The Impact of Poor Municipal Solid Waste Management Practices and Sanitation Status on Water Quality and Public Health in Cities of the Least Developed Countries: the Case of Juba, South Sudan

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Abstract

The inadequate and un-scientific municipal solid waste management practices and the poor state of sanitation in most cities of the developing countries have resulted into the pollution of the environment: contamination of both surface and ground water which is in turn a serious human health risk. This study aimed at investigating the effect of indiscriminate municipal solid wastes dumping on water resources with specific focus on fecal coliform contamination in Juba city. Also some physical parameters such as temperature, pH, Total Dissolved Solids (TDS) and Electrical Conductivity (EC) were tested. The results revealed that the River Nile and the streams within Juba are highly contaminated; with an average range of 15.25 – 102.6 Coliform Forming Unit/100ml (CFU/100ml) for the River Nile. The pH and temperature were within the normal range. TDS showed very high values with range of 47 – 123 mg/100ml which is far beyond the USEPA and WHO recommended 500 ml/L. The EC was not so high; ranges between 59µs - 201µs/cm which is slightly above the recommended 160 µs/cm. For the streams, the CFU/100ml was found to be abnormally high ranging from 1.25 – 11,540.5 CFU/100ml. TDS and EC were also high ranging from 41 – 868 mg/100ml and 15 – 1761 µs/cm respectively. The pH and the temperature showed normality. The CFU/100ml readings of the boreholes and the well were within the range of 0 – 26 CFU/100ml. Out of the eleven sampled boreholes, six were clean with 0 CFU/100ml the EPA and WHO recommended value but the other five and the well were contaminated. The TDS and EC were extremely high ranging between 481 – 823 mg/100ml and 1032 – 1775 µs/cm respectively. pH and temperature were within normal range. The study concluded that the poor municipal solid waste management in Juba is posing high risk to the human health and the environment.

Key words: Municipal Solid Waste, Sanitation, Fecal Coliform, Water Contamination, CFU/100ml

1. Introduction

The current municipal solid wastes management practices especially collecting, processing and disposing are considered to be inefficient in the developing countries. The typical problems are low collection coverage and irregular collection services, crude open dumping and burning without air and water pollution control, the breeding of flies and vermin; and the handling and control of informal waste picking or scavenging activities (Bartone, 1995).

Generally, one to two thirds of the municipal solid wastes generated in the cities of the developing countries are not collected (World Resources Institute *et al*., 1996). As a result, the uncollected waste, which is often also mixed with human and animal excreta, is dumped indiscriminately along the streets and in drains, so contributing to flooding, breeding of insect and rodent vectors and the spread of diseases (Cointreau, 1982; UNEP-IETC, 1996; Zurbrugg, 2002).

The uncontrolled and un-scientific dumping of municipal solid wastes has brought about a rising number of incidents of hazards to human health; contamination of both surface and ground water which is in turn a serious human health risk. Surprisingly, the indiscriminate dumping of municipal solid wastes in water bodies' sources and low lying areas without consideration of its effect on the environment is a common practice in many cities of the developing countries (Medina, 2010; Zurbrugg, 2003; Da Zhu *et al*., 2008). All these waste management malpractices coupled with the poor state of sanitation make things extremely unbelievable to be happening in the cities of the least Developed Countries.

