Non-point source pollution and its impact on drinking water quality in River Nile- A case study of Juba South Sudan

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Abstract- Continuous deterioration of River Nile water quality in the Juba has become a major area of concern. Population growth, urbanization, and rural-town immigration have to lead to a population increase in the Juba. This study attempted to investigate the impact of urbanization and industrialization on water quality. Secondary data and mathematical models were used to compute the concentration of pollution in drinking water quality. The results reveal that anthropogenic pollutants were highly contributing to the pollution of the basin by 78%, non-anthropogenic factors contributed 22%. The pollutant concentration found was 9.13 g/m3. Nutrients was as low as 0.000055g/L and phosphorous was 0.000009g/L. The average fecal coliform range from 15.25–102.6 CFU/100ml that shows highly contaminated. The pH and temperature were normal. TDS showed very high, ranging from 47–123 mg/100ml that is far beyond the EPA, and WHO recommended 500 ml/L. The EC was not so high, fluctuating between 59µs-201µs/cm, which is slightly above the recommended 160 µs/cm. The study concluded that the raw water from River Nile is not suitable for drinking without treatment. Therefore, the study recommended appropriate water quality management and the installation of a drinking water plant.

Index Terms- River Nile. Non-Points Source Pollution, Total load concentration, Nutrients concentration, Drinking-Water Quality.

I. Introduction

Water pollution has become a global issue that calls the attention of academicians, Politicians, and society [1, 2]. Water pollution is the leading worldwide cause of deaths and diseases and accounts for the deaths of more than 14,000 people daily[3]. The water crisis in both quantity and quality has risen as a global issue and has drawn more attention from government, industry, and academe. Generally, a series of physical, chemical, and biological parameters are designed as water quality criteria for evaluating the safety of water, not only for drinking water but also for reclamation [4].

The human right to water and sanitation was recognized by the United Nations General Assembly in 2010 and reflected in the new United Nations Sustainable Development Goals (UN-SDGs) of September 2015. Goal 6 ensures universal access to safe and affordable drinking water for all by 2030[5]. The United Nations World Water Development Report 2015 puts water at the core of sustainable development goals. It is an essential element of services, which supports poverty reduction, economic growth, and environmental sustainability[6].

Water pollution refers to the contamination of water bodies such as aquifers and groundwater. It occurs when pollutants are discharged directly or indirectly into water bodies without adequate treatment to remove harmful compounds[7-9]. Natural phenomena such as volcanoes, algae blooms, storms, and earthquakes cause savior changes in water quality and the ecological status of water. The anthropogenic factors which contributing to water pollution such as demographic processes, economic growth, social change, technological innovation, policies, and laws also exert pressure on water quality. Unfortunately, the alteration of water masses endangers human health, which is greatly affected by unsafe water and prevents adequate sanitation and hygiene, which in turn increases the risk of contracting and transmitting water-related diseases[10].

Recently many water resources are contaminating with anthropogenic sources and agricultural activities[11]. The poor fecal disposal and poor hygienic practices favor the spread of pathogenic microorganisms, including viruses, bacteria, and parasites. These microorganisms are responsible for various illnesses and may lead to death[12, 13]. Therefore, the same water that is essential to life may be the source of the disease that may lead to suffering, chronic disability, and death[14-16].

River Nile is one of the world's longest rivers; its basin is shared by 12 countries[17]. It rises and flows from Lake Victoria to sudd wetland and connects with the Blue Nile in Khartoum and other Rivers and flow to the Mediterranean Sea after covering 3,349,000 square kilometers. River Nile entered Juba with a width of 402 meters[18].

Juba is flowing with water throughout the year. Pollution of water bodies in the area has become a critical issue, which is more difficult because of the inadequacy or non-existence of surface water quality protection or management policies. Lagoons, rivers, and streams are becoming dumping sites for wastes without little treatment[19]. The discharge of raw sewage, garbage, as well as oil spills are threats to the diluting capabilities of the lagoons and rivers. Heavily polluted water may traverse long distances before a significant degree of purification is achieved. Therefore, rivers and streams become increasingly polluted from domestic and industrial wastewater dumped by residential and small factories. Water pollution threatens both environmental and human health concern[20].

Drinking water quality has increasingly become a critical issue in Juba. Streams, lagoons, and River Nile that are the mean source of drinking water become more contaminated, due to lack of technology and knowledge people in Juba relay on natural purification and considered previous rive and lagoons water quality and consume with basic or without basic drinking water treatment. However, the specific objectives of this study are; To assess the amounts of anthropogenic and animal pollutants within the Juba area that contribute to water pollution, the concentration of the loads in the river, and raw water quality.

II. Materials and Methods

2.1-Study area.

Juba is the capital city of the new country Republic of South Sudan, after its independence in 2011. The city is located in the southern part of South Sudan in Central Equatoria State along both sides of the White Nile River Bank. Its geographical coordinates are 4° .51' .0" North and 31° .37'. 0" East. With an elevation of 457 meters above sea level, is situated in vast expanses of open space, including swamplands and agrarian landscapes. It is estimated to occupy approximately 23,300 hectares. Greater Juba, including the surrounding rural lands, encompasses roughly 23 kilometers in diameter with a population density of 1,577,902 with a growth rate of 1.92[21]. Juba has a spectacular landscape rugged topography, high grounds, and plains, the general ground has an average altitude, 468 meters above sea level with a gentle slope to the north[22].

The River Nile system is the dominant physical feature, and all streams in the area drain into the Nile. The Nile enters the city with a width of about 400 meters and an average discharge of 34,000 million cubic meters per year, it may increase in early or late May due to the heavy rainfall in the upper streams and will drop wat late December with the decrease in rainfall. [23]. The Nile basin receives an average of 650 millimeters of rain annually [24, 25], with a flow velocity of 0.85 m/s to 1.15 m/s[26]. The area consists of a light loamy and heavy loamy soil that is not heavy cracking, medium water holding capacity with medium over[23].

The area under study was from latitude 4.799425 N^0 to the longitude of 31.604538E^0 upstream, to the latitude 4.948336 N^0 and longitude of 31.65393E^0 downstream respectively.

