

Effects of Seasonality on Physico-Chemical Properties and Selected Ligands on Rivers in Sigor Division, West Pokot County, Kenya

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ABSTRACT

There is need to determine the exact nature of river systems for key decisions such as water treatment, construction of irrigation dams, piping systems or bridges to be made. Seasonality affects the nature and amounts of compounds getting into or out of rivers. It is therefore critical to know the exact amounts of physico-chemicals and ligands in water systems. This study aimed at analyzing the levels of various physico-chemicals and ligands in the rivers of Sigor division, West Pokot county, Kenya during different seasons. Sampling was done at four different parts of the four rivers (Weiwei, Chesogon, Lomut and Muruny) during both the wet and dry seasons. Analysis was then conducted, in situ for most physico-chemicals and later on by UV-VIS spectroscopy for the ligands. The findings revealed that there was a great impact of seasonality on most of the physico-chemical parameters analyzed. Crucial parameters such as pH, temperature, conductivity and turbidity were all affected by seasonality. The rivers did not however differ significantly in most of the physico-chemical parameters. Muruny river, however experienced more values of physico-chemical parameters due to its agricultural neighborhood. The phosphate values in the rivers were way above the permissible values. However, nitrate values were within the recommended values whereas sulfate values in the rivers were below the threshold values.

Keywords: water, physico-chemicals, ligands, West Pokot County

BACKGROUND

Clean water is a very scarce resource especially in developing nations. Sigor division in West Pokot county, Kenya contain vast dry regions. Her inhabitants are nomadic pastoralists and small-scale farmers. Water for animal and human consumption is derived primarily from four rivers that originate from Cherengany hills, in the nearby Trans Nzoia county. The rivers are River Chesogon, Weiwei, Lomut and Muruny. They latter on merge after downwards to form the great Tukwel river. The regions enjoy two major seasons in a year i.e the wet and dry season. During the dry season, the pastoralists move seeking pasture. Due to strong winds and loose soil structure experienced in dry seasons, many particulates end up in the rivers. In the wet seasons, there is an increase in discharge into the rivers from poor sewage systems and agricultural runoffs. These particulates contain chemical and bio-chemical compounds that affect the physico-chemical properties of the rivers (Aniyikaiye *et al.*, 2019).

Several compounds (mostly inorganic) affect the physico-chemical nature of water. The total solids (TS), whether dissolved or suspended are attributed to solid particulates such as from dust and agrochemicals. Most of the dissolved solids are inorganic and quite ionizable. Therefore, together with other parameters such as pH and temperature, they affect water electric conductivity. Electrical conductivity is therefore a function of dissolved solids (Butler and Ford, 2018). High water electrical conductivity implies a lot of chemical pollution and such water is unfit for human consumption. Variation of pH also determine the solubility of organic and inorganic complexes in water (National Research Council (US) safe drinking water committee, 1977). The recommended pH value for clean potable water is between 6.5-8.0. However, this might not be the case in a polluted water system such as rivers. Extreme pH values affect growth of aquatic life and corrode water pipes (Kumar and Puri, 2012). Extreme pH values mobilize toxic heavy metals such as lead compounds which have severe effects to humans. Water with more dissolved solids has a higher density minimizing its portability.