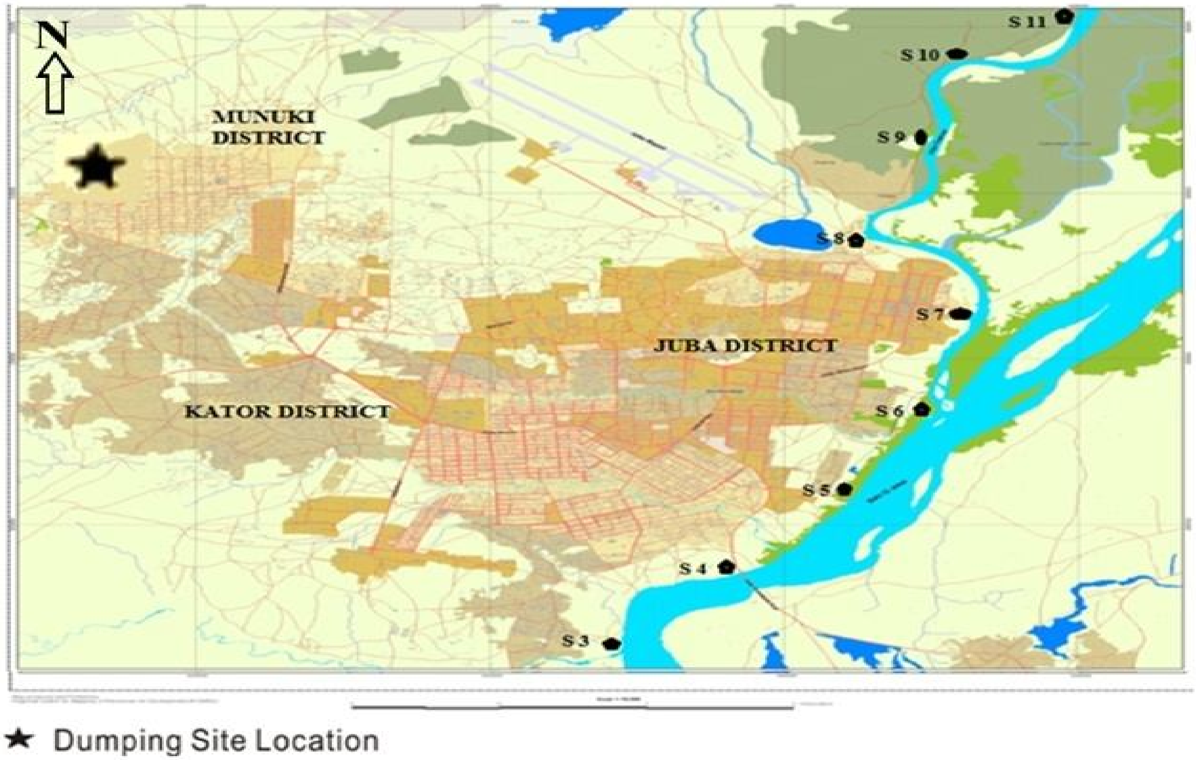
Sanitation refers to the provision of facilities and services for the safe disposal of human waste in toilets, or versions of toilets such as latrines. Most developed countries are well-equipped with flush toilets, however in developing countries, sanitation is based around much more basic facilities that are often little more than a hole in the ground (World Bank, 2012). In 2010, an estimated 2.5 billion people worldwide were still without improved sanitation. This means that it is unlikely that the world will meet the MDG sanitation target 10 (Halve the proportion of the population without sustainable access to safe drinking water and basic sanitation) by 2015: although encouraging progress is being made (WHO and UNICEF, 2006; UNICEF and WHO, 2012). Despite this progress, the situation remains horrible in most of Sub-Sahara African countries: this is what (UNICEF and WHO, 2012) described as "NOT ON TRACK" countries; for example, the World's newest country the Republic of South Sudan with its capital city Juba. Therefore, this study tries to determine the degree of the impact of poor municipal solid waste management practices and sanitation programs on the water quality and public health in Juba city.

2. Materials and Methods

2.1. The Study Area

Juba is the capital city of the newest world's country the Republic of South Sudan in North East Africa. The city is located within the southern part of South Sudan in Central Equatoria State along the western bank of the River Nile. Its geographical coordinates are 4° 51' 0" North and 31° 37' 0" East (Amanda, 2011). Juba is a county made up of three districts *(payams)* which include Juba, Kator and Munuki and is directly administered by the city mayor. Juba is situated in the midst of vast expanses of open space, including swamplands and agrarian landscapes. It is estimated to occupy a 12 kilometer area in diameter from the center of town (approximately 11,300 hectares). Greater Juba, including the surrounding rural lands, encompasses roughly 100 kilometers in diameter. Juba is one of the most undeveloped places in the world: although slow to moderate developmental progress is being made in many physical, social, political and economic sectors. It was reported that Juba is perhaps currently among the fastest developing places in the world (UNEP, 2012).

More specifically, growth in its population is noticeable. In 2011, Juba's population was estimated at approximately more that 500,000 inhabitants (Global Water Intelligence, 2011). The city is characterized by rapid development, urban sprawl and inadequate services provision. Due to this rapid growth in the population and with majority of the people settling in urban centers: all forms of waste and associated residual materials have tremendously increased in the City. Unfortunately, there is no proper waste management infrastructure. The lack of the waste management infrastructure is evident in sight of trash deposits everywhere – dumped beside streets, clogging streams, bobbing down into the River Nile, littered around buildings, even strewn across the graves in the municipal cemetery and with plastic trash predominating all over the city. Some locals describe the mounting waste in the city as raindrops from the clouds. The poor sanitation is what one can describe as unacceptable situation in this modern global society. Figure 1 below shows the map of Juba city:



*NB: **S** represents the water sampling sites along the River Nile.*

Figure 1: Shows the map of the study area (Adopted and modified from USAID, 2006).