Table (1) showing population growth in Juba from 1972 to 2019

[1] Year	[2] 1973	[3] 1993	[4] 2005	[5] 2010	[6] 2019
[7] Population	[8] 56,737	[9] 114,980	[10] 250,000	[11] 548,953	[12] 1,577,902

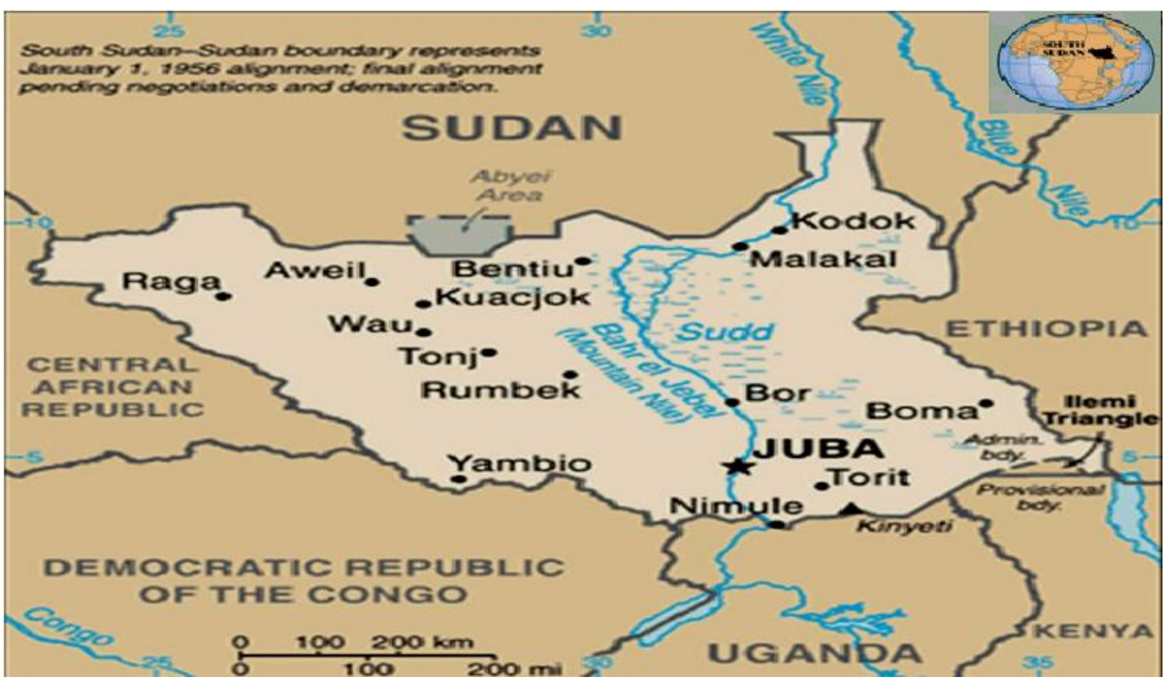

Figure (1) shows the map pointing to the location of Juba in South Sudan and the River Nile.
Source: (https://www.cia.gov/library/publications/the-world-factbook/geos/geos/od.html, 2013)

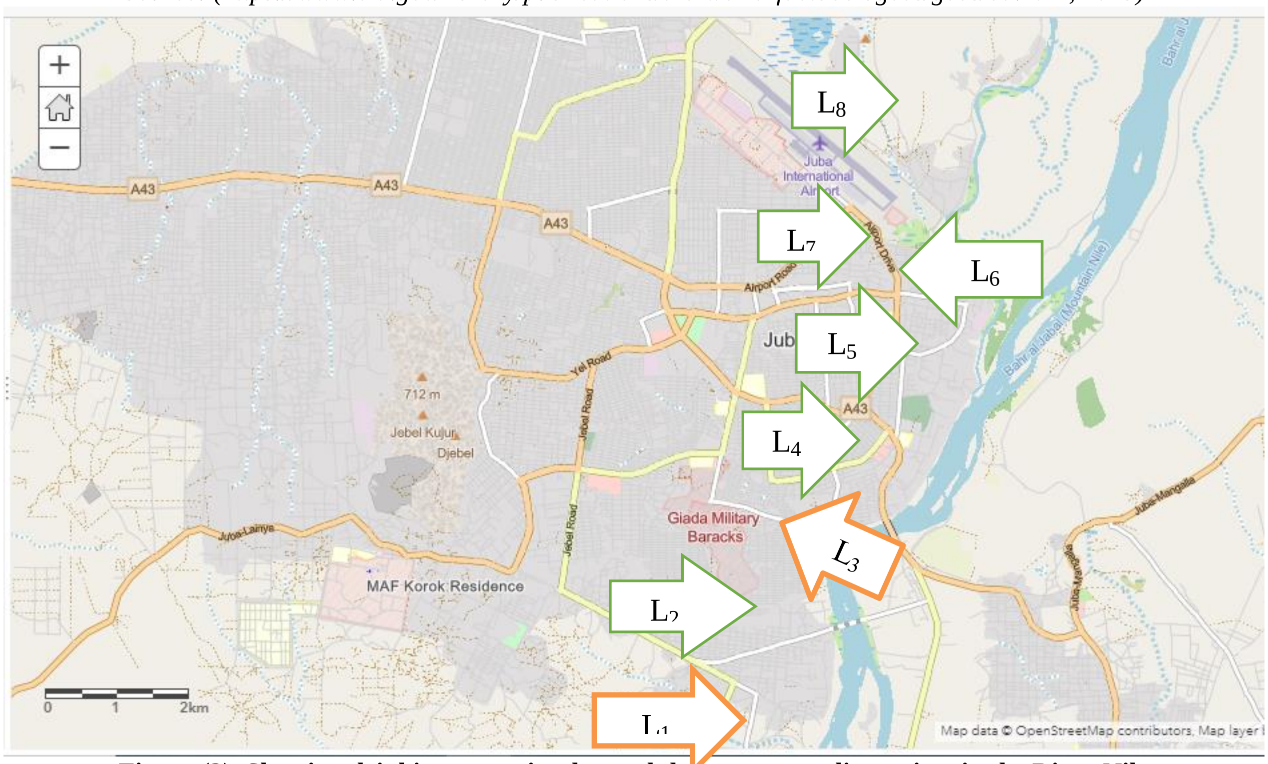

Figure (2). Showing drinking water intake, and the water sampling points in the River Nile

ArcGIS Online is used to develop a map for the location of the River Nile, residential areas, agricultural areas. And water sampling points.

