ASSESSMENT OF POLLUTION IN NDARUGU RIVER DUE TO AGRICULTURAL WASTEWATER DISPOSAL

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Abstract
River Ndarugu is a tributary of Athi River in Kenya and is one of the main sources of fresh water for domestic use to the villages along the river bank and Nairobi City. It traverses Juja Township in Kiambu County, Central Kenya. During its course through the different agricultural and industrial areas of Gatundu, Gachororo and Juja farms, it receives untreated industrial and agricultural waste discharges, effluent from coffee and tea factories, and other agricultural activities in the catchment area. This paper aims at assessing the level of pollution due to these activities. Water samples were collected from eight sampling points during the dry season and analysed at Jomo Kenyatta University Environmental laboratory for eight parameters; pH, temperature, electrical conductivity (EC), Turbidity, Nitrogen, Phosphorous, Biochemical oxygen demand (BOD_5) and dissolved oxygen (DO) in order to assess the present water quality of the river. The samples were collected at 15cm depth (to avoid floating materials) and geographical positioning system (GPS) device was used to spatially locate the sampling sites. Samples were taken from upstream and downstream of point sources of pollution. Results indicated that the wastewaters discharged to the river had BOD_5 of 350 to 600mg/l and EC of 482 to 620µS/cm. BOD_5 of the river water was found to be 20mg/l, while EC ranged from 55 to 85µS/cm. This led to decrease in the river water quality in general and DO content in particular, with DO level reducing from 6.3 to 3.4mg/l. The water is being polluted by the human activities in the catchment. There is need for proper control of wastewater by various techniques, and preliminary treatment of waste discharges prior to effluent disposal. Management of the watershed is necessary so as to protect the river from the adverse impacts of agricultural activities and save it from further deterioration.

Key words: Biochemical oxygen demand, dissolved oxygen, electrical conductivity, pollution

1.0 Introduction

Rivers are the most important freshwater resources for human being as social, economic and political development has been largely related to the availability and distribution of freshwaters contained in river systems. Nowadays, catchments are becoming polluted by various human activities, including littering, pouring chemicals down drains and agro-industrial discharges, all of which are washed into creeks and storm water drains. Water quality is generally related to surrounding land use. There is a clear link between population growth, urbanization, industrial development and human activities that are likely to generate pollution (Nhapi *et al*., 2011). Polluted water is an important means for the spread of diseases. In developing countries about 1.8 million people, majority children, die every year as a result of water related diseases (WHO, 2004).

Environmental pollution is a major global concern. When sources of water pollution are enumerated, agriculture is, with increasing frequency, listed as a major contributor. As nations make efforts to correct abuses to their water resources, there is a need to determine the causes of water quality degradation and to quantify pollution contributions from many sources. Until such time as adequate facts are made available through research to delineate causes and sources, conflicting opinions continue to flourish and programmes to control and abate pollution will be less effective and efficient in the use of limited resources (Ongley, 1996).

Existing knowledge indicates that agricultural operations can contribute to water quality deterioration through the release of several materials into water: sediments, pesticides, animal manures, fertilizers and other sources of inorganic and organic matter. Many of these pollutants reach surface and groundwater resources through widespread runoff and percolation and, hence, are called "non-point" sources of pollution. Identification, quantification and control of non-point pollution remain relatively difficult tasks as compared to those of "point" sources of pollution (Ongley, 1996).

Water pollution due to industrial and agricultural activities has become a serious problem both globally and in surrounding environment. A huge amount of domestic, agricultural, municipal and industrial wastewaters discharges to water bodies all around the world. Discharging raw wastes, with high levels of contaminants, washing away to rivers of pesticides and fertilizers are among the worst pollution sources to rivers. Disposal of these wastewaters into the rivers with little or no treatment prior to discharge is common in many developing countries. Rivers and streams are among the main sources of fresh water that suffer a big amount of pollutant loads and wastewater, due to influx of pollutants without prior treatment, around the world. This has caused a serious concern over the deterioration of river water quality. These discharges of degradable wastewaters in water bodies result in decrease in water quality in general and DO (Dissolved Oxygen) concentrations in particular.