2.2. Data Collection: Sampling, Sample Collection and Analysis

The study was carried out in two different phases: that is, the assessment of the municipal solid waste pollution (with the main target being waste disposal) and the water samples' analysis.

2.2.1. Assessment of the Municipal Solid Waste Management Practices in Juba

In order to obtain the quantity and the composition of the municipal solid wastes generated, a household survey was conducted for a period of two month: this involved visiting a total of 500 houses. The households were selected using random non-probabilistic sampling and working only with households that agreed to participate in the survey. The presence or absence of sanitary facilities was also observed during the household survey. A visit was paid to the open dumping site which is about 16 Km West of Juba; along the Juba – Yei road so as to allow the reseacher to personally observe the site. It was found that the dumping site is a home to a good number of people who are involved in scavenging. Few convenient individuals among them were interviewed on specifically concerning their general feeling of life in such a place. Local residents and a private Municipal Solid Waste handling company's drivers were also interviewed. The questions asked during the interviews were focused towards obtaining information on: how satisfied they are with the municipal solid waste management in Juba. The qualitative data from the interviews conducted with all other categories of respondents were analyzed manually by making summaries of the views of the respondents and supporting these with relevant data from documentary sources and my own field observation of the waste situations in the city.

2.2.2. The Water Samples' Analysis Procedure

2.2.2.1 Sampling Design

This research was carried out during the rainy season (April to September 2012). Water samples were collected from the River Nile, five streams, eleven boreholes and a well; all of which are within Juba city. From the River Nile, twelve sampling sites were chosen with the upstream to downstream pattern and assigned a representing symbol **S** (S1 – S12).

S1 was at Rajaf (upstream), S2 at Tokiman, S3 at Lologo, S4 at Juba Bridge, S5 at Juba Port, S6 at Urban Water Corporation (Intake point), S7 at Jebel Nyoka, S8 at Gabat, S9 at Nyaying, S10 at Roton, S11 at Walawalang and S12 at Morlobor Village (downstream) as shown in figure 1 above. However, S1, S2 and S12 did not appear on the study area's map (fig. 1 above) becauase they are beyond the map coverage. S1 is 7 km from Juba to the South and S12 is 13 km away to the North; these two sites were considered to be the control points. The rest of the sites were within Juba city with a distant interval of about 1.5 – 2 km. For the five streams, a randomized sampling design was applied. Three of these streams directly transverse the city (Khor Bou, Lobuliet and Khor Williang) and the other two are at the outskirt of the city; that is Khor Romula to the South and Gumba-losok to the North. Also for the boreholes/well; they were randomly chosen that is: eleven boreholes and each one of them assigned a representing symbol **BH** (BH1 – BH11) and one well with the symbol **W**.

2.2.2.2. Samples' Collection and Analysis Procedure

The water samples were collected mostly during the morning hours under controlled temperature conditions using 1000 ml properly labeled screw-capped sterile plastic bottles. Immediately after taking a sample, it was put in a portable cooler box containing ice boxes in it so as to maintain the 4^0C temperature before reaching the Laboratory as recommended by (USEPA, 1985; APHA, 1992). The samples were then transported to the Central Laboratory for Water Quality (Juba, South Sudan) for analysis at least within a maximum of 6 hours. They were then properly analyzed following quality control procedure for water quality analysis as recommended by USEPA (1985). The method used was the "Membrane Filtration Method".

"*Membrane filtration method involves filtering several different-sized portions of the sample using filters with a standard diameter and pore size, placing each filter on a selective nutrient medium in a petri plate, incubating the plates at a specified temperature for a specified time period and then counting the colonies that have grown on the filter. This method varies for different bacteria types (variations might include, for example, the nutrient medium type, the incubation temperature and time; and the number and types of incubations, etc. (EPA, 1985)*".

The medium used was enriched medium (Lauryl Sulphate Broth). The requirement is that 35g is to be dissolved in one litre of distilled water (1000 ml).