2.1.1-Climatic condition of the study area

The climate of Juba is tropical, with an average yearly maximum temperature of 34 ℃ and the average annual minimum temperature of 21 ℃, the Maximum temperature is experienced from January to March and the minimum temperature from April to July. The rainy season starts from April to October. The average annual rainfall was 953.7 mm[19]. It has a dry season with a small amount of rain, start from November and intensifies from December to March. The type of vegetation is more biologically diverse and is not generally very dense. Examples of common trees are Teak, shrubs, mango trees, etc. The rate of weathering is very high due to the combination of both high temperature and rainfall, the environment condition hydrolysis, oxidation, and reduction, and the physical condition of the area[22].

The table (2-1) showing temperature, humidity and wind velocity

[1] Month	[2] Min Temp	[3] Max Temp	[4] Humidity	[5] Wind	[6] Sun	[7] Rad	[8] ETo
[9]	[10] ℃	[11] ℃	[12] %	[13] Km/day	[14] Hours	[15] MJ/m^{2}/day	[16] Mm/day
[17] January	[18] 19.0	[19] 36.7	[20] 43	[21] 78	[22] 6.9	[23] 18.5	[24] 4.45
[25] February	[26] 21.5	[27] 37.5	[28] 45	[29] 78	[30] 6.4	[31] 18.7	[32] 4.65
[33] March	[34] 22.6	[35] 37.2	[36] 51	[37] 112	[38] 5.9	[39] 18.6	[40] 5.10
[41] April	[42] 23.2	[43] 35.2	[44] 63	[45] 112	[46] 5.7	[47] 18.1	[48] 4.70
[49] May	[50] 22.4	[51] 33.5	[52] 74	[53] 112	[54] 7.4	[55] 20.1	[56] 4.64
[57] June	[58] 21.6	[59] 32.2	[60] 79	[61] 78	[62] 7.1	[63] 19.1	[64] 4.12
[65] July	[66] 20.9	[67] 31.0	[68] 81	[69] 78	[70] 5.8	[71] 17.3	[72] 3.69
[73] August	[74] 20.8	[75] 31.3	[76] 79	[77] 78	[78] 6.7	[79] 19.3	[80] 4.06
[81] September	[82] 21.0	[83] 32.6	[84] 75	[85] 78	[86] 7.6	[87] 21.0	[88] 4.49
[89] October	[90] 21.2	[91] 33.8	[92] 71	[93] 78	[94] 7.0	[95] 19.7	[96] 4.37
[97] November	[98] 20.8	[99] 34.5	[100] 63	[101] 78	[102] 7.0	[103] 19.0	[104] 4.31
[105] December	[106] 19.7	[107] 35.7	[108] 55	[109] 78	[110] 7.1	[111] 18.5	[112] 4.31
[113] Average	[114] 21.3	[115] 34.3	[116] 65	[117] 86	[118] 6.7	[119] 19.0	[120] 4.41

CLIMAT WATER and CROP WATER Soft wares were used for metrological data by using Juba international airport automatic rain gage 300 meters from the study area.

Table (2-2) showing monthly precipitation and annual precipitation in the area.

[1] Months	[2] Rain/ mm	[3] Effective Rainfall/mm
[4] January	[5] 3.6	[6] 3.6
[7] February	[8] 11,6	[9] 11.4
[10] March	[11] 44.9	[12] 41.7
[13] April	[14] 91.9	[15] 78.4
[16] May	[17] 148.5	[18] 113.2
[19] June	[20] 119.7	[21] 96.8
[22] July	[23] 136.2	[24] 106.5
[25] August	[26] 144.4	[27] 111.0
[28] September	[29] 116.6	[30] 94.8
[31] October	[32] 101.7	[33] 85.2
[34] November	[35] 46.3	[36] 42.9
[37] December	[38] 7.0	[39] 6.9
[40] Total Rainfall	[41] 972.4	[42] 792.4

2.1.2-Economic growth

Economic in Juba depending on the economics of the country, it depends on 98% on the oil revenues. But the country's economy is considered low. Real GDP growth was an estimated 5.8% in 2019, a large increase from 0.5% in 2018. Inflation fell to 24.5% in 2019 from 83.5% in 2018 due to reduced financing of the fiscal deficit. The central bank commitment to reduce monetization of the fiscal deficit is expected to continue, with resulting inflation declining further to 16.9% in 2020 and 9.7% in 2021.

The 2019 state budget was estimated at $1.3 billion, a 155% increase from 2018. Nonoil revenue increased by an estimated 19% in 2019. The fiscal deficit was estimated at 2.5% of GDP in 2019, down from 6.1% in 2018. Reforms will help move the fiscal deficit, projected at 1.3% of GDP in 2020, to a surplus of 0.5% in 2021. Private investment in the non-oil sector reached an estimated $22 million in 2019[27]. GDP per capita is 275$, GINI co-efficiency is 45.5 medium, and the human development index is 0.413 low to 0.264(Inequality-adjusted Human Development Index) IHDI[28]. As the poverty line is $2 a day[29]. 36% of the population in Juba is below 2%[30]. That means the poverty rate in Juba is 36%.

2.1.3-Agriculture activities

The rain-fed Agriculture system is dominant in the area. 99% percent of agricultural activities in the area are substantial farmers of small scale. The application of organic fertilizer in vegetable farms is common with zero chemical fertilizer application [23].
Animal production is one of the cultures in the area for social and economic purposes. However, people are growing Goat, Sheep, Pigs, and Poultry on a small and large scale. With the growth of livestock farming, animal dung has increasingly become one of the sources of water pollution in the capital city through the excretion they produce that include feces and urine [31]. Table (7) shows domestic animal waste excretion in the area.

