthy for bathing.

Conclusions

This study has provided information about the water quality status of the Ruguti River. The temperature, pH, electrical conductivity, total dissolved solids, total alkalinity, total hardness, sulphates, chlorides and fluorides were within the limit set by WHO. The values of turbidity, nitrites, and nitrates obtained for drinking water which makes it to be unfit for use. The values for all the elements at all the sampling sites of the river were below the WHO maximum guideline values for the respective elements in drinking water, except for Fe, Mn and Al.

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