During the six months' sampling period, the surface water was sampled for five consecutive months (April – August, 2012) with sampling frequency of 4 times per month for each site. This was done in order to obtain a representative value. A total of 160 samples from the River Nile and 100 from the five streams were analyzed. The underground water (boreholes/well) was sampled only in one month that is September, 2012. The total number of samples analyzed was 48. All samples were incubated at the temperature of 44^0C for 24 hours as the target was only feacal colliform. Then the number of colonies formed was counted. There was one exceptional case that is Morlobor stream whereby both Total and Feacal Colliform were tested; here the incubation temperature for the Total Coliform was 37^0C. This was done because there was a very small village of less than 50 people that uses the stream water for direct drinking without any kind of treatment. The physical parameters were analyzed on site using a pH, EC and TDS meter (Model HI 98129, manufactured by HANNA). They include Temperature, pH, EC and TDS. Table 1 below shows the CFU/100 ml recommended standard values.

Table 1: *Fecal coliform (CFU/100ml) standards*

Water Use	**Desirable Level (CFU/100ml**	**Permissible Level (CFU/100ml**
Drinking	0	0
Swimming	<200	<1000
Boating or fishing	<1000	<5000

Source: (USEPA, 1985; APHA, 1992)

3. Results and Discussion

3.1. The Sanitation Status in Juba City

According to WHO (2012), "around 1.1 billion people globally do not have access to improved water supply sources whereas 2.4 billion people do not have access to any type of improved sanitation facility.

About 2 million people die every year due to diarrhoeal diseases, most of them are children less than 5 years of age. The most affected are the populations in developing countries, living in extreme conditions of poverty, normally peri-urban dwellers or rural inhabitants". The sanitation situation in Juba city practically agrees with the above statements. In Juba, about 45% of the population in the city has no any kind of sanitary facility. Although there was no formal survey carried out to verify this percentage, personal field observation can agree with. This estimation is also in line with the South Sudan's National Bureau of Statistics (NBS) Baseline Household Survey report of 2009. In this report it was clearly indicated that, "80% of South Sudan population does not have access to any toilet facility; that is 86% of the population in the rural areas and 46% in the urban. Most people both in urban and rural areas who have access to toilet facilities use private pit latrines. 53% of the population in urban areas has access to toilet facilities compared to 13% of the rural areas (NBS, 2009)". Table 2 below show the situation of the sanitary facilities in South Sudan.

Table 2: Shows the main types of toilet facilities by place of residence (in percent)

	No toilet facility	**Shared and private pit latrine**	**Other sources of toilet**	**Total**
South Sudan	80	18	1	100
Place of residence				
Urban	46	50	3	100
Rural	86	13	0	100

Source: National Baseline Household Survey, NBS, 2009 – South Sudan

3.2. Municipal Solid Waste Generation and its Composition in Juba

The amount of municipal solid waste generation differs from place to place to a great extent; its production pattern is being influenced by consumption pattern, standard of living, climate, season and cultural practices (UNEP, 2003; Visvanathan and Glawe, 2006). The municipal solid waste generated per-capita (kg/day) in Juba 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 which vary in a range from 0.3 to 0.9 kg/person/day (WWF–Pakistan, 2001). Table 3 below shows the household municipal solid waste (kg) generated in Juba city.

Table 3: Household municipal solid waste (in kg) generated/house/day and per capita/day

Payam	**Population**	**MSW(kg)/house/day**	**MSW(kg)/capita/day**
Kator	152,000	2.29	0.33
Juba	113,776	3.3	0.36
Munuki	243,000	3.05	0.44
Total	**508,776**	**-----**	**-----**
Average		**2.88**	**0.37**

3.2.1. Household Municipal Solid Waste Generated (In Tons)/Payam/Month and Per Year

In this study, it was found out that the three districts (*payams*) of Juba generate quite a huge amount of municipal solid waste as shown in table 4 below:

Table 4: Shows household municipal solid waste generated (in tons)/payam/month and per year

Districts (Payams)	**Tons/Month**	**Tons /Year**
Munuki district (payam)	1,518 tons/month	18,216 tons/year
Kator district (payam)	633.6 tons/month	7,603.02 tons/month
Juba district (payam)	569.98 tons/month	6,839.77 tons/year

The figure below shows the percentages of the waste generated by the three payams.