Table (3) shows different categories of animals and its excretion in Kilogram

[1] Item	[2] cows	[3] sheep	[4] Goat	[5] Pigs	[6] Poultry
[7] Number	[8] 8,434	[9] 28,283	[10] 32,783	[11] 758	[12] 85,568

2.1.4-Urbanization

The urbanization in Juba is estimating at around 52km2. Since 2005, is expanding westwards through Munuki Payam towards Gudele, Guri, and Northern Bari and southwards towards Rajaf Payam and along Yei road[32]. Rural-urban immigration, internal displacement due to the conflict, and the flow of people from foreign countries have seen to be the indicator of high population growth in Juba. Although fluctuating significantly at times, Juba's population has increased steadily over the years.

Table (4) shows population density in Juba from 1965 to 2019

Year	1956	1973	1993	2005	2010	2019

Population density	10,600	56,737	114,980	250,000	500,000	1,577,902

2.1.5- Organic Waste Generation and its Composition

The amount of municipal Organic waste generation in Juba differs from place to place to a great extent; its production pattern has been affected by consumption patterns, the standard of living, climate, economic, season, and cultural practice. The municipal organic waste generated per-capita (kg/day), is relatively low when compared to some South Asian countries. Its per-capita ranges between 0.33 to 0.44 kg/person/day, unlike that of the South Asian countries that vary in a range from 0.3 to 0.9 kg/person/day. Table (5) shows the household municipal waste (kg) generated in Juba city[33].

2.1.6-Source of water pollution in the River Nile area

Contamination of water (River Nile) bodies was recognized to become a critical issue due to the inadequacy or non-existence of surface water quality protection and sanitation[34]**.** Lagoons, rivers, and streams are sinks for wastes[35].

Generally, 80% of the municipal wastes generated in Juba are not collected. As a result, the uncollected garbage, which is often also mixed with human and animal waste founding their way into the water body without treatment[20, 36]. The discharge of raw sewage, garbage, and oil spills has become a threat to human health as well as the aquatic ecosystem. Although the government of Juba believes in natural purification, however, heavily contaminated water may travel for long-distance for days before a significant degree of decontamination obtains [38]**.**

2.1.7-Sources of data

Secondary data were collected from the literature on human population density, the number of animals, River Nile water discharge, etc, CROPWAT and CLIMWAT databased were used to collect climatic data, actGIS online was used to produce a map of Juba.

2.2-Methods

2.2.1-Surface Runoff Volume

Empirical Equations were applied to calculate Runoff Volume[39]. Precipitation is needed to calculate the amount of water that forms run-off due to saturation of the soil. Was calculated by using formula bellow;

$$\mathbf{R=P*P_j*R_v*A} \qquad \mathbf{(1)}$$

Where: R is the Run-off, P is annual rainfall in the study area as abstracted from Juba international airport metrological station which is 972 mm, Pj is the fraction of a rainfall event that causing run-off, is consistent usually 0.9, Rv is run-off co-efficient and for residential areas are 0.5, and A is the total catchment area, was measured by ArcGIS online and found to be 214.2 km^2.

2.2.2-Estimation of total load components

The excretion coefficient method was applied to compute the amount of waste generated by animals and human beings in residential areas and around[40]. Data on the population density, number of animals, and their categories were obtained from the literature[19, 40, 42]. Sewage generated per capita and animal dungs excreted per capita by domestic animals were collected[8]. "X" is the manure excrement (kg/animal/day) "i'' the category of an animal. 365.25 is the days per year. Tables (5,6 and 7) Showing the calculation of waste generated by animals and human beings and contributing to River Nile drinking water pollution by using the model bellow.

$$\mathbf{Load=\sum_{i=1}^{365.25} Xi1, Xi2, Xi3, Xi4, \ldots \ldots.} \qquad \mathbf{(2)}$$

Whereby " I " represent the category of organic waste products, X representing the category of animals produced the waste.

2.2.3. Estimation of nutrients generated by waste.

Nutrient Balance Model was used to compute the composition of nutrients (N and P) generated from domestic, sewage, and animal waste [40]. The following are the formulas.

$$N_{\text{residential areas}} = NUM_{pop}\ X\ \ EXC_{human}\quad N \qquad (3)$$
$$P_{\text{residential areas}} = NUM_{pop}\ X\ EXC_{human}\quad P. \qquad (4)$$
$$N_{livestock} = \sum_{i=1}^{n} NUMi\ X\ \ EXC_i \quad N. \qquad (5)$$
$$L_{livestock} = \sum_{i=1}^{n} NUMi\ \ X\ \ EXC_i \quad P \qquad (6)$$

Here, "N" refers to $_{\text{residential areas}}$, "P" $_{\text{residential areas}}$, N $_{livestock}$, and P $_{livestock}$ are the amounts of Total Nitrogen and Total Phosphorus from feces of city residential areas and livestock manures, respectively. In Equations. (4) and (5), NUM_{pop} is the population of the study area, obtained from the Statistical Yearbook; EXC $_{human}$, N and EXC $_{human}$, P are the annual excretion coefficients per capita[19].

In Equations. (5) and (6), "n" is referred to the number of livestock categories, and NUM $_i$ is the number of animals in the ‘’ i" livestock category, both obtained from the statistic book of the study area[41]. EXC_i, N, and EXC_i, P are the excretion coefficients of Total Phosphorus and Total Nitrogen for the ‘ i’ livestock category, with values obtained from the literature[40]. All the information is required to compute the Total Nitrogen and Total Phosphorous from waste generated from residential areas and domestic animals as listed in Tables (5,6 and 7).

2.2.4-Load of pollutant and Nutrients amount entered the waterbody

SWAT (Soil & Water Assessment Tool) formula was used to calculate Export Coefficient for load and nutrients (N &P) delivered annually to a water body as the result of water overflow[43]. Below is the formula for export efficiency calculation.

$$L= \sum_{i=1}^{n} Ei(\text{pi ai}) \qquad (7)$$

Whereby L: output load of a pollutant (kg/year) for human or domestic animals; Ei; export coefficient in residential areas is equal to 0.5; Pi: number of people or domestic animals (head); αi: unit load (kg/year/head) the amount of organic waste produced by person varied from one area to another based on the cultural, economic and educational level table (5,6 and 7) shows the organic waste generated per capita in different residential areas in Juba [33]. The data on the average amount of feces produced per person per day obstructed from the literature[42]. The total number of animals in the area collected from an article[44]. Waste generated per animal per day abstracted from a book[20, 42].