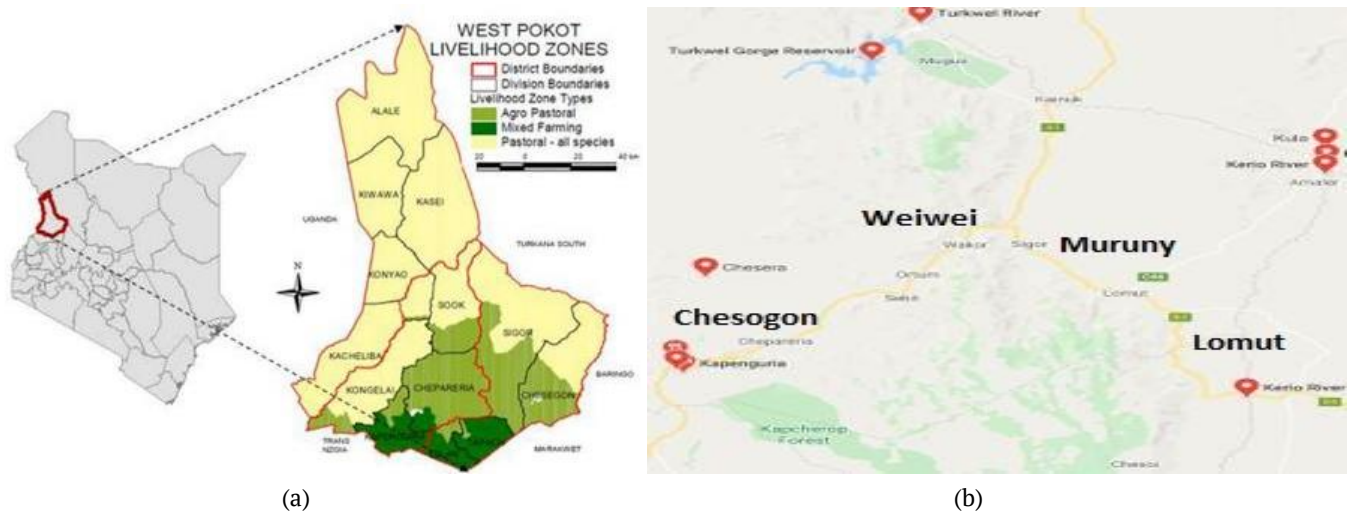


Figure 1. Map of West Pokot county in Kenya (a) Sigor division showing the locations of the rivers (b)

Most of the suspended solids affect water turbidity. This has a toll on other parameters such as visibility and flow rate. Poor water visibility reduces the intensity of sunlight reaching planktons, essential for aquatic life. Poor water visibility also minimize navigation in the rivers for fear of unforeseen hazards. The flow rate of water is key for modelling of several socio-economic factors such as where best to tap water for piping purposes or build a dam for irrigation. Water with a high flow rate distribute any pollutants present over a wider surface, owing to its fast velocity. High turbidity also offers more surface area for attachment of pathogens in water (Chahal *et al.*, 2016).

Water should be well aerated (around 6%) in an unpolluted water system (Kumar and Puri, 2012). Dissolved oxygen values in water are very critical for sustenance of aquatic life and human/animal consumption. Water alkalinity determines the ability of the water to buffer itself against extreme acidic conditions. This is very crucial for the survival of aquatic life and for human/animal consumption. Low alkalinity values can result due to acid rain into the system. Excessive alkalinity values resulting from fecal discharge by animals or humans affect the availability of other water minerals and ligands such as nitrates, sulfates, chlorides and phosphates. Abundance of these ligands in river systems above permissible limits is an indicator of polluted water.

Variation of seasons lead to different quantities of physico-chemicals in rivers. During the dry seasons, there is less precipitation and higher temperature values leading to more evaporation of the little water present in the rivers. The solid particulates are also increased owing to stronger winds. Irradiation in the water systems is also increased due to higher sunlight intensities. During wet seasons, there is more precipitation and lower temperature. The water capacity is thus more. On the other hand, there is less sunlight irradiation and little particulates resulting from dust get into rivers. However, most sewerages are full and there are more agrochemical residues leaching into the rivers. It is thus very difficult to know the exact position of river systems as far as physico-chemicals are concerned unless analysis is done during both seasons.

This study aimed at analyzing the levels of physico-chemicals in four rivers of Sigor division, West Pokot county during wet and dry seasons. The amounts of these compounds and parameters are essential in informing relevant authorities on the right decisions to make at the appropriate time. Crucial factors such as the exact point to construct a bridge or dam, where to tap water for piping and materials to use as well as choice of chemicals to use for water softening or to kill pathogens are all based on such decisions.

MATERIALS AND METHODS

Study Area

The research was conducted in Sigor division, West Pokot county, Kenya (between latitude 1.1359°N and longitude 35.7121°E). Samples were taken from four different points of the rivers (P₁, P₂, P₃ and P₄ with P₁ being the river mouth and cascading down to the other points). Lomut river was an estuary to Muruny river while Chesogon river was the main feeder for River Weiwei. The two rivers then merge together with other rivers to form the great Tukwel river. **Figure 1** illustrates the four rivers and regions that were sampled.

Sample Collection

Samples were collected from 4 locations located immediately upstream and at least 100m downstream. This was done four times over a period of eight months as from January to September 2013 which spanned through the dry season (January 2013 - March 2013) and the rainy season (April 2013 - June 2013) to cater for seasonal variations. Samples at the different courses of a particular river were used to make a composite sample. A total of 32 samples were collected during the sampling period with each point sampled four times. The sample size for the study was determined using Fisher formula with a confidence level of 95% with a margin error of 5% (Fisher, 1998).

$$n = \frac{Z^2 PqD}{d^2} \quad (1)$$

Where; n = sample size, p = anticipated prevalence which was 3% (0.03) in this study, q = failure which was calculated as

(100% - 3%) giving 97% (0.97), Z = is the appropriate value from a normal distribution for the desired confidence level which was 1.96 in this study, d = allowable error (0.086) and D = design effect which was given a value of 2 because replication was carried out based on 3% prevalence and Z value of 1.96. A final sample size of 30 samples was finally obtained.

Data Collection and Analysis

Some of the physico-chemical measurements were taken in situ at the sampling point whereas others required analysis in the lab. These samples were properly packed in sterile 500ml polypropylene bottles. 1% nitric acid and formaldehyde solution was added to the samples whose tests don't interfere with these solutions. They were then transported to Kenyatta University Microbiology Laboratory for analysis. The maximum storage duration before analysis was 48 hours for all the samples transported to the lab.

Water temperature ($^{\circ}\text{C}$), pH, dissolved oxygen (mg/L), turbidity and conductivity were measured in situ using Universal Multiline P4 WTW (Wilhelm, Germany). Electrical conductivity was measured using a conductivity probe expressed in Micro Siemens per centimeter (μScm^{-1}) and turbidity was recorded in Nephelometer Turbidity Units (NTU).

The ligands; phosphates, sulfates and nitrates were determined using UV VIS (Jenway 6850) analysis as outlined below.

Phosphates: A conditioning reagent was made by dissolving 1.7081g of ammonium molybdate and ascorbic acid (5.82g/300ml distilled water) in 150ml warm water. The solution was cooled before diluting to 250ml. 0.125g of hydrazine sulphate in 100ml distilled water was added. Analyte samples were diluted by a factor of 10 and added the conditioning reagent before measuring the absorbances at 830-860 nm against those of the blank and standards.

Nitrates: Nitrate standards were prepared by dissolving 8.0g of salicylic acid in 100ml of 1M H_2SO_4 acid then swirling to fully dissolve. 10ml of this solution was added to 90ml of aliquot sample solution. Acidification using 1M HCl was done to minimize interference by other ligands. Absorbance was checked in the range of 270-320nm against those of the blank and standards.

Sulfates: For standard preparation, 10g of NaCl and 10ml of conc HCl acid were added to 40ml of glycerol solution. A yellowish color was formed. 5ml of this solution was added to 45ml of analyte solution and the absorbance read at 410-430nm against those of the blank and standards.

Statistical Analysis

95% level of confidence was used for all the statistical analyses done. Ms Excel (version 2016) and OriginLab (version 6.5) statistical softwares were used.

RESULTS AND DISCUSSIONS

Physico-chemical Parameters in the Rivers

All the rivers had alkaline water with Muruny river having the most basic water (8.17 in the wet and 9.20 during the dry season). The high alkalinity values in the rivers can be traced

down to contaminants such as soaps and detergents as well as agricultural pesticides (National Research Council, 1998). Muruny river is located in an agricultural zone, therefore susceptible to most of these basic agrochemicals that increase the pH of its water. On contrary, Chesogon river located in a pastoralist region had the lowest pH values indicating less entrance of these compounds. The samples analyzed during the dry season had a higher pH than those analyzed during the wet season. During the wet seasons, there is more precipitation and the rivers have more water. The compounds leading to production of a basic environment in the water are thus diluted by a higher factor leading to a lower pH value. Another factor leading to lower pH values in the rivers in the wet season is influx of acidic compounds into the rivers during this period. For example, acid rains have a low pH value and when it precipitates into the river, they definitely lower the pH of this water. While very acidic water (below pH 5.0) is bad for farming, very basic water (above pH 9.0) is bad for construction. The optimal pH range for coliforms and other bacteria is 6.5-8.5 (Halage *et al.*, 2015). Therefore, all the rivers were prone to these pathogens.

There was a similar trend in the temperature levels of the rivers with Muruny river also having the highest average temperature. Temperature is a physical and very dynamic environmental parameter that depends on other factors. Ambient conditions such as sunlight intensity are key in determining the temperature of water in a river. Shallow rivers are affected more than deep ones. In this region, there was no significant difference in sunlight intensity based on the residents' perception. There was no significant difference in the temperature of different river points. Change in temperature affects the chemical and biochemical compounds as well as influence other physico-chemical parameters in the river. At higher temperature systems, critical parameters such as dissolved oxygen, crucial for aquatic life reduce. Several bacteria and coliforms such as *E. coli*, *V. cholerae*, *Salmonella* and *Shigella* species as well as *Fecal streptococci* thrive well at high temperatures (35-45 $^{\circ}\text{C}$) (Scott *et al.*, 2002). These pathogens have a lower tolerance to low temperature thus, the cooler the water, the safer it is.

Electrical conductivity values in the rivers were significantly high during the dry season compared to the wet season ($P > 0.05$). There was no significant deviation in electrical conductivity values across the rivers at different points. Several factors can be drawn for these findings, key amongst them the correlation between electrical conductivity and other physico-chemical properties such as temperature, pH and turbidity. High temperature increases the ionization of compounds in water leading to a higher electrical conductivity (Brini *et al.*, 2017). pH also affects the immobilization of complex compounds affecting their conductivity. During the dry season, there is less precipitation and movement of water. The ions in rivers thus have a higher concentration and are more still, enabling them to be detected thus leading to higher electrical conductivity values. Chesogon river ($192.75 \pm 2.06 \mu\text{Scm}^{-1}$ during the wet season and $221.83 \pm 2.51 \mu\text{Scm}^{-1}$ during the dry season) and Muruny rivers ($163.00 \pm 6.22 \mu\text{Scm}^{-1}$ during the wet season and $194.50 \pm 13.89 \mu\text{Scm}^{-1}$ during the dry season) had the highest levels of electrical conductivity. The high level of conductivity in Chesogon river can be attributed to low

Table 1. Physico-chemical properties of rivers in the study area

Parameter	River	Season	Sampling Point (P> 0.05)						
			P ₁	P ₂	P ₃	P ₄	Avg.	Sd	
pH	R. Weiwei	Wet	8.51	8.66	8.10	8.21	8.37	0.26	
		Dry	8.82	8.91	8.70	8.72	8.79	0.10	
	R. Chesogon	Wet	7.72	7.67	7.70	7.82	7.73	0.07	
		Dry	7.99	7.89	7.90	8.00	7.95	0.06	
	R. Lomut	Wet	7.90	7.96	7.66	7.92	7.86	0.14	
		Dry	8.23	8.25	7.90	8.10	8.12	0.16	
	R. Muruny	Wet	8.33	8.92	8.18	8.17	8.40	0.35	
		Dry	8.96	9.91	8.99	8.95	9.20	0.47	
	Temp. (°C)	R. Weiwei	Wet	21.5	21.5	21.4	21.7	21.53	0.13
			Dry	22.5	22.5	22.5	22.6	22.53	0.05
R. Chesogon		Wet	21.0	21.5	20.5	20.0	20.75	0.65	
		Dry	22.5	22.0	22.2	21.9	22.15	0.26	
R. Lomut		Wet	20.5	20.1	20.0	20.5	20.28	0.26	
		Dry	22.8	21.1	22.2	22.7	22.20	0.78	
R. Muruny		Wet	21.5	22.0	22.6	21.5	21.90	0.52	
		Dry	22.8	23.5	23.0	22.9	23.05	0.31	
Electrical Conductivity (µScm ⁻¹)		R. Weiwei	Wet	107	113	117	110	111.75	4.27
			Dry	138	147	151	146	145.50	5.45
	R. Chesogon	Wet	195	193	193.0	190	192.75	2.06	
		Dry	225	221	222.3	219	221.83	2.51	
	R. Lomut	Wet	148	142	194	140	156.00	25.56	
		Dry	166	163	224	158	177.75	31.01	
	R. Muruny	Wet	156	166	170	160	163.00	6.22	
		Dry	175	201	207	195	194.50	13.89	
	Dissolved Oxygen (mg/L)	R. Weiwei	Wet	4.05	4.11	3.99	3.92	4.02	0.08
			Dry	4.25	4.21	4.19	4.18	4.21	0.03
R. Chesogon		Wet	3.96	4.00	4.09	4.02	4.02	0.05	
		Dry	4.12	4.10	4.14	4.17	4.13	0.03	
R. Lomut		Wet	3.91	3.99	4.09	3.71	3.93	0.16	
		Dry	4.01	4.01	4.18	3.85	4.01	0.13	
R. Muruny		Wet	4.15	4.20	4.21	4.12	4.17	0.04	
		Dry	4.29	4.36	4.27	4.25	4.29	0.05	
Turbidity (NTU)		R. Weiwei	Wet	11.0	10.5	10.9	10.7	10.77	0.22
			Dry	10.4	9.0	10.2	9.7	9.85	0.64
	R. Chesogon	Wet	12.5	12.1	12.44	12.0	12.26	0.25	
		Dry	11.7	11.5	11.55	11.2	11.48	0.21	
	R. Lomut	Wet	13.4	13.0	12.5	12.9	12.95	0.37	
		Dry	12.8	12.2	11.8	11.8	12.15	0.47	
	R. Muruny	Wet	9.2	8.3	9.0	8.9	8.85	0.39	
		Dry	8.6	7.1	8.2	7.3	7.80	0.72	

water volumes in the region resulting from its more arid nature. On the other hand, Muruny river gets more influx of agrochemicals and other pollutants such as soaps and detergents from the local residents. These compounds are quite soluble in water leading to high electrical conductivity (Savjani *et al.*, 2012). Weiwei and Lomut rivers receive more sewer discharge which contain more microorganisms than chemical compounds. The microorganisms are less soluble and do not greatly impart the conductivity. The electrical conductivity values of the rivers were within the permissible WHO limits of clean water (150-500 µScm⁻¹). **Table 1** summarizes the physico-chemical parameters of the rivers in Sigor division.

Dissolved oxygen is a crucial parameter of rivers as it is very key in survival of aquatic life. The permissible dissolved oxygen values in clean river water range 5-6 mg/L for warm biota and 6.5 to 9.5 mg/L for cold biota (WHO, 1996). All the rivers in the study region were found to have insufficient dissolved oxygen values for survival of fish and human and

animal consumption during all seasons. Muruny river had the most appreciable values of dissolved oxygen compared to the other rivers (4.17±0.04 mg/L in wet season and 4.29±0.05 mg/L in the dry season). Seasonality of the rivers did not affect the amount of dissolved oxygen. There was also no clear disparity in levels of dissolved oxygen across the rivers in either season. Several coliforms are facultative anaerobes and thrive well in limited amount of dissolved oxygen (Cabral, 2010). Therefore, reduction in oxygen levels in the rivers promote growth of these harmful microorganisms.

The turbidity values in the rivers were high during the wet season compared to the dry season. This is due to the increased discharge of materials into the rivers during wet seasons. Water movement during wet seasons is also quite higher leading to erosion of the river walls and thus adding more particulates (silts and sediments) that increase turbidity. The turbidity levels of the rivers were above the permissible limits of 10 NTU in clean rivers except for Muruny and River Weiwei during the dry season (Guidelines for Drinking-Water Quality:

Table 2. Levels of selected ligands in the study area

Ligand	River	Season	Sampling Point (P> 0.05)						
			P ₁	P ₂	P ₃	P ₄	Avg.	Sd.	
Phosphates (mg/L)	R. Weiwei	Dry	0.53	0.55	0.56	0.57	0.55	0.02	
		Wet	0.51	0.51	0.52	0.52	0.52	0.01	
	R. Chesogon	Dry	0.44	0.45	0.46	0.55	0.48	0.05	
		Wet	0.42	0.41	0.42	0.50	0.44	0.04	
	R. Lomut	Dry	0.56	0.57	0.58	0.59	0.58	0.01	
		Wet	0.52	0.51	0.52	0.54	0.52	0.01	
	R. Muruny	Dry	0.59	0.55	0.50	0.60	0.56	0.05	
		Wet	0.57	0.54	0.55	0.56	0.56	0.01	
	Sulfates (mg/L)	R. Weiwei	Dry	15.00	16.00	17.00	13.00	15.25	1.71
			Wet	13.00	14.00	15.00	10.00	13.00	2.16
R. Chesogon		Dry	13.00	14.00	15.00	12.00	13.50	1.29	
		Wet	11.00	12.00	13.00	10.00	11.50	1.29	
R. Lomut		Dry	16.00	17.00	18.00	15.00	16.50	1.29	
		Wet	14.00	15.00	16.00	13.00	14.50	1.29	
R. Muruny		Dry	17.00	18.00	19.00	17.00	17.75	0.96	
		Wet	15.00	15.00	16.00	15.00	15.25	0.50	
Nitrates (mg/L)		R. Weiwei	Dry	32.00	35.00	36.00	33.00	34.00	1.83
			Wet	29.00	31.00	32.00	31.00	30.75	1.26
	R. Chesogon	Dry	28.00	31.00	32.00	32.00	30.75	1.89	
		Wet	26.00	26.00	27.00	30.00	27.25	1.89	
	R. Lomut	Dry	34.00	37.00	38.00	35.00	36.00	1.83	
		Wet	30.00	32.00	33.00	33.00	32.00	1.41	
	R. Muruny	Dry	35.00	39.00	40.00	37.00	37.75	2.22	
		Wet	33.00	36.00	37.00	35.00	35.25	1.71	

Fourth Edition Incorporating the First Addendum. Geneva: World Health Organization; 2017). Lomut river had the highest turbidity levels (12.95 ± 0.37 NTU during the wet season and 12.15 ± 0.47 NTU during the dry season). High water turbidity affects locomoture in the rivers as well as minimizing the intensity of sunlight radiations entering the river. High turbidity has also been associated with providing attachment sites for water pathogens such as bacteria and coliforms.

Ligand Analysis in the Rivers

All the rivers in the study region had higher phosphate values to the recommended one (0.03mg/L). This imply that there was a lot of pollution leading to these high values. River Chesogon had significantly lower phosphates in her water during both dry and wet seasons (0.48 ± 0.05 mg/L and 0.44 ± 0.04 mg/L respectively). Chesogon river enjoys the least human population around and thus the fewest anthropogenic pollution. The highest phosphate values were reported in Muruny river, where there is more agricultural practice. Phosphates are a key part of essential nutrients (ideally as elemental phosphorus or frequently as ammonium phosphate fertilizers) (Sharma *et al.*, 2013). These compounds are also quite soluble in water and quickly leach into rivers. Phosphates can also be supplied from sewer discharge, explaining the high amounts of this contaminants by rivers Weiwei and Lomut, which enjoy more human population around them. Phosphates enrich algae population thus increasing the risk of their existence as well as other pathogens. **Table 2** summarizes the levels of phosphates, sulfates and nitrates in the sample area.

The sulfate levels in all the rivers were higher during the dry season compared to the wet season. Sulfates, exist as ions together with other metals or compounds. During wet seasons,

there is more water levels and thus the dilution factor is high. During dry seasons there is less water and thus the concentration of sulfates is more. The sulfate levels in all the samples analyzed were well below the limits of 250 mg/L (Nkansah *et al.*, 2010). Therefore, the water of all the rivers were safe for consumption as far as sulfates are concerned. The same observation was observed for nitrates which had vales ranging between 27.25 ± 1.89 mg/L to 37.75 ± 2.22 mg/L. These values were within the given permissible range of 20 to 60 ppm (mg/L) for safe river water. Both sulfates and nitrates find their way into rivers through agricultural chemicals and sewer wastewaters. It can thus be noted that the residents of Sigor division do not over-utilize fertilizers with nitrate and sulfate ligands.

CONCLUSIONS

Seasonality affected the levels of several physico-chemical properties. However, there were no major deviations in physico-chemical properties between different river positions in the study area. All the rivers had low temperature values of about 20.5-22.5°C and were quite alkaline in nature. The electrical conductivities of the rivers were way above the recommended guidelines while dissolved oxygen was below the threshold 5mg/L. The rivers experienced high turbidity values especially during the wet seasons. All the rivers had excessive phosphates values during all the seasons. The levels of sulfates were below the recommended threshold while nitrate levels were in the recommended range of clean water.

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