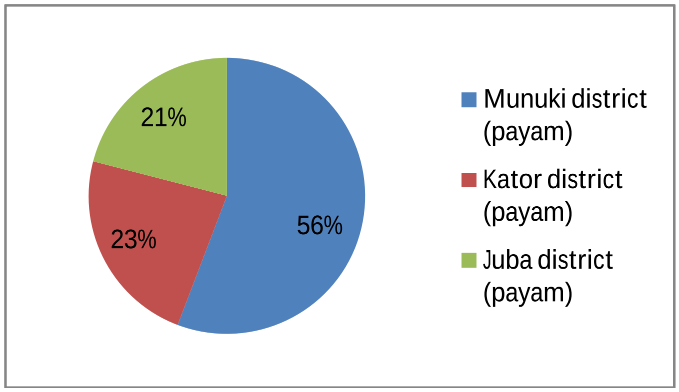


Figure 2: Shows the percentages of municipal solid waste generated in tons/year in Juba

Table 5: Shows the types of household municipal solid wastes generated by the three payams of Juba

Type of waste	Kator Payam	Juba Payam	Munuki Payam
Plastic	73.42%	80.65%	64.18%
Wood	21.34%	11.87%	26.73%
Worn out cloth(textile)	1.26%	1.61%	4.48%
Metals	1.93%	1.61%	1.49%
Organic (mostly food waste)	2.00%	4.26%	3.12%

Table 5 above presents the different types of municipal solid wastes being generated in the study area. From the table it is clear that 80.65% of the total household municipal solid waste generated in Juba payam is plastic; 11.87% wood; 1.61% are worn out cloth (textile) and metals respectively and 4.26% organic. Whereas in Kator payam, plastic makes up 73.42%; wood 21.34%; worn out cloth (textile) 1.26%; metals made up 1.93% and organic constitute 2.00%. In Munuki payam, plastic makes up 64.18%; wood 26.73%; worn out cloth is 4.48%; metals make up 1.49% and organic 3.12%. Therefore, considering the averages of the entire household municipal solid waste generated in Juba city; it becomes 72.75% is plastic, 19.98% wood; 2.36% worn out cloth, 1.84% is metal and 3.13% is organic. The predominance of the plastic is due to the fact that many people in Juba and esppecially the well off class prefer drinking distilled bottled water; a means, they think of avoiding bacterial infection. The poor sanitation situation in the is being sensed by any body: thus, everybody believes that the River Nile's water is not safe for drinking.

3.3. Municipal Solid Waste Disposal in Juba County's Districts (Payams)

In Juba city, there are three main agents responsible for the municipal solid waste disposal namely; random by householders themselves, the district (*payam*) waste management unit and the private company. Table 6 below shows the percentages disposed by each one of them:

Table 6: illustrates the agents responsible for household municipal solid waste collection and disposal in Juba

Agent	Kator district *(Payam)*	Juba district *(Payam)*	Munuki district *(payam)*	Average
Random disposal by householders themselves	54%	75.58%	77.78%	69.12%
Through the district (payam) unit	40%	19.77%	5.55%	21.57%
Private company	6%	4.65%	16.67	9.11%

The table above highlights that 54% of the municipal solid wastes in Kator district *(payam)* are disposed of randomly by the householders themselves whereas 40% of the wastes are disposed through the district *(payam)* waste management unit and 6% through the private company. In Juba district *(payam)*, 75.58% of the household municipal solid wastes are disposed randomly by the householders themselves; 19.77% disposed through the district's *(payam's)* waste management unit and 4.65% disposed by the private company. While in Munuki district *(Payam*), 77.78% of the household municipal solid wastes are disposed randomly by the householders themselves; 5.55% by the district's *(payam's)* waste management unit and 16.67% disposed by the private company.

Typically one to two thirds of the municipal solid waste generated is not collected in many cities of the developing countries and the most underdeveloped (Firdaus and Ahmad, 2010). Most wastes are disposed of in open dumps, deposited on vacant land or burned by residents in their backyards (Visvanathan and Glawe, 2006; Medina, 2010). Insufficient collection and inadequate disposal generate significant pollution problems and risks to human health and the environment (Medina, 2010). The situation in Juba totally and practically is in accordance with those authors findings. In Juba, there is no sanitary land fill available for municipal solid waste disposal: Juba's municipal solid wastes are being dumped indiscriminately on the land and partially outside of the city at the designated open dumping site which is about 16 km away from the city.

Most literature of the municipal solid waste management in the developing countries highlights that the seriousness of the municipal solid waste pollution problem has been acknowledged by most governments; however, the rapid population growth over-whelms the capacity of most municipal authorities to provide even the most basic services (Asnani, 2006). This is the case in Juba: the government is unable to render the services to all. Thus, there is that tendency to direct the services to the high profile residential areas. Hence, it becomes obvious that the low-income residential areas are neglected. Therefore, left with no any other option, residents tend either to dump their garbage at the nearest vacant land, public space, river bank/streambeds or simply burn it in their backyards. Uncollected waste can accumulate besides the streets and clog drains when it rains, which might cause water stagnation. Waste can also be carried away by run-off water to streams and rivers and this has a negative effect on the water sources in and around the city. One of the worse practice of all the above mentioned with regards to municipal solid waste disposal in Juba city is the illegal dumping in streambeds.