2.2.5-Load Concentration calculation.

Load concentration is the concentration of pollutants in the water body as the result of discharging of pollutants by tributaries from points and non-points source into the waterbody and diluted with the water volume. It was calculated by summing up the total load entered into the watershed divided by river water discharge, the formula below illustrating the method.

$$C = \frac{L}{Q} \qquad (8)$$

Whereby C is the concentration, L is the load of the pollutants, and Q is the annual river discharge.

2.2.6- Raw water analysis result

Systematic literature review method was used under MATA ANALYSIS protocol to compile the findings of the studies done on River Nile water quality analysis in Juba, Web of Science, Google Scholar, and Science Direct search engines was tried by entering key words "River Nile Water Quality in Juba". With control years of publication from 2010 to 2010. So far, one article was found, which was published in 2013[19].

III. RESULT AND DISCUSSION

3.1-Total run-off in the area

The Run-off was determined using rainfall data obstructed from Juba airport automatic metrological station through CLIMWAT & CROPWAT software. The station is 50 meters from the study area. The result obtained using formula (1).

P = Annual rainfall (inches)=972.4 Pj= Fraction of annual rainfall events that produce run-off (usually 0.9)
Rv = Runoff coefficient for residential areas=0.5
A= the total catchment area
R=972*0.9*0.5* 214,200,000m
R = 93,729,636,000 m^3/ year

3.2-Result for a total load of waste and nutrients generated in Juba

The tables (5,6 and 7) show the amount of waste and sewage generated by residents of Juba, Dung excreted from the animals in and around Juba, and amounts of Nutrients P and N that would be produced by the load.

Table (5): Shows household municipal organic waste and nutrients generated in Juba per year

[1] Residential areas	[2] Population	[3] MW(Kg)/Capita/	[4] MW(Kg)/area/day	[5] MW(Kg)/ area /year	[6] N (Kg/t)	[7] P (Kg/t) of MW	[8] N (Kg)/t/population	[9] P (Kg)/t/population

		day			of MW			
[10] Kator	[11] 184,300	[12] 0.67	[13] 123481	[14] 45070565	[15] 1.58	[16] 0.16	[17] 71211.49	[18] 7211.29
[19] Juba	[20] 124,776	[21] 0.56	[22] 69874.56	[23] 25504214	[24] 1.58	[25] 0.16	[26] 40296.66	[27] 4080.67
[28] Munuki	[29] 413,000	[30] 0.58	[31] 239540	[32] 87432100	[33] 1.58	[34] 0.16	[35] 138142.72	[36] 13989.14
[37] Referendum	[38] 281,480	[39] 0.51	[40] 143554.8	[41] 52397502	[42] 1.58	[43] 0.16	[44] 82788.05	[45] 8383.60
[46] Gudele)(1 & 2)	[47] 502,867	[48] 0.62	[49] 311777.54	[50] 113798802	[51] 1.58	[52] 0.16	[53] 179802.11	[54] 18207.81
[55] Rajaf	[56] 12,415	[57] 0.65	[58] 8069.75	[59] 2945458.8	[60] 1.58	[61] 0.16	[62] 4653.82	[63] 471.27
[64] Gumbo	[65] 45,460	[66] 0.56	[67] 25457.6	[68] 9292024	[69] 1.58	[70] 0.16	[71] 14681.40	[72] 1486.72
[73] Lologo	[74] 13,604	[75] 0.59	[76] 8026.36	[77] 2929621.4	[78] 1.58	[79] 0.16	[80] 4628.80	[81] 468.74
[82] Total	[83] 1,577,902	[84] 4.74	[85] 929781.61	[86] 339,370,287.7 [87]	[88] 1.58	[89] 0.16	[90] 536205.05	[91] 54299.25

Table (6) showing the amount of sewage produce in Juba city discharge to open space and contributing to water pollution.

Residential areas	Population	Average sewage(Kg)/person/day	Sewage(Kg)/area/year	Average TN(Kg)/a	Average TP(Kg)/a
Kator	184,300	0.25	16817375	290940.59	29430.41
Juba	124,776	0.25	11385810	196974.51	19925.17
Munuki	413,000	0.25	37686250	651972.13	65950.94
Referendum	281,480	0.25	25685050	444351.37	44948.84

Gudele (1 & 2)	502,867	0.25	45886613.75	793838.42	80301.57
Rajaf	12,415	0.25	1132868.75	19598.63	1982.52
Gumbo	45,460	0.25	4148225	71764.29	7259.39
Lologo	13,604	0.25	1241365	21475.61	2172.39
Total	1,577,902		143,983,557.5	2490915.54	251971.23

Table (7) showing manure extracted by different categories of animals and nutrients produced.

[1] Animal	[2] Amount	[3] Manures(kg/animal/Day)	[4] Manure (Kg)/ animal / year	[5] Manure (Kg)/ animal population /year	[6] TN (Kg)/Tone	[7] TP (kg)/ Tone	[8] TN (kg)/ Animal category/ year	[9] TP (kg)/ Animal category/ year
[10] cattle	[11] 8,434	[12] 29.5	[13] 10,620	[14] 89,569,080	[15] 4.37	[16] 1.2	[17] 391416.88	[18] 107482.90
[19] sheep	[20] 28,283	[21] 2.3	[22] 828	[23] 23,418,324	[24] 6.32	[25] 4.5	[26] 148003.81	[27] 105382.46
[28] goats	[29] 32,783	[30] 1.8	[31] 640	[32] 20,981,120	[33] 6.92	[34] 4.9	[35] 145189.35	[36] 102807.49
[37] Pigs	[38] 758	[39] 5.1	[40] 1,836	[41] 1,391,688	[42] 5.88	[43] 3.4	[44] 8183.13	[45] 4731.74
[46] Poultry	[47] 85,568	[48] 0.08	[49] 30	[50] 2,567,040	[51] 9.84	[52] 5.4	[53] 25259.67	[54] 13862.02
[55] Total	[56] 155,826	[57] 39.008	[58]	[59] 137,927,252	[60]	[61]	[62] 718052.84	[63] 334266.60

3.3-Total organic waste generated in the area

Total organic waste generated in the area was calculated by summing the other organic waste and sewage generated by the individual in Juba and multiply by the number of people living in Juba, plus amount dung excrement by each category of the animal as shown in model (2)

Total organic waste generated = 339,370,287.7 + 143,983,557.5 + 137,927,252
=621,281,097.2 kg

Load =621,281,097,200g * 0.5= 310,640,548,600 g

3.4-Load Concentration calculation in the basin

Load concentration is the concentration of the load in the water body, was calculated by using formula (8) above.

