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Bacteriological Examination and Physico-chemical Properties of Streams Receiving Industrial Effluents in Rosslyn, Pretoria, South Africa

ABSTRACT

The reliance on streams and rivers to provide water for agricultural purposes and to some extent- domestic purpose, is still in existence especially in the semi-urban and rural areas. This study investigated the bacteriological load and physicochemical properties of water from streams receiving industrial effluents and a reservoir receiving wastewater from a hospital. Water samples were collected from March to August, 2015 from ten sampling stations and analysis were carried out following standard procedures. The water pH ranged from 6.21 ± 0.03 – 8.22 ± 0.08. Phosphate ranged from 0.0 – 7. 80 ± 0.38 mg L^{-1}. Nitrate ranged from 0.03 ± 0.04 – 209 ± 2.26 mg L^{-1} while nitrite ranged from 0.00 – 14. 00 ± 0.30 mg L^{-1}. The TSS (total suspended solids) and TDS (total dissolved solids) were in the range 40.0 ± 2 .00 – 58.70 ± 130 mg L^{-1} and 40 ± 6.0 – 1010 ±45.0 mg L^{-1} respectively. The bacteriological loads ranged from 4.85 ± 2.0 – 36.5 ± 7.0 cfu 100 ml^{-1}. Sites receiving effluents from industrial and hospital wastes were highly polluted with values obtained for parameters exceeding the standard set by World Health Organizatio (WHO). The shapes of the bacteria examined under the microscope were Coccobacilli, Cocci, Vibrio, Diplococci and Bacilli. Vibrio shaped bacteria was only observed from streams receiving wastewater from the hospital. In conclusion, it is necessary to educate people on the danger of using water from these streams and a proper waste management method should be established at the hospital and the industrial areas.

Key words: *Anions, Bacteria, Pollution*

Kafilat Taiwo Salvador–Oke [1*]
Piet King[1]
Joshua Oluwole Olowoyo[1]

[1] Department of Biology, Sefako Makgatho Health Sciences University, Medunsa, Pretoria, South Africa, 0204

*Corresponding author: woleolowoyo@yahoo.com

INTRODUCTION

Industrialization plays a critical role in the growth and development of any country. It also has both direct and indirect adverse impact on the environment, such as the release of untreated or partially treated effluents into the surrounding water bodies. These may lead to soil and water pollution if the guidelines are not followed (*Nasrullah et al. 2006*). The content of effluent from industries highly differs, based on the function and activity of a particular industry and may contain large amount of contaminants, thus rendering the receiving water bodies unsafe either for domestic or agricultural purposes (*Shittu et al. 2008*).

The existence of life is impossible without water because it is the sole component of all living things. It is physiologically and ecologically important due to its vital role in temperature control and its use as habitat for many organisms (*Chaurasia and Tiwari 2011*). The disposal of untreated industrial effluents and other wastes may add to the contaminants present originally in water. As a result, the pollution load in fresh water bodies may become high and increases the nutrient load of water, which may ultimately lead to rapid alteration of pH and increase in the amount of pathogenic bacteria and other pollutants (*Odonkor and Ado 2013*).

Over the years, it has been noted that excessive discharge of industrial effluents in water bodies will result in polluted water thus leading to health problems either for grazing animals or end users and eutrophication (*Gopalkrushna 2011*). Ground water, streams and rivers are the main sources of drinking water in many rural and urban areas and it is vital to the existence of humans. Only 1% part of water is available on land for drinking, agriculture, domestic power generation, transportation and waste disposal (*Parihar et al. 2012*). The World Health Organisation (WHO) estimated that about 4 B cases of diarrhea, and about the 2.2 M annual mortality is due to the consumption of unsafe water that have been contaminated via discharge of untreated industrial effluents (*WHO 2004*).

In South Africa, the reliance on streams and rivers to provide water for agricultural purposes and to some extent domestic purpose is still in existence especially in the semi-urban and rural areas due to water scarcity (*Musingafi and Tom 2014*). Freshwater quality of the available sources in South Africa has declined due to increased pollution caused by industries, urbanisation, afforestation, mining, agriculture and power generation (*Ashton et al. 2008*). Therefore, it is important to monitor the discharge of effluents into streams in order to check for the physicochemical properties of the receiving streams and surrounding rivers to make water safe for all. The information regarding the physicochemical status and bacteriological load of discharged effluents into streams around the industrial area of Rosslyn has not been documented. It is important to develop a practical and scientific guide to manage and control industrial effluent discharge to municipality sewers, in order to prevent pollution of downstream water resources. Bacteriological examination of water bodies is very important because of its direct influence on human health (*Kolawole et al. 2011*). The presence of some bacteria such as *Escherichia coli* will provide information on the presence of fecal pollution in the water body (*WHO 1997*). Effluent analysis have been done in this regard in many parts of the world, including African countries and in some part of South Africa, but there is no available record of the analysis on the industrial area of Rosslyn located in Pretoria, South Africa.

The present study investigated the bacteriological load and physicochemical properties of streams receiving discharged effluents from industries around Rosslyn with a view of determining its suitability for domestic or agricultural purposes. The study aims to characterize the physicochemical parameters of effluents from the streams around Rosslyn in Pretoria, Gauteng Province and estimate the number of bacteria load present in the water and determine if the bacteria are Gram-positive or Gram-negative, and compare the pollution rate of the different effluents during summer and winter periods.

MATERIALS AND METHODS

Materials

Water samples were collected from streams receiving industrial effluent discharge around the Rosslyn industrial area of Pretoria, Gauteng, South Africa (**Figure 1**). The area is located towards the Northern part of Pretoria and comprises of many industries that manufactures rubber, petroleum-related products, food, truck industries, as well as an associated industry that consist of steel, metals and plastic industries (**Figure 2**). The sites used were Site 1: Stream next to Rubber Industry; Site 2: Downstream of the Rubber Industry; Site 3: Stream close to a Petrol Garage; Site 4: Downstream around the petrol garage; Site 5: Stream next to Truck Assemblage Plant; Site 6: Downstream next to Truck Assemblage plant; Site 7: Stream next to Steel Industry; Site 8: Stream next to Plastic Industry;Site 9: Stream receiving Hospital waste; and Site 10: Stream receiving hospital waste (**Figure 3**).

Sample Collection and Analysis

The water samples were collected with careful observation of standard sampling guidelines (*WHO 1997*). The samples were collected once every month from March to August, 2015 covering 10 different stations. The analysis on anions were performed only in March and April. While the bacteriology and other parameters were analysed from March through August 2015. The samples were collected in a pre–sterilized bottles and transported immediately to the laboratory for analysis.

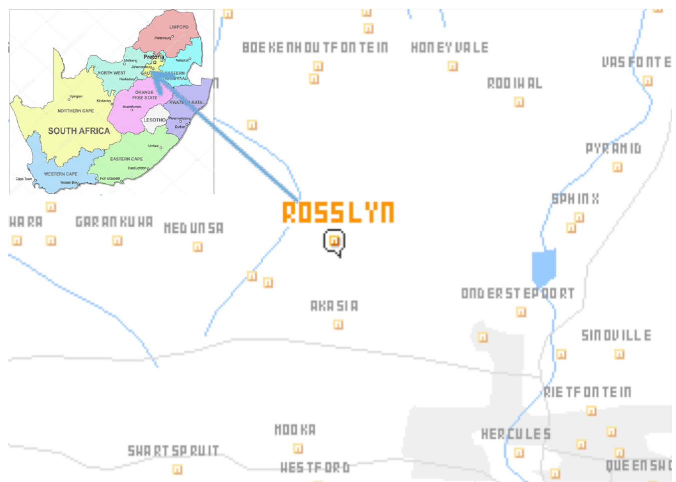

Figure 1. Map of the Sampling Area: Rosslyn, Pretoria, South Africa.

Figure 2. Map of Rosslyn Industrial Area.

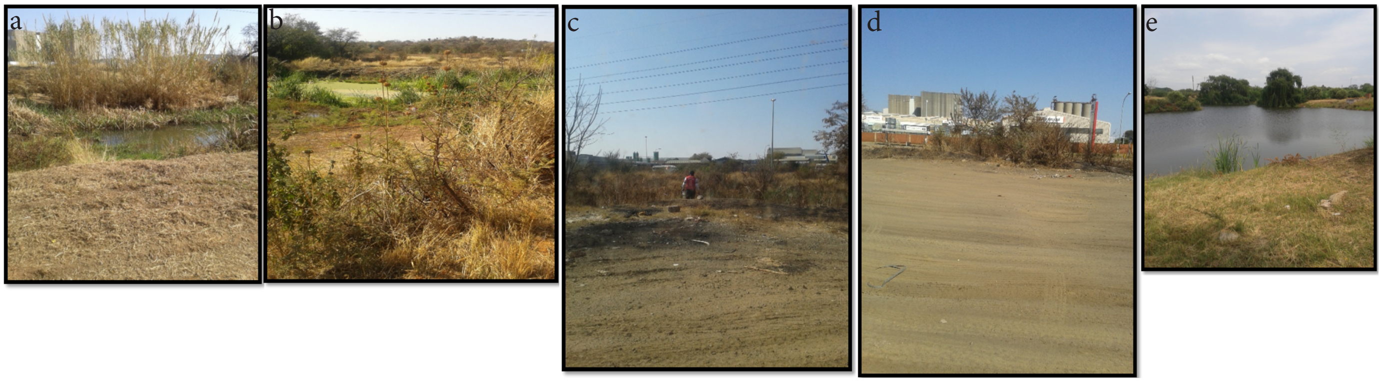

Figure 3. The sampling sites- a: Rubber Industry (Sites 1 & 2); b: Stream close to petrol filling station (Sites 3 & 4); c: Truck Manufacturing Industry (Sites 5 & 6); d: Associated Industries (steel, metal & Plastic) (Sites 7 & 8); and e: On Campus from Hospital waste (Sites 9 & 10).

Water temperature and pH were determined *in situ*. For the determination of the bacteria types and the colony counts, 10 ml of each water sample were made up to 100 ml with distilled water. The diluted sample were passed through the membrane filter placed on the filtration chamber with vacuum and the filter paper removed with forceps and placed on a suitable selective culture medium in a petri dish. The petridish was then incubated for 24 hrs at 37°C to allow the growth of the indicator organisms. The colonies formed on the plate were counted and the results were expressed in number of colony forming unit (CFU) per 100 ml of the original sample. All the sample isolates were Gram stained in order to determine if the bacteria present in the sample were either Gram-positive or Gram-negative.

The analyses of other water parameters such as phosphate, nitrate, nitrite, chloride, fluoride were performed using the Ion Chromatography method (*Zeyrek et al. 2010*). The water pH and temperature were determined in the field using a pH meter fitted with electrode.

Data analysis

The data was captured on Microsoft excel 2010 (Microsoft Office, USA) and analysed using statistical techniques such as analysis of variance (ANOVA) and standard deviation to evaluate seasonal variation and determine the pollution rate of the streams. The maximum acceptable limit of quality parameters was based on WHO and the South African Water Quality guidelines. The physicochemical parameters were calculated and expressed in mean ± standard deviation (STD) and the numbers of bacterial populations was compared and expressed in colony forming unit 100 ml^{-1} of each sample (CFU 100 ml^{-1}). The standard deviation of each sample can be calculated using the following equation:

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}}$$

where x represents each value in the population, $\bar{x}$ is the mean value of the sample, Σ is the summation (or total), and n^{-1} is the number of values in the sample minus 1.

RESULTS AND DISCUSSION

The pH for the water samples were in the range 6.21 ± 0.03 – 8.22 ± 0.08 during the sampling period (**Tables 1** to **6**). There were no significant differences in the values obtained from the same stations during the sampling period, however there were significant differences when values obtained from different stations were compared ($p < 0.05$). Generally, the values obtained from all the stations were within the limit of 6.5-8.5 with the exception of Site 1 (*EPA 2002*). Differences obtained from different stations may be related to different activities carried out around the streams. From Site 1 for instance, activitiessuch as car washing and industrial effluent direct discharge to the stream may be responsible. Various activities in Site 1 may bring about increase in the toxicity of poisonous substances in the stream (*Okonko et al. 2008*).

The TDS ranged from 160 ± 6.0 – 1010 ± 45. 0 mg L^{-1}. The TSS ranged from 40.0 ± 2 .00 – 4680 mg L^{-1} (**Tables 1** to **6**). There were significant differences in the values obtained from all the sites ($p < 0.05$). High levels of TSS and TDS may suggest that organic waste, industrial waste and hospital waste might have been discharged directly into the streams. Similar observation was noticed from the study carried out by *Ogedengbe* *and Akinbile* (*2010*) where they reported that the high levels of TSS and TDS were the result of either organic or industrial waste discharged directly into the streams.

The mean value for the concentrations of Cl- (chloride ion) during the sampling periods ranged from 31.00 – 328.00 ± 0.79 mg L^{-1} (**Table 7**). The highest concentration for the chloride ion was recorded from Site 1 during the month of March, while the lowest concentration was recorded from Site 4. The maximum permissible level of chloride ion by WHO was set at 250 mg L^{-1}. From our study, Sites 1 and Sites 2 values were more than the permissible limit. Sources of chloride ion in the environment may be linked to anthropogenic sources such as washing, farming and industrial activities (*Schlesinger 2004*).Though from other streams receiving industrial effluents, the level of chloride ion is low when compared to the allowable limit in the environment. However, Sites 1, 2, 9 and 10 have values that were above or close to these values.

Table 1. Mean and Standard Deviation of Bacterial Count and Physicochemical Parameters of the Water Samples in Streams from the Industrial Area of Rosslyn in the Month of March, 2015.

Location Sites	Colony Count (CFU 100 ml^{-1})	pH	Temperature (˚C)	TDS (mg L^{-1})	TSS (mg $L^{-1)}$	TS (mg L^{-1})
1	133 ± 39	7.36± 0.05	27 ± 0.41	350 ± 40	2590±650	2950±660
2	60 ± 24	7.47± 0.38	25 ± 2.04	360 ± 117	2140± 100	2510± 100
3	131 ± 47	6.55 ± 0.06	26 ± 0	320 ± 210	4360± 2230	4680± 2430
4	123 ± 83	7.06 ± 0.27	26 ± 0	490± 290	2080± 610	2570 ± 320
5	158 ± 70	7.83 ± 0.47	24 ± 0.71	110 ± 50	870± 130	870± 50
6	211 ± 33	7.53 ± 0.38	24 ± 0.71	210 ± 180	1580±530	1800 ± 350
7	145 ± 95	7.9 ± 0.27	27 ± 0.41	800 ± 480	580± 200	1380± 580
8	110 ± 66	7.53 ± 0.25	27 ± 0.41	1010± 450	1150± 500	2160± 210
9	133 ± 75	7.78 ± 0.19	22 ± 0.82	170± 50	1160± 570	1330± 550
10	112 ± 48	8.22 ± 0.08	22 ± 0.82	510 ± 210	1180± 380	2020± 230

Table 2. Mean and Standard deviation of the Bacterial Count and Physicochemical Parameters of the Water Samples in Streams from the Industrial Area of Rosslyn in the Month of April, 2015.

Location Sites	Colony Count (CFU 100 ml^{-1})	pH	Temperature (˚C)	TDS (mg L^{-1})	TSS (mg $L^{-1)}$	TS (mg L^{-1})
1	30 ± 21	6.21 ± 0.03	21 ± 0	790 ± 170	480 ± 190	1270 ± 210
2	285 ± 36	6.56 ± 0.23	20 ± 0.71	640 ± 160	5870 ± 130	6510 ± 50
3	28 ± 4.71	6.81 ± 0.07	19 ± 0.41	90 ± 20	320 ± 120	410 ± 90
4	201 ± 94	6.76 ± 0.12	21 ± 0.41	160 ± 90	180 ± 50	340 ± 140
5	59 ± 37	6.7 ± 0.06	20 ± 1.22	80 ± 4	1210 ± 10	1290 ± 20
6	85 ± 17	6.65 ± 0.07	21 ± 0.41	160 ± 40	90 ± 40	260 ±30
7	44 ± 53	6.59 ± 0.02	20 ± 0	340 ± 30	50 ± 20	390 ± 50
8	85 ± 28	6.48 ± 0.05	21 ± 0	130 ± 30	150 ± 40	280 ± 30
9	53 ±18	6.85 ± 0.09	19 ± 0.41	180 ± 30	50 ± 10	240 ± 40
10	181 ± 16	6.93 ± 0.05	20 ± 0	220± 120	380 ± 300	600 ± 290

Table 3. Mean and Standard deviation of the Bacterial Count and Physicochemical Parameters of the Water Samples in Streams from the Industrial Area of Rosslyn in the Month of May, 2015.

Location Sites	Colony Count (CFU 100 ml^{-1})	pH	TDS (mg L^{-1})	TSS (mg $L^{-1)}$	TS (mg L^{-1})
1	159 ±63	6,96 ± 0.04	770 ± 230	660 ± 320	1430 ± 510
2	54 ± 12	6.94 ± 0.06	620 ± 190	440 ± 270	1060 ± 440
3	119 ± 6.8	6.93 ± 0.06	250 ± 170	550 ± 290	800 ± 330
4	218 ± 55	6.9 ± 0.07	200 ± 90	240 ± 50	450 ± 80
5	87 ± 47	6.94 ± 0.02	190 ±130	1840 ± 1270	2030 ± 1230
6	196 ± 58	6.89 ± 0.09	210 ± 120	290 ± 60	500 ± 170
7	240 ± 30	7.14 ± 0.05	560 ± 250	520 ± 390	1080 ± 190
8	321 ± 32	7.15 ± 0.02	230 ± 80	820 ± 470	1050 ± 480
9	276 ± 9.89	7.37 ± 0.17	130 ± 120	1730 ± 610	1860 ± 730
10	276 ± 17	7.29 ± 0.02	120 ± 80	780 ± 670	890 ± 730

Table 4. Mean and Standard Deviation of Bacterial Count and Physicochemical Parameters of the Water Samples in Streams from the Industrial Area of Rosslyn in the Month of June, 2015.

Location Sites	Colony Count (CFU 100 ml^{-1})	pH	Temperature (˚C)	TDS (mg L^{-1})	TSS (mg L^{-1})	TS (mg L^{-1})
1	235± 23	6.93 ±0.07	19 ± 0.41	830 ± 80	310 ± 50	690 ± 110
2	178 ± 62	6.74 ± 0.06	21 ± 0	450 ± 100	3590 ± 850	4030 ± 940
3	162 ± 74	6.42 ± 0.03	19 ± 0	40 ± 10	330 ± 220	370 ± 230
4	143 ± 47	6.87 ± 0.04	20 ± 0	260 ± 90	310 ± 300	560 ± 250
5	178 ±109	6.49 ± 0.01	18 ± 0	100 ± 20	250 ± 150	360 ± 140
6	294 ± 124	6.78 ± 0.28	17 ± 0	150 ± 60	4040 ± 60	4190 ± 90
7	256 ± 93	6.89 ± 0.03	17 ± 0.41	230 ± 90	710 ± 530	940 ± 470
8	261 ± 46	6.89 ± 0.09	18 ± 0	270 ±140	490 ± 50	750 ± 100
9	254 ± 115	7.05 ± 0.10	17 ± 0	220 ± 10	300 ± 50	520 ± 40
10	365 ± 79	6.50 ± 0.004	16 ± 0.41	510 ± 170	2030 ± 530	2540 ± 460

Table 5. Mean and Standard Deviation of Bacterial Count and Physicochemical Parameters of the Water Samples in Streams from the Industrial Area of Rosslyn in the Month of July, 2015.

Location Sites	Colony Count (CFU 100 ml^{-1})	pH	Temperature (˚C)	TDS (mg L^{-1})	TSS (mg L^{-1})	TS (mg L^{-1})
1	152 ± 119	7.07 ± 0.15	17 ± 0.81	490 ± 150	520 ± 160	1100 ± 60
2	73 ± 8.60	7.01 ± 0.09	16 ± 0.47	550 ± 130	40 ± 20	590 ± 150
3	34 ± 8.17	6.79 ± 0.008	15 ± 0.47	960 ± 100	1110 ± 180	2070 ± 260
4	12 ± 1.69	6.37 ± 0.04	14 ± 0.47	220 ± 30	130 ± 40	350 ± 40
5	11 ± 3.39	6.27 ± 0.15	14 ± 0.47	160 ± 50	1440 ± 430	1610 ± 410
6	20 ± 2.16	6.72 ± 0.18	15 ± 0.47	190 ± 60	90 ± 60	280 ± 20
7	16 ± 5.43	6.99 ± 0.31	16 ± 0.47	210 ± 50	120 ± 40	330 ± 10
8	38 ± 21	6.94 ±0.23	15 ± 0.47	270 ± 20	1150 ± 110	1430 ± 90
9	89 ± 59	7.21 ± 0.26	14 ± 0.47	300 ± 60	1690 ± 170	2000 ± 170
10	131 ± 105	6.76 ± 0.29	14 ± 0.47	250 ± 30	1110 ± 250	1370 ± 230

Table 6. Mean and Standard Deviation of Bacterial Count and Physicochemical Parameters of the Water Samples in Streams from the Industrial Area of Rosslyn in the Month of August, 2015.

Location Sites	Colony Count (CFU 100 ml^{-1})	pH	Temperature (˚C)	TDS (mg L^{-1})	TSS (mg L^{-1})	TS (mg L^{-1})
1	159 ± 42	7.43 ± 0.18	17 ± 0.47	60 ± 30	140 ± 20	200 ± 20
2	132 ± 74	7.19 ± 0.10	19 ± 0.47	550 ± 190	210 ± 9	760 ± 190
3	189 ± 92	6.77 ± 0.08	16 ± 0.47	600 ± 120	2550 ± 290	2910 ±170
4	165 ± 43	6.71 ± 0.09	17 ± 0.47	440 ± 180	360 ± 20	790 ± 60
5	36 ± 31	6.77 ± 0.03	18 ± 0.47	450 ± 180	1260 ± 210	1710 ± 170
6	99 ± 44	6.78 ± 0.12	18 ± 0.47	390 ± 190	520 ± 230	910 ± 420
7	5.33 ± 4.10	7.57 ± 0.10	17 ± 0.47	470 ± 310	2090 ± 180	2560 ± 210
8	4.85 ± 5.90	7.5 ± 0.16	17 ± 0.47	190 ± 50	240 ± 180	420 ± 170
9	145 ± 65	7.97 ± 0.03	17 ± 0.47	260 ± 90	1510 ± 520	1770 ± 480
10	120 ± 74	7.02 ± 0.04	18 ± 0.47	350 ± 130	640 ± 180	990 ± 220

These sites are associated with manufacturing industries but the effect of local food sellers using detergents in washing dishes that are dumped directly to the stream and car washing centre could not be overlooked. *Panno et al.* (*2007*) noted from a separate study that the most important sources of Cl- to waters may come from water conditioning salt coming from detergents used in washing dishes, sewage, industrial discharge and livestock waste. The study further pointed out that Cl- and other contaminants can persist for many years if travel times are slow.

The mean concentration of phosphate ranged from 0.00 - 7.80 mg L^{-1}. The highest mean concentration for phosphate was recorded at Site 4 during the month of March and closely followed by Sites 9 and 10 (**Figures 4** and **5**). Generally, the value obtained for phosphate from all the streams were above the recommended limit of

Table 7. Mean and Standard deviation of the Physicochemical Parameters of the Water Samples in Streams from the Industrial Area of Rosslyn in March and April, 2015.

	March			April		
Location Sites	NO2- (mg L^{-1})	CL- (mg L^{-1})	F- (mg L^{-1})	NO2- (mg L-1)	CL- (mg L^{-1})	F- (mg L^{-1})
1	14 ± 0.30	144 ± 1.09	0.096 ± 0.03	1.79 ± 0.10	328 ± 0.79	18 ± 0.21
2	3.66 ± 0.04	97 ± 0.72	0.087 ± 0.04	1.77 ± 0.02	325 ± 0.89	17 ± 0.34
3	0.047 ± 0.02	36 ± 0.40	0.123 ± 0.001	0.08 ± 0.01	82 ± 0.74	0.14 ± 0.008
4	0.012 ± 0.009	35 ± 0.35	0.177 ± 0.02	0.12 ± 0.02	84 ± 0.72	0.76 ± 0.44
5	0.35 ± 0.008	31 ± 0.31	0.221 ± 0.01	0.08 ± 0.007	81 ± 0.68	0.15 ± 0.02
6	0.86 ± 0.006	36 ± 0.40	0.124 ± 0.03	0.01 ± 0.00	80 ± 0.62	0.14 ± 0.01
7	0.76 ± 0.02	54 ± 0.49	0.281 ± 0.03	0.00	61 ± 0.43	0.17 ± 0.02
8	0.052 ± 0.02	46 ± 0.47	0.026 ± 0.009	0.00	62 ± 0.68	0.13 ± 0.01
9	0.52 ± 0.02	63 ± 0.56	0.208 ± 0.01	6.31 ± 0.32	70 ± 0.61	0.43 ± 0.13
10	0.43 ± 0.02	81 ± 0.63	0.22 ± 0.02	7.17 ± 0.16	70 ± 0.69	0.18 ± 0.03

0.1 mg L^{-1} with the exception of Site 5. The results from this study were above those reported by *Fadiran et al.* (*2008*). The values obtained from the study of *Fadiran et al.* (*2008*) showed that the phosphate level ranged from 0.08-1.60 mg L^{-1}. The highest value from that study was recorded from the industrial sites. Similar observation was recorded from this study; however, the highest value for phosphate was recorded from the stream receiving direct discharge from the hospital waste water (**Figures 4** and **5**). The study attributed the sources of phosphate to industrial activities, agricultural activities, population density, location (urban, suburban or rural) and soil/rock type in the vicinity of the sampling point, climate as well as rainfall pattern of the area or region concerned. This study may elucidate agriculture and rainfall as factors that might have influenced the high levels of phosphate. The major problem associated with high level of phosphate is that excessive amounts in water bodies can lead to eutrophication, a condition of accelerated, algal production to extreme quantities until they die off. In turn, excessive algae on the water surface can accumulate into a scum which can result in clogged pipelines, restricted recreation and foul odors (*Nolan and Stone 2000*).

Generally, from all the sampling sites, the concentrations recorded for nitrate were above the recommended limit of 6 mg L^{-1} except for sites 7 and 8 (**Figures 6** and **7**). Nitrates in most cases are present in run-off from agricultural land where nitrogenous fertilizers are used. Nitrates act as a ready source of nutrients for plant growth and can give rise to rapid growth aquatic plants in streams and algal blooms in reservoirs (*Morrison et al. 2001*). However, from this study, significantly high levels of nitrate were noticed from Sites 1, 2, 9 and 10. These are areas associated with industrial effluents and hospital wastewater. Nitrite levels exceeded the permissible limit from Sites 1 and 2 (**Table 7**). These high values might be due to leakage or spills of volatile organic compounds from the rubber industry into the water source, due to improper storage. High level of nitrite is possible because of the method of processing of

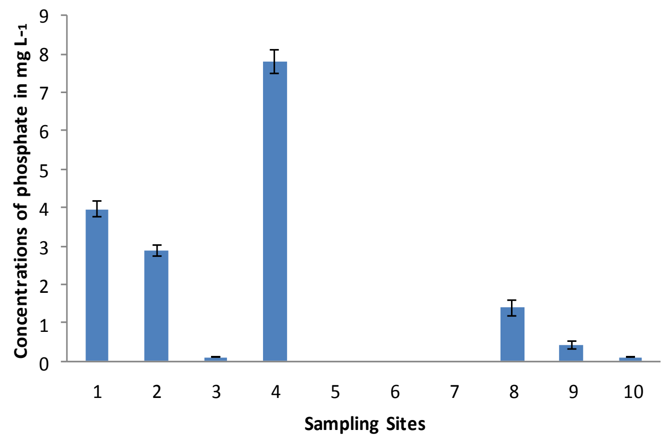

Figure 4. Concentrations of phosphate during the month of March, 2015.

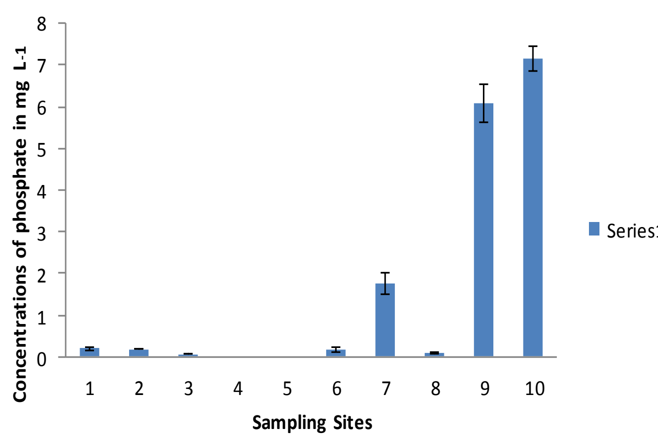

Figure 5. Concentrations of phosphate during the month of April, 2015.

the rubber products called salt bath vulcanization which is a liquid curing method (LCM), whereby blends of nitrate and nitrite salt like 53% potassium nitrate, 40% sodium nitrite and 7% sodium nitrate are used. The disadvantage of salt bath LCM is that it has been associated to the formation of nitrosamines, which are suspected human carcinogen. These chemicals are produced when nitrogen and oxygen from a "nitrosating" compound bind to the amino group nitrogen of the amine compound. The nitrite and nitrate salt used in salt bath act as a nitrosating agents and combine with amines in the rubber compounds like sulphenamine (NDphA) to form nitrosamines (*Pokorny et al. 2006*). The fluoride level observed in April for Sites 1 and 2 (**Table 7**) with values 18 mg L^{-1} and 17 mg L^{-1} were above the required standard. Fluoride is cumulative and toxic to all forms of life at exceptionally low dosages.

The investigation carried out to determine the colony count for the presence of bacteria in the streams showed that the values obtained for all the colony counts during the study exceeded the allowable limit in water bodies. The highest colony count was reported at Site 10 with a value of 365 ± 7 cfu 100 ml^{-1} (colony forming unit per 100 ml of sample) during the month of June while the lowestcount was reported at Site 8 with a value of 4.85 ± 5.90 cfu 100 ml^{-1}. The differences obtained in the colony count from all the sites were statistically significant ($p<0.05$). Microscopic examination revealed that the bacteria were either gram positive or gram negative bacteria with shapes ranging from *Cocci*, *Bacilli*, *Streptobacilli*, *Streptococci*, *Vibrio* and *Diplococcic* (**Figures 8** to **11**). The monthly variation in bacteria load, peak during the month of June (**Figure 12**). The maximum water pH was observed in March (**Figure 13**). The variation in Total Solids of the water samples demonstrate that the pollution rate was highest during summer period in April and lowest during winter in July (**Figure 14**).

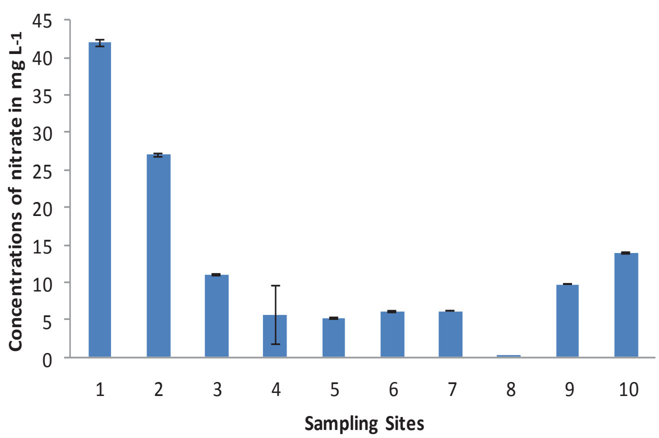

Figure 6. Concentrations of nitrate during the month of March, 2015.

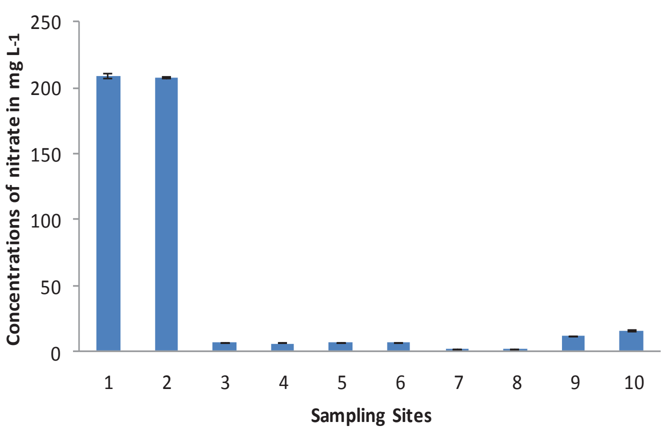

Figure 7. Concentrations of nitrate during the month of April, 2015.

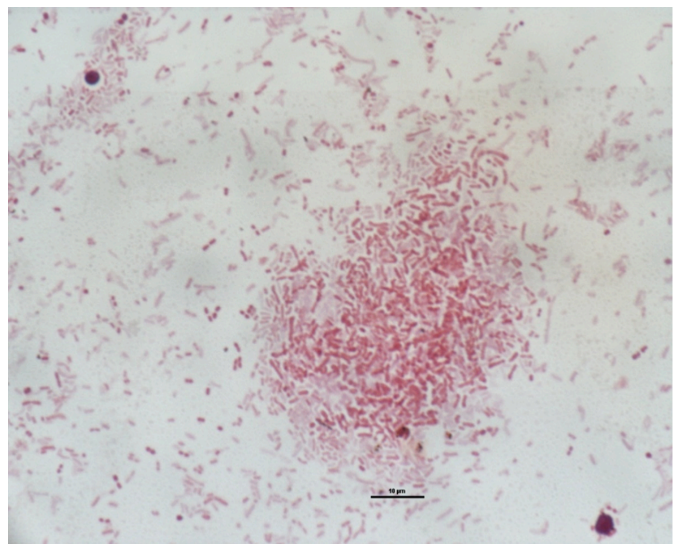

Figure 8. Gram-positive and Gram-negative Bacteria (*Bacilli* and *Cocci* shaped bacteria) from Site 1.

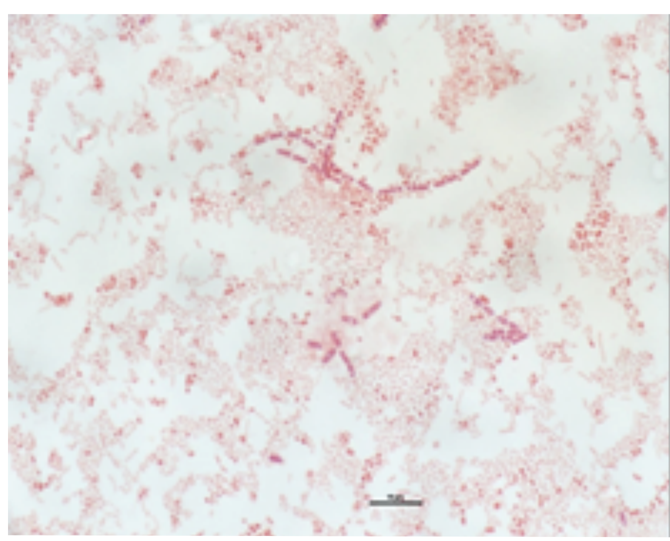

Figure 9. Gram-positive and Gram-negative Bacteria (*Streptobacilli*, *Diplobacilli*, *Cocci* and *Bacilli* shaped bacteria) from Site 2.

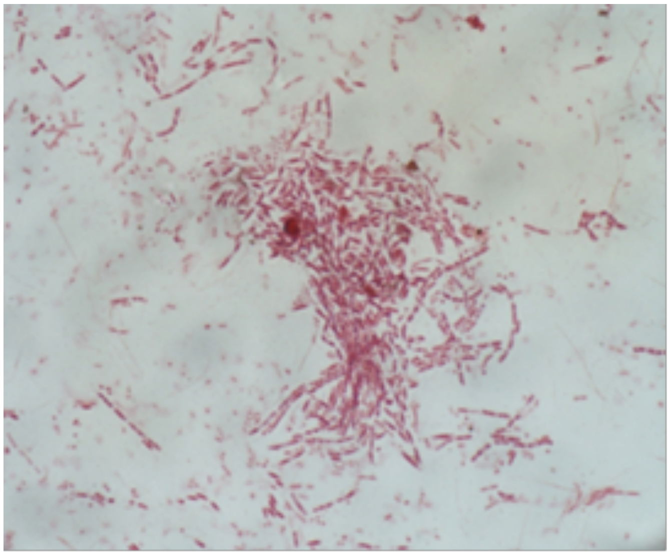

Figure 10. Gram-positive Bacteria (*Streptobacilli, Diplobacilli*, *Bacilli* and *Cocci* shaped bacteria) from site 9.

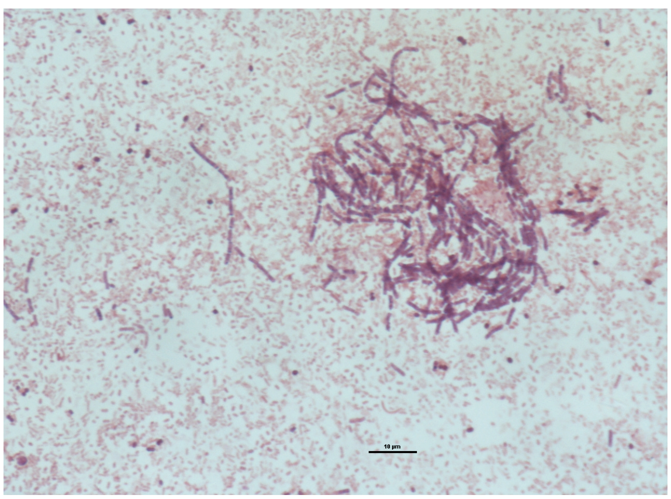

Figure 11. Gram-positive Bacteria (*Coccobacilli*, *Cocci*, *Vibrio* and *Diplococci* shaped bacteria) from Site 10.

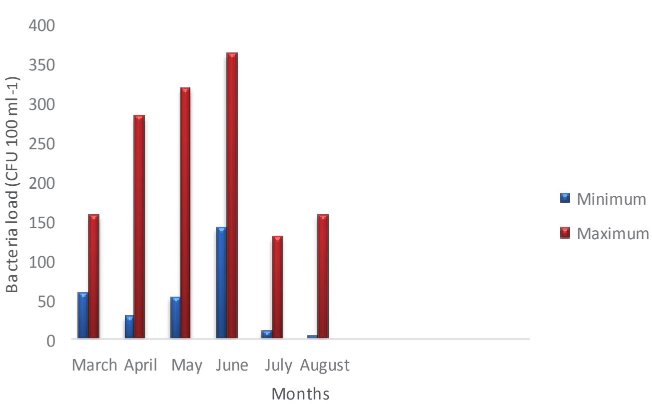

Figure 12. Monthly Variation in Bacteria load of water Samples.

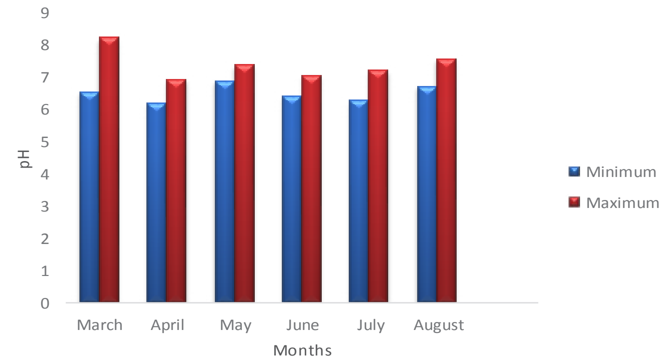

Figure 13. Monthly Variation in Water pH.

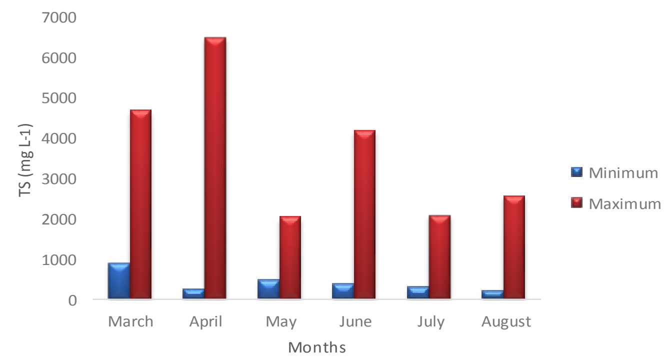

Figure 14. Monthly Variation in Total Solids of water Samples.

CONCLUSION AND RECOMMENDATIONS

The study provided information on the quality of streams around the industrial area of Rosslyn. Monitoring of water quality around industrial area is important in order to have access to good water and protect aquatic life. Water in the streams sampled in this study showed that sampling stations around the industrial area and the streams receiving effluents directly from the hospital waste are indeed polluted. The findings of the study are important because people staying around the hospital rely on the stream for the supply of water for washing and agricultural purposes. Nutrients load, especially phosphate and nitrate from the streams are probably due to anthropogenic effect. Though the study did not determine the actual name of bacteria present in the streams, the CFU showed that the streams are highly polluted with different types of bacteria. The study concludes that most streams around the industrial area are polluted and due to the fact that people living around the area especially the hospital rely on this streams for supply of water, it will be necessary to educate those that rely on the streams on the dangers of using the water from the streams. It will also be necessary to inform the hospital management and those in the industries on the importance of treating wastewater effectively before discharging them into the nearby streams or reservoir.

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