3.3.1 The Direct Impact of Illegal Dumping in Streambeds on Public Health

The majority of local inhabitants of Juba do not have any garbage service and many use the dry streambeds that transverse the city as dumping areas. Once the rains come, these masses of municipal solid wastes are washed into the adjacent River Nile. Unfortunately and regrettably, most residents of Juba city still depend on these surface water bodies for water supply and especially for drinking and bathing; explaining in part the high incidence of persistent typhoid, dysentery, diarrhea, hepatitis A and cholera at certain times of the year. This is a clear indication that there exists a strong relationship among rainy season (water pollution), municipal solid waste pollution and some water-borne diseases. However, a more detailed research with regards to the correlation among municipal solid waste pollution, water pollution and water-borne diseases is recommended to be conducted by the young scholars in Juba so as to prove it.

3.3.2. The Dumping Site

The dumping site is located about 16 km away from the city along the Juba – Yei road. It is a kind of a small valley: and this could have been the reason for its choice so as to reduce the excavation cost. The site (figures 3 & 4) lacks all the necessary sanitary landfill practices. There are also no pollution control measures and it is not fenced. In this dumping site, there is no waste separation practice; all kinds of wastes including medical wastes are just dumped like that: and when the heap is mounting, a shovel loader is hired by the city council in order to flatten and compact it. Disposal operations are usually disrupted during the rainy season due to heavy rains and also by the frequent breakdown of the Lorries; all these can lead to the delay of waste disposal. Due to the lack of environmental protection measures, small ponds of highly polluted water can be seen in the site; and these in turn provide good breeding places for mosquitoes and flies. This is also another health risk to the people scavenging as the site is a home to most of them. So, in order to reduce the number of mosquitoes and flies and also the volume of the waste, the scavengers practice frequent burning.

Another scenario is that, at times wastes from the slaughterhouses (offal) are dumped at the site. This site is soon expected to begin producing leachate; and this is already a risk to the underground water and even to the River Nile as it is not very far from the site.

Figure 3: The scene at the dumping site (photo by the author during the field observation period)

Figure 4: People scavenging at the dumping site (photo by the author during the observation period)

3.4. The Water Samples' Analysis

Water is a prerequisite of life and an important component of human survival. It should be purified for a better life style therefore; iIt is the basic duty of every individual to conserve water resources. Drinking water quality is affected by the presence of micro-organisms and different soluble salts (UN-HABITAT, 2010). Thus, water quality depends on the concentration of these micro-organisms and the physical and chemical soluble constituents due to natural occurrence, anthropogenic activities and weathering of parent rocks (Akinbile and Yusoff, 2011). The major problem with water is that once contaminated, it is difficult to restore its quality especially the ground water. Clean drinking water is essential to humans and other life forms. The greatest risks to consumers of drinking water are pathogenic micro-organisms.

Protection of water sources and treatment are of paramount importance and must never be compromised (ADWG, 2004). Standards for fecal coliform are considerably more strict if the water is used for drinking and total body contact such as swimming, rather than used only for boating with minimal direct contact. Fecal coliform is measured in Colony Forming Units per 100ml (CFU/100ml) of the water tested.

3.4.1. The Results of Water Samples' Analysis of the River Nile

Table 7: Shows averages of the readings of (CFU/100ml) and some physical parameters of the sampled sites of the River Nile

Site's Number	Site's Name	CFU/100ml Average Reading	Physical Parameters			
			pH	Temperature	TDS	EC
S1	Rajab West (Upstream)	33.04	8.3	28^0C	92	185µs
S2	Tokiman	31.6	8.3	28^0C	91	184µs
S3	Lologo	38.19	8.3	28^0C	94	187µs
S4	Juba Bridge	43.95	8.2	28.3^0C	98	189µs
S5	Juba Port	77.85	7.2	28.1^0C	79	190 µs
S6	Urban Water Cooperation (Intake Point)	97.05	8.2	28^0C	98	201µs
S7	Jebel Nyoka	102.6	8.4	28.3^0C	123	229µs
S8	Hai Gabat	98.6	7.4	28.1^0C	98	205µs
S9	Nyaying	70.9	7.4	28^0C	86	126µs
S10	Roton	46.6	7.3	28^0C	78	106µs
S11	Walawalang	33.6	7.4	28.1^0C	63	98µs
S12	Molobor Village (Downstream)	15.25	6.8	28^0C	47	89µs

The overall analysis results showed that the average fecal CFU/100ml concentration for all the twelve sampled sites of the River Nile range between 15.25 – 102.6 at sites S12 and S7 respectively. This fecal coliform count range is far above the 0 mpn/100ml for drinking water as the recommended standard by (WHO, 1984; 1998; 2001; USEPA, 1985; 2002). Unfortunately and unacceptably, most of the poor population of Juba city still directly depends on the River Nile's water for drinking and all other domestic needs. The presence of high fecal coliform concentration in the River Nile's water is not only a clear indication of the serious municipal solid waste pollution in Juba but also it signifies the high percentage of both human and animal excreta in the waste stream. This is in accordance with the findings of (Cointreau, 1982; UNEP-IETC, 1996; Zurbrugg, 2002) that "in the developing countries, municipal solid waste is often mixed with human and animal excreta". Another major source of this contamination is the illegal direct discharge of untreated sewage into the River Nile from the hotels along it.

The river water is therefore, contaminated with pathogens which can cause various water-borne diseases. This is in part explained by the high incidence of diseases such as typhoid, diarrhea, hepatitis A and gastro-intestinal infections in the city. This is in accordance with the findings of (Pielou, 1998) when he pointed out that "human and animal excreta waste contains disease-carrying organisms such as the bacterium *Escherichia coli* and pathogens that cause cholera, typhoid, diarrhea, dysentery, hepatitis A and cryptosporidiosis". Thus, the river water is not fit to be used for domestic purposes, except otherwise if treated: but it can be use in recreational purposes for example, swimming. The sites S1 and S12 to some extent performed their role as control points by showing the low readings.The values of pH at all the sampling sites ranged from 6.8 to 8.3 and were normal according to the USEPA and WHO recommended values. The temperature for all the sites was also within the normal range. The TDS for all the sites ranges between 47 – 123mg/100ml. Eleven of the sites except site 12 have their range far beyond the 500mg/l USEPA and WHO recommended value. This clearly shows that the banks of the River Nile are exposed and lack natural vegetation. The EC ranges between 59µs - 201µs/cm: eight of the sites (S1 – S8) results were all above the WHO 160 µs/cm recommended value and this is due to the fact that there are a lot of human activities around.

For example, car washing, swimming, cloths washing, bathing and many others; all these activities could be a good source of chemicals input into the river. S9, S10, S11 and S12 were below due to the fact that they are having very low human activities and also far from the city centre especially for the case of S12.

3.4.2 The Results of the Water Samples' Analysis of the Streams

Table 8: shows averages of the readings of CFU/100ml and some Physical Parameters of the sampled Streams

Serial Number	Stream's Name	CFU/100/ml Average Reading	Physical Parameters			
			pH	Temperature	TDS	EC
1	Khor Romula	404.5	8.3	28^0C	88	44µs
2	Khor Williang	455	8.2	28^0C	129	1329µs
3	Lobuliet	11,540.4	8.3	28.3^0C	868	1749µs
4	Khor Bou	2,411.5	8.3	28^0C	880	1761µs
5	Gumba-losok	1.25	7.1	28.5^0C	41	15µs

From table 8 above, it is clear that the fecal CFU/100ml concentrations were abnormally so high except for Gumba-losok stream; the range was between 1.25 – 11,540.5 CFU/100ml. Khor Romula stream has very high concentration despite the fact that it is at the out skirt of the city. The reason for the high fecal contamination is that, at its upstream, there are a good number of cattle herds which supply Juba with fresh beef. So during rainy season, all these cattle dung is washed into the stream. For Khor Williang, Lobuliet and Khor Bou, they are just passing through the heart of the city. They are being used for open air defecation by the kids during the day time and at night by the grown up. This is because in Juba, almost 45% of the population doesn't have toilets/pit-latrines in their houses (a very serious and unacceptable sanitary problem). Also, there are some domestic animals (goats, sheep and cattle) in some individuals' houses in the city: a kind of maintaining some African cultures and traditions. All these are the contributing factors of the extremely high fecal concentrations. As for Gumba-losok stream, the so low colonies' count is attributed to the fact that it is far (13 km) from the city and also the village near it is of about less than 50 persons. The pH and the temperature of all the streams were within the normal range. For the TDS and EC of the three streams Khor Williang, Lobuliet and Khor Bou their concentrations were extremely high: the high human activities in the city is probably the cause. While Khor Romula and Gumba-losok fall within the WHO recommended value due to the very small vicinity population.

A special consideration was given to Gumba-losok stream: whereby its total coliform was tested and the result was so alarming. The reading was 980,000 CFU/100ml. It is so sad and painful to see that the small village around the stream was using this highly contaminated water for direct drinking. One of the villagers was a student in the University of Juba in the department of Forestry; he told us that many of the village's children are admitted in Juba Teaching Hospital due to gastro-intestinal infections and especially Schistosomiasis (Bilharzia). This is a real serious problem facing this village, he added.

3.4.3 The Underground Water Samples' Analysis Results

Table 9: the Averages of CFU/100ml and some physical parameters of the Underground Water (Boreholes/Well) Samples' Analysis Results

Serial Number	Station's Name	CFU/100ml Average Reading	Physical Parameters			
			pH	Temperature	TDS	EC
BH1	Esko Company Juba - Nabari (Borehole)	9	7.5	29	693	1661 µs
BH2	Juba Nabari (Kolo Road) (Borehole)	0	7.4	29.7	670	1405 µs
BH3	Hai Jejira (Munuki) (Borehole)	0	7.3	28.9	517	1144 µs
BH4	Hai Nyakuron (Borehole)	0	7.4	29.6	499	1092 µs
BH5	El-Sabah Children Hospital – Juba (Borehole)	0	7.3	30.2	613	1253 µs
BH6	Pentecostal Church –Juba (Borehole)	26	7.8	29.3	823	1775 µs
BH7	Hai Neem (Borehole)	20	7.7	29.5	805	1714 µs
BH8	Hia Amarat (House of the Minister of Finance) (Borehole)	0	7.3	28.6	490	1135 µs
BH9	Hai Dongoda - Juba (Borehole)	10.5	7.6	28.3	714	1637 µs
BH10	Juba Medical Complex (Borehole)	9	7.6	29	689	1617 µs
BH11	Munuki Block B (Borehole)	0	7.4	28.8	481	1032 µs
W1	Lologo (Well)	17.5	7.7	28.1	793	1730 µs

Table 9 above highlighted that the underground water was lightly contaminated compared to the surface water. The results for BH2, BH3, BH4, BH5, BH8 and BH11 indicated that there was no fecal coliform contamination; and this is in accordance with the USEPA and WHO recommendation of 0 CFU/100ml. Thus, the water has the highly desirable level for human consumption. For BH6, the one with the highest concentration; there are three factors suspected of causing the contamination. These include: (i) The borehole is very old; it was drilled in 1986. Thus, there is the probability that the sink pipes (metal) might have started to get corroded, hence, leakage can happen. (ii) There is a row of six pit-latrines dug so close to the borehole (just about 10 meters away). These pit-latrines serve a considerable number of people every day; the Juba Pentecostal Church's Basic School pupils and also a big number (those who come to pray) on Sundays. (iii) The borehole is just about 15 meters from the Khor Bou stream which is highly contaminated. For BH7, the main factor contributing to the contamination is the pit-latrines.

Hai Neem is a residential area of upper class citizens thus; every house has at least a pit-latrine. Also the oldness of the borehole could be another factor. Results for BH9 and BH10 also showed contamination. The suspected cause is mainly the presence of pit-latrines near them and also their age.

For BH1, the contamination could be from underground leakage into the borehole. This is because Juba Nabari is a low lying flat area near Juba International Airport. During the rainy season, all the wastes from the highland are washed and get settled down in this low lying land. The pH and temperature were within the normal range. The TDS and EC analysis results showed extremely so high readings which are so far above the EPA and WHO recommended value. These high values imply that the dissolved salts within are also to their maximum. According to (Blyth and de Freitas, 1984), "the water molecule (H_2O) is strongly polar and thus, it is a powerful solvent. Groundwater usually adopts the chemistry of the rocks/soil in which it resides". For the well, it is also contaminated with fecal coliform. The cause is due to the fact that it is located at a valley of a creek; and is usually surrounded by stagnant water during the rainy season. This stagnant water when it settles down it can get mixed up with the well's water thus, causing the contamination. The findings of this study agree with a general boreholes analysis (targeting fecal coliform only) survey in and around Juba conducted by