C= Concentration (mg/L) =Load/discharge
Discharge=34,000,000,000 m^3

Load =310,640,548,600 g

=310,640,548,600 g /34,000,000,000 m^3

C= 9.13g/m^3

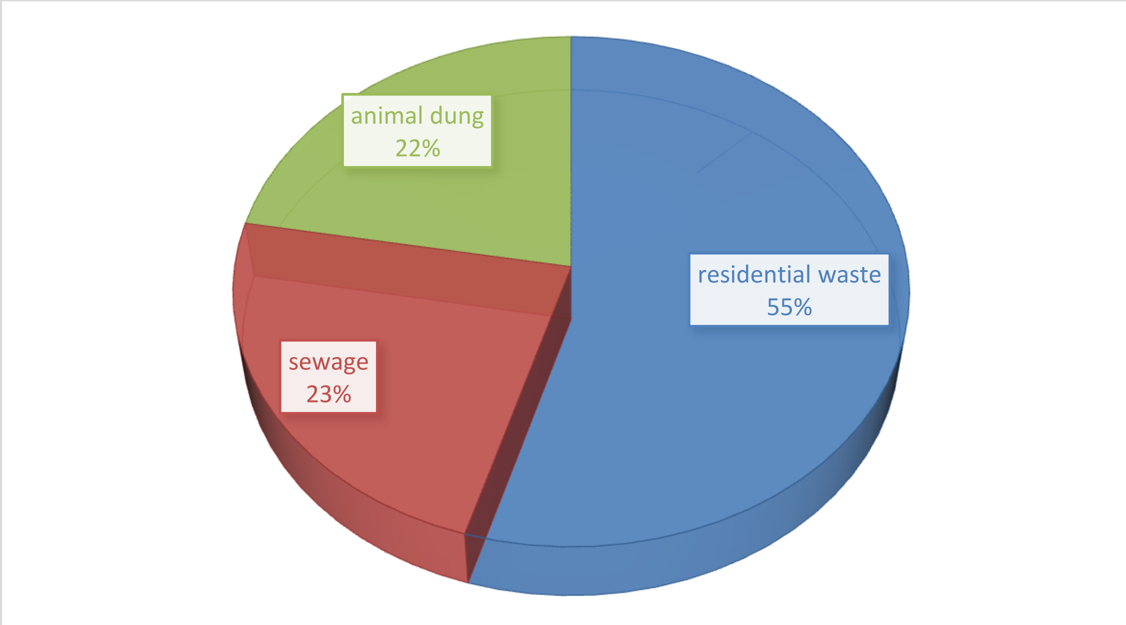

Figure (3) Showing percentage of pollutant load shared by Livestock and human being

The chart clarified the pollutant rate contributing by the human being and domestic animals around the catchment areas discharging water to the River Nile area of Juba. The result shows that human beings are highly contributed to water pollution in Juba with a percentage of 78% which involved residential waste and sewage produced by people in Juba as goes together with the result of the study by[19]. These pollutants may found their way to the water body through surface flow due to inappropriate waste and waterbody management in the country. The river water is, therefore, get contaminated with pathogens that come as a result of the discharge of sewage, animal waste, and other domestic waste. The study indicated that each person would release 100-400 billion coliforms per day in addition to other harmful bacteria[45]. These coliforms are dangerous to the health of human beings because of the consequences seen in the high cases of water-related diseases in the area such as typhoid, diarrhea, hepatitis A and gastrointestinal infections that appear to be chronic[46].

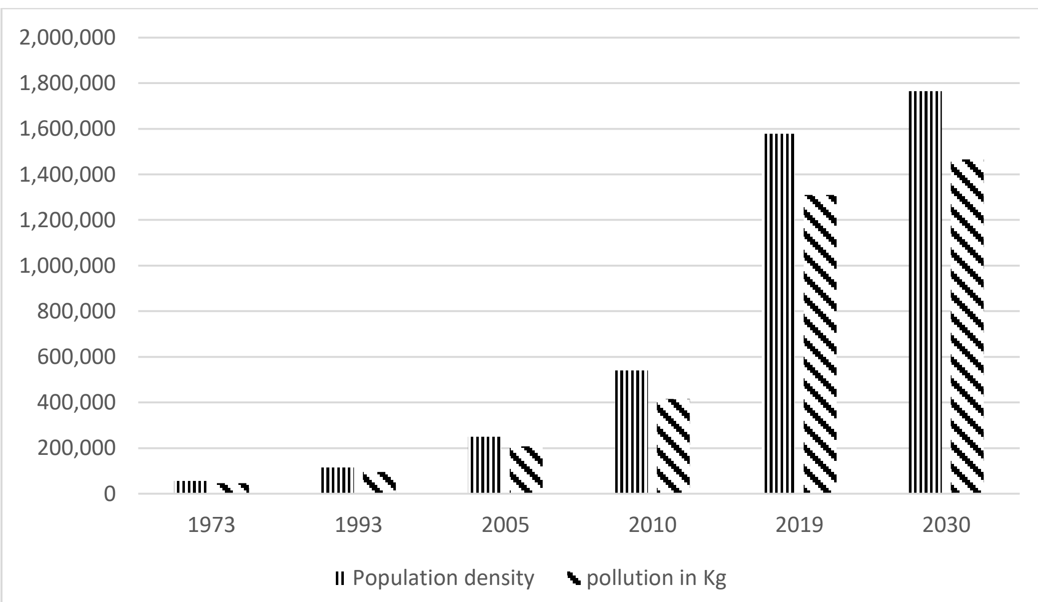

Figure (4) residential and sewage generated in Juba and expectation for 2030

Then graph showing that an increase in population density is positively correlated with an increase in waste production if we assume other waste generated parameters are consistent such as economic, education level, culture, and environmental protection policies with the same population growth rate which is 1.92%.