Ndarugu River is one of the main sources of fresh water for domestic use to people of many villages and towns along the river bank. Being a tributary of Athi River, it also contributes to water supply of Nairobi City. It traverses Juja Township in Thika District, Central Kenya. During its course through the different agricultural and industrial areas, it receives untreated industrial and agricultural waste discharge and effluent from coffee factories, tea factories, flower plants and other agricultural activities situated on the catchment of the river.

The main objective of this research was therefore to evaluate effects of agricultural activities on the environment and specifically on water quality along River Ndarugu**.** The specific objective was to determine how agricultural wastewater causes pollution to the river.

2.0 Materials and Methods

2.1 Description of Study Area

2.1.1 Location

Ndarugu Sub Basin is located in the central part of Kenya. The river traverses Juja Township in Kiambu County, Central Kenya. The area under study is bounded between latitudes 1° 00' South and 1° 08' South and longitudes 36° 53' East and 37° 10' East at an average altitude of 1560 meters above sea level. The drainage area is coded by the Government of Kenya as 3CB sub catchments in Athi Basin. Ndarugu River is one of the tributaries of Athi River. Ndarugu sub-catchment extends from Kieni and Kinale forest eastwards and parts of ridges of Aberdares to Juja farm all the way to Munyu where it is joined by River Komu before it joins Athi River. River Ndarugu is a perennial river with its source in the Kikuyu escarpments. It meanders through farmed slopes of Gatundu and Thika District before joining Athi River at Munyu near Kilimambogo. The tributaries of Ndarugu River are Ruabora, Githobokoni and Karakuta rivers.

2.1.2 Climate

The study area is located in a bimodal two rainfall season zone (March to May and October to December). The long rainy season is usually between March and May while the short rainy season is between October and December with peaks in April and November respectively. The mean annual rainfall for Ndarugu sub-basin is 1126mm. Rainfall is largely influenced by altitude. Air temperatures are moderate with monthly average low temperatures varying from 12 to 15^{o}C and average high temperatures varying from 23 to 28^{o}C. March is the hottest month with mean of 21.5^{o}C and July is the coldest month with a mean of 17.5^{o}C. Mean annual maximum is 25.7^{o}C and mean annual minimum is 13.6^{o}C.Water temperatures vary seasonally from 13.5 to 19.5^{o}C.

River Ndarugu is recognized for its diverse flora and fauna. The area surrounding the river also offers a mild climate and natural beauty. Its freshwater is both ecologically and economically valuable to residents of the area. One of its social economic values is that it provides water for domestic and agricultural use to people within its surroundings (Ndegwa et al., 2008).

2.2 Sources of Pollution

Generally sources of water pollution are categorized as point and non-point sources. The major sources of river water pollution during dry season are categorized as point sources through which the polluting substance is emitted directly into the waterway. The non-point (diffuse) sources were not considered because the study was made during dry season and the non-point sources are related to rainfall.

2.3 Sampling

Surface water samples for physico-chemical analysis were collected from eight different sampling sites of the river during the dry season in June and July 2013. Sampling bottles made of plastic each of size 500ml were used to collect the water samples. The samples were taken at a depth of 15cm and filled directly in to rinsed and clean bottles. Air entrapping was avoided as much as possible in order to get the actual DO of samples. Global Positioning System (GPS) was used to determine the exact locations of each sampling points so that each time samples were taken from the same place .To get a sample from the main flow of water and not the edges or where water is held in pools, where there is likely to be more variation from the main body of the river the sampling pole was used. The running water in the centre of the river was sampled to give the best overall sample. The bottles were rinsed few times by the river water before taking the samples and touching the rim was avoided to prevent from any contamination of the samples. The bottle was placed inverted in the body of water 15 cm below the surface and then turned horizontal facing in the direction of to the flow of water (Fig 1). The sampling sites were selected based on the presence of point source of pollution from domestic wastewater, industries, coffee and tea factories (Figure 2).The first site was chosen at the upstream site near the Mitaro Estates diversion and the last site was at Juja farm (Downstream). The last (seventh) sampling point was at 15kilometers downstream of the first sampling point. The description, elevation and UTM coordinates of the sampling points are given in Table 1.

Table 1: Location (UTM coordinates) of sampling points

Sampling Point. Code	Sampling location	Elevation(m) A.S.L.	UTM-X(East)	UTM-Y(North)
01	Mitaro estates diversion	1495	274472.37	9885428.23
02	Azania estates	1481	276601.39	9882997.45
03	Benifer bridge	1454	279199.82	9881136.68
04	Jkuat intake point	1449	280481.44	9880392.92
05	Juja water company	1435	281633.98	9879394.94
06	Kenya Plant Production	1419	282601.16	9878382.41
07	Juja Farm	1402	284470.28	9877526.10
08	Raw wastewater from coffee processing	-	-	-

Figure 1: Sampling for water quality at Ndarugu River

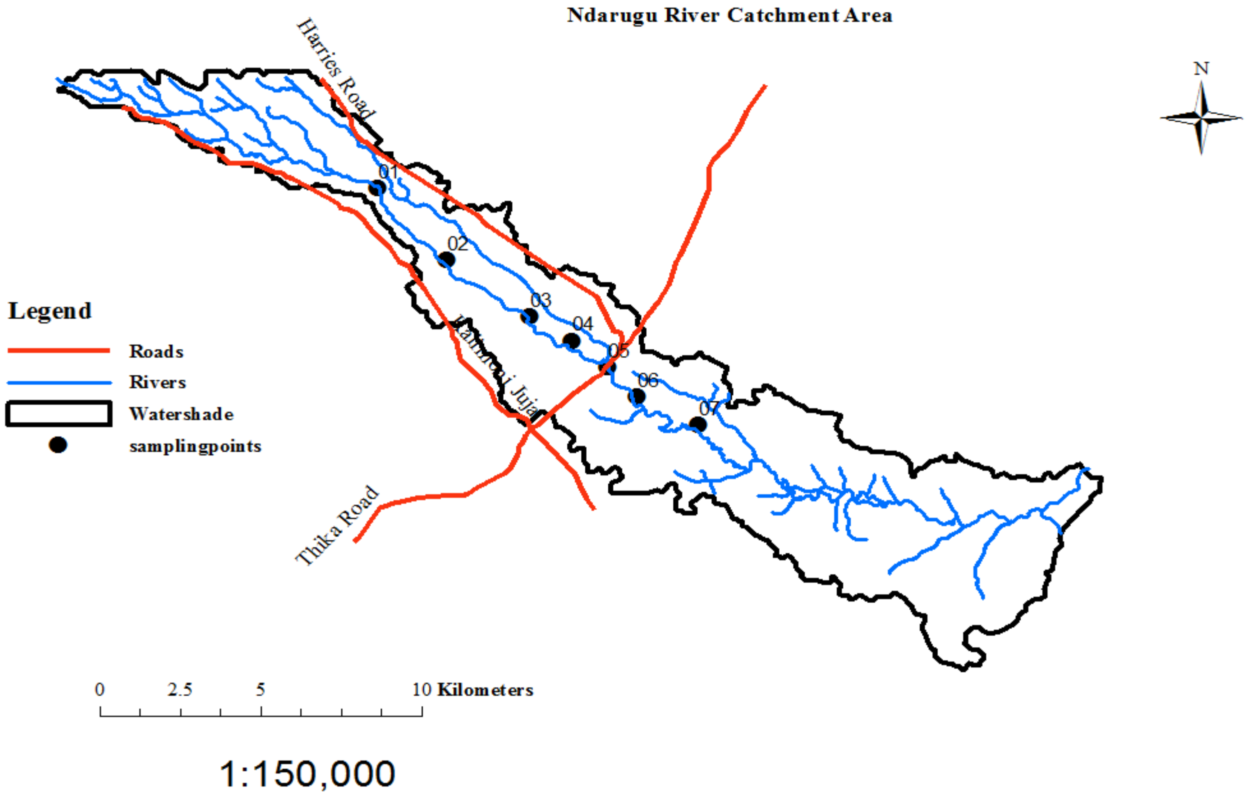

Figure 2: Ndarugu River catchment and sampling points

2.4 On Site and Laboratory Analysis

The methods outlined in the standard methods for the examination of water and waste water (APHA, 1998) were followed for the analysis of the physico-chemical parameters. Temperature, pH and Electrical Conductivity (EC), were measured in-situ using a temperature probe and a portable Microprocessor pH meter (pH-211) and a portable conductivity meter respectively. Turbidity, Nitrates, Nitrites, Phosphorous, DO and BOD_5 were measured in the JKUAT environmental laboratory using, Turbidi-meter (Nephelometric NTU), COD and Multi-parameter photometer (HI-83099) and titration method respectively.

3.0 Results and Discussion

The physico-chemical characteristics and location of sampling points of Ndarugu River are presented in Tables 2 and 3 and Figure 3(a, b and c).

3.1 Physical Characteristics (Parameters)

The pH of the river was neutral at all stations for the study period ranging from 6.57 to 7.82. This pH range falls within the range associated with most natural waters which is between 6.5 and 8.5 (Chapman, 1992), stipulated for drinking and domestic purposes. The temperature during the study ranged from 17.7^oC to 19 ^oC. The EC meter used automatically standardizes the readings to 25^oC. EC was measured in microSiemens/centimetre (µS/cm). It was observed to be very high in the raw wastewater before it joins the river as compared to the EC of the river. The mean electrical conductivity of the river ranged between 55µS/cm to 85µS/cm. For the raw waste directly discharged from coffee processing (pulping) factories the electrical conductivity was between 482µS/cm to 620µS/cm. The electrical conductivity of water estimates the total amount of solids dissolved in water, Total Dissolved Solids (TDS), which stands for Total Dissolved Solids. TDS is measured in parts per million (ppm) or in milligram per litre (mg/l). Since the electrical conductivity is a measure of the capacity of water to conduct electrical current, it is directly related to the concentration of salts dissolved in water, and therefore to the TDS. Salts dissolve into positively charged ions and negatively charged ions, which conduct electricity. Since it is difficult to measure TDS in the field, the electrical conductivity of the water was used as a measure. TDS (ppm) is calculated as 0.55 to 0.9 times EC (µS/cm), usually 0.7 times EC.

EC can be converted to TDS using the following calculation:
TDS (ppm) = 0.70 * EC (µS/cm) = 700 * EC (dS/m)

The turbidity range of the river was found to be between 18.3and 35.6NTU exceeding the allowable limit of 5NTU. The DO range for the different sampling points was between 3.4 and 6.3mg/l. Lower DO level leads to death of many aquatic animals. BOD_5 increased from upstream to downstream end of the river due to several point sources of pollution with very high BOD_5 concentration. At the source of the river the BOD_5 concentration was 12mg/l and at downstream site BOD_5 was found to range from17.5mg/l to22mg/l.

Table 2: Physical parameters of the water samples

	pH		**Temperature (^oC)**		**Conductivity µS/cm)**		**Turbidity (NTU)**		**DO(mg/l)**		**BOD_5 (mg/l)**	
Sample Points	**Range**	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**	**Average**	**Range**	**Average**
01	6.57-7.82	7.18	18-18.8	18.42	55-78	61.50	18.3-35.1	25.73	5.1-6.3	5.79	17.5-20.8	19.15
02	6.79-7.32	7.10	17.8-18.9	18.24	57-67	58.60	19.3-32	25.11	4.9-6.2	5.57	18.3-20.5	19.19
03	6.73-7.42	7.09	18-19	18.45	56-69	63.70	19.5-29.3	24.85	4.1-6.2	5.17	18.5-21.1	19.45
04	6.5-7.24	7.06	17.9-18.9	18.4	56-80	66.90	19.8-35.6	25.53	4.1-5.7	4.82	18-21	19.78
05	7.01-7.35	7.20	17.8-19	18.44	60-79	66.10	18.9-26.5	22.09	3.4-4.7	4.14	18.7-21	19.84
06	6.65-7.21	6.93	17.9-19	18.37	62-85	67.70	22.8-33	28.21	3.6-5	4.21	18.7-22	20.24
07	6.78-7.17	6.98	17.7-18.8	18.24	59-84	72.10	19.3-34.2	27.23	3.4-4.3	3.82	20-22	20.99
08	4.23-4.66	4.44	18.9-20.6	19.81	482-620	558.10	-	-	-	-	350-600	492.80
WHO	**6.5-8.5**		**-**		**500-5000**		**5**					

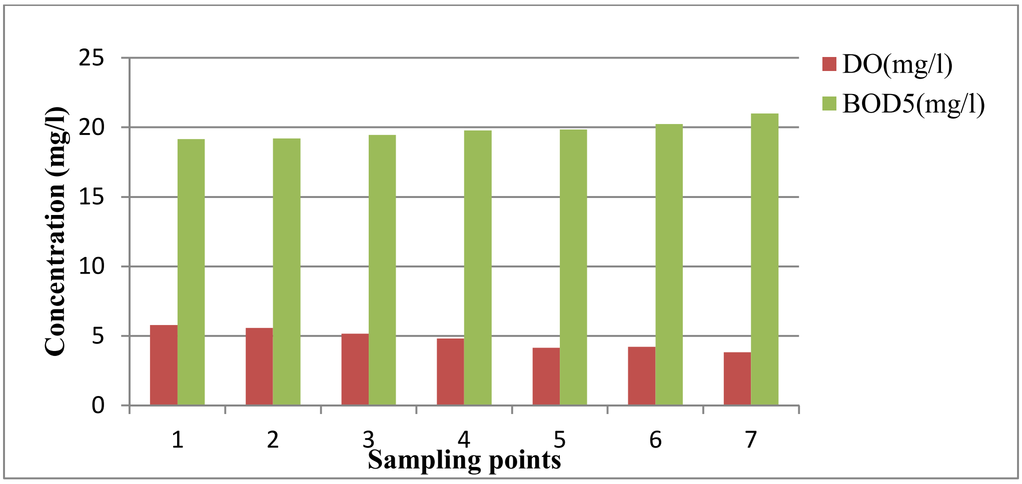

Figure 3(a): Variation of DO and BOD along the river

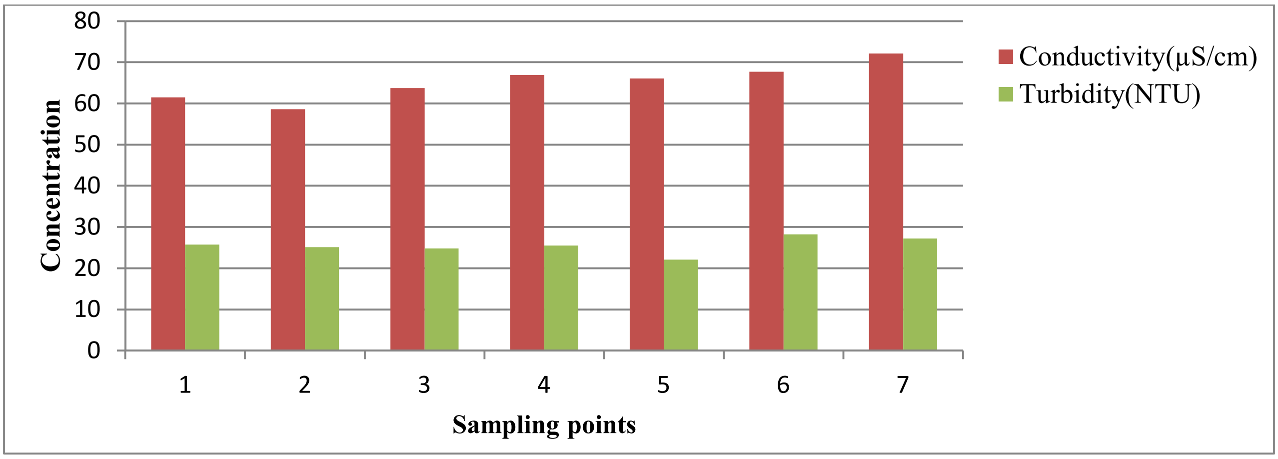

Figure 3(b): Variation of Conductivity and Turbidity along the river

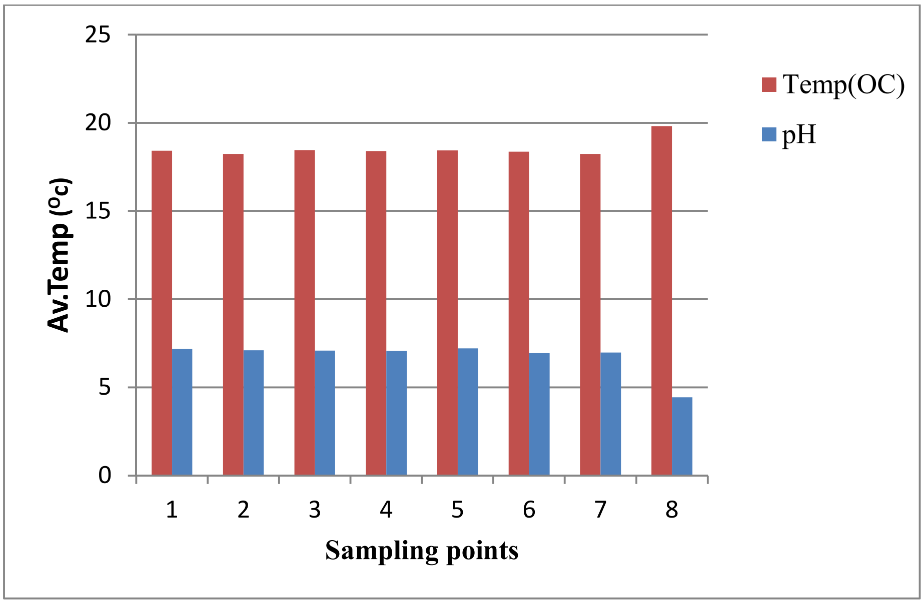

Figure 3(c): Variation of Temperature and pH along the river

3.2 Chemical Characteristics (Parameters)

3.2.1 Nitrates, Nitrites and Phosphorus

The nitrates, nitrites and phosphorous content of the water samples were analysed using the Multimeter photometer. Maximum value of Nitrates and Nitrites Nitrogen in the water samples was between 4 mg/l and 6mg/l. All nitrate concentration values within Ndarugu River are below the recommended standards for drinking water of 5 to 10mg/l. From the above analysis River Ndarugu is not polluted by nitrates during dry season. Phosphorus was detected as low as 0.1mg/l in the water samples only in few samples. The nitrate and nitrite concentrations were as presented in Table 3.

Table 3: Nitrate and Nitrite concentrations for four sampling sites

Parameters	**NO_3-N (mg/l)**	**NO_3^- (mg/l)**	**NO_2^- (mg/l)**	**NO_2-N (mg/l)**	**$NaNO_2$ (mg/l)**
Azania CRF	4.6	20.4	21	6	31
JKUAT intake point	4.0	17.6	12	4	18
Juja W.C	4.2	19.2	17	5	24
KPP	4.1	18.1	15	4.5	21
WHO	5-10	50	3		

4.0 Conclusion and Recommendation

4.1 Conclusion

The results indicated that most of the physical water quality parameters for Ndarugu River were within the WHO limits for drinking water. The water may therefore be suitable for domestic purposes. The pH of river was not affected much by the low pH level of the wastes discharged. It was observed to have neutral pH. However wastewater disposal without any treatment caused the river to reduce its dissolved oxygen content due to the high biochemical oxygen demand of the incoming waste. The DO was significantly depleted and reduced due to the mixing of these wastewaters even though re-aeration (replenishing with dilution and surface re-aeration) is expected at the surface of the river. Turbidity level was higher than the WHO limit for drinking water.

4.2 Recommendation

There is need for proper control of wastewater by various techniques, such as constructing an oxidation pond at estate level and preliminary treatment of waste discharges prior to effluent disposal. Each farm company needs to construct its own oxidation ponds where it collects its wastewater. The wastewater can be retained in these oxidation ponds for several days so that the BOD can be reduced considerably. Management of the watershed is necessary so as to protect the river from the adverse impacts of agricultural and industrial activities and to save it from further deterioration.

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