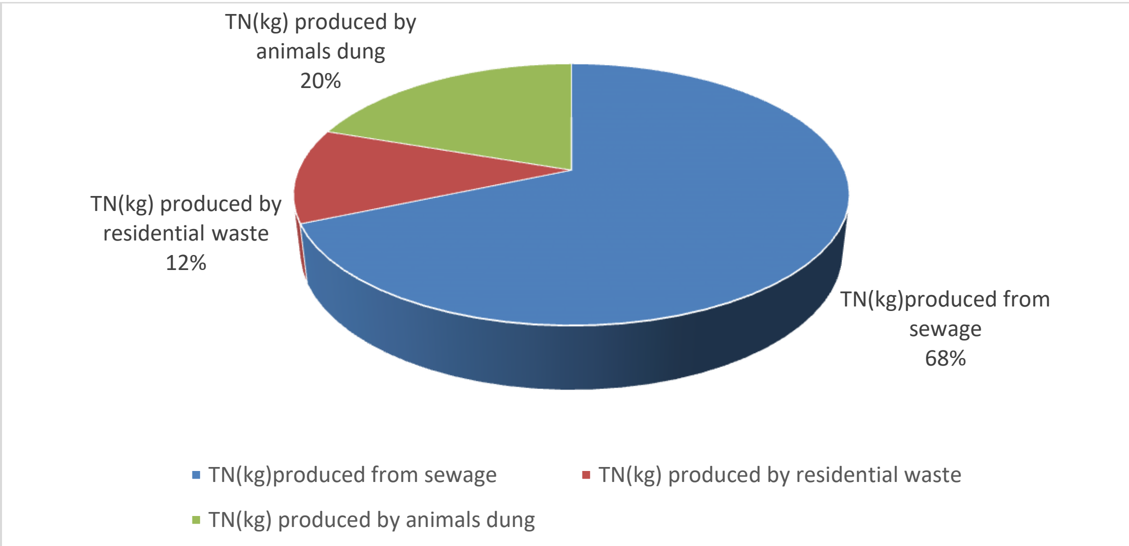

Figure (5) showing the percentage of Total Nitrogen produced by different waste

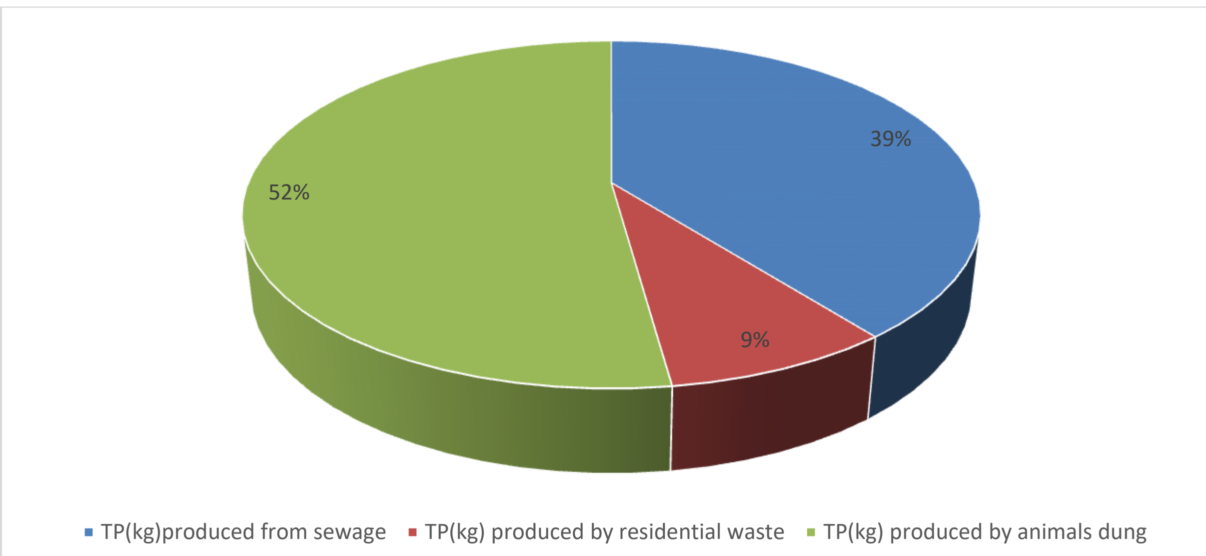

Figure (6) shows the percentage of Total Phosphorus produced

The effects of human activities and animals nearby reservoir watershed can be realized by the accumulation of nutrients in the water body, resulting in cultural eutrophication of the reservoir with subsequent bloom in algae and changes to the water quality[47]. Based on the analysis, the result proving that sewage is the mean source of N and second for P production.

3.5-Nutrient concentration in the River Nile

The concentration of Nutrients is measured by summing total Nitrogen after subtraction of the run-off coefficient divided by river discharge. The reason for nutrient concentration calculation is to measure whether the nutrient amount generated from residents and animals within Juba is enough to cause eutrophication in the River Nile area of Juba.

Total Nitrogen load =3745173.43 * 0.5= 1,872,586,715 g
Nitrogen concentration in the river = Load divided by discharge
1,872,586,715g/34,000,000,000,000 L = 0.00005507608g/L

Total Phosphorous load = 640537.08 *0.5 = 320,268,540 g

Phosphorous concentration in the River = 320,268,540/34,000,000,000,000 L
= 0.000009419663 g/L

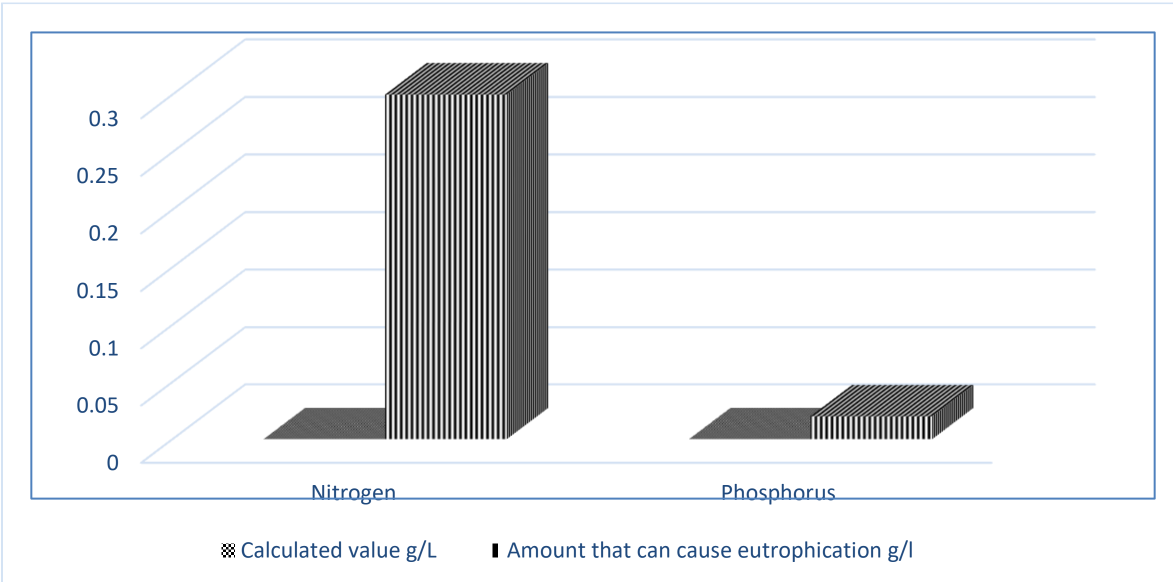

Figure (7) showing the concentration of N and P in the River Nile area of Juba.

Based on the models (2 to 8), the concentration of Nitrogen and phosphorus produced from the residential areas and animals in and around Juba is P=0.000009419663 g/L and N=0.00005507608g/L. Refer to (Yang 2008), shows that the concentration of the nutrients is not enough to cause eutrophication. As was recommended that the eutrophication or red tide occurs when Nitrogen concentration in water reaches 0.3g/L[47], and Phosphorus concentration reaches 0.02g/L[48]. Therefore, eutrophication is not the problem of drinking water quality in the River Nile area of Juba.

3.6- Water quality analysis

Eight mean drinking water collection sides were selected, from upstream of Juba Rajaf to its downstream Molobor Village.

Table (8) Shows the result of the River Nile water analysis.

[1] Site's Number	[2] Site's Name	[3] CFU/100ml Average Reading	[4] Physical Parameters			
			[5] PH	[6] Temperature	[7] TDS	[8] EC
[9] L_1	[10] Rajaf west(upstream)	[11] 33.04	[12] 8.3	[13] 28ºC	[14] 92	[15] $185\mu_s$
[16] L_2	[17] Lologo	[18] 38.19	[19] 8.3	[20] 28ºC	[21] 94	[22] 187 μ_s
[23] L_3	[24] Juba Bridge	[25] 43.95	[26] 8.2	[27] 28.3 ºC	[28] 98	[29] 189 μ_s
[30] L_4	[31] Juba water port	[32] 77.85	[33] 7.2	[34] 28.1ºC	[35] 79	[36] 190 μ_s
[37] L_5	[38] Urban water cooperation (intake point)	[39] 97.05	[40] 8.2	[41] 28 ºC	[42] 98	[43] 201 μ_s
[44] L_6	[45] Jebel Nyoka	[46] 102.6	[47] 8.4	[48] 28.3ºC	[49] 123	[50] 229 μ_s
[51] L_7	[52] Gabat	[53] 98.6	[54] 7.4	[55] 28.1ºC	[56] 98	[57] 205 μ_s
[58] L_8	[59] Molobor village	[60] 15.25	[61] 6.8	[62] 28ºC	[63] 47	[64] 89 μ_s

The results showed that the average fecal CFU/100ml concentration for all the eight sampled sites of the River Nile range between 15.25 – 102.6 at location L_1 to L_8 accordingly. The fecal coliform count range is far above the 0mpn/100ml for drinking water as the standard recommended by WHO [49, 50]. The fluctuation of PH was within the range[47]. The increase of fecal coliform varies from one station to another; it shows directly in relationship with the population density of the areas. The contamination of this water body was not only due to human beings but a high population of animals within the catchment areas. It is following the finding of other writers[45].

This poor quality of water comes as contamination of the river with human wastes, animal manure, improperly treated septic, and sewage discharge into the river without treatment. During precipitation, bacteria and harmful microorganisms may be drained into the water body [46].

Refer to the WHO recommended standard for drinking water, raw water from the River Nile area of Juba is not suitable for drinking without treatment. 72.5% of the people in Juba depending on River Nile raw water for drinking[20], which means 72.5 % of the people in Juba under risk of waterborne disease.

IV. Conclusion

Generally, drinking water pollution becomes a critical issue, especially in a developing country, which is not only affecting human health but also the aquatic ecosystem. Due to heavy rains and flooding, waste generated by human beings and animals in and around the city would be swept into the water body, and contributing to water quality deterioration[51]. The result of the study shows that water of the River Nile in the areas of Juba is contaminated. It would be a key pillar of waterborne diseases such as diarrhea, cholera, hepatitis A. On the other hand, the result revel that the nutrient concentration generated by waste is too little to cause eutrophication in the water body. Figure (4) shows that waste generation in Juba positively correlating with population density. The water analysis result shows that the raw water from River Nile areas of Juba is not healthy for drinking due to the high fecal coliform count range that was found high than the recommended standard of WHO that is design to be 0mpn/100ml[48]. The study concluded that without integrated waste and drinking water body management, it will be difficult for the government of South Sudan in Juba to meet Sustainable Development Goal SDG 6 by 2030 [52]. Therefore, the study recommended that there should be intergraded water resources management, waste disposal system, wastewater and sewage should be treated before discharge into water bodies. Awareness programs and pollution control law enforcement body is needed, drinking water treatment plant is recommended to reduce the risk caused by poor water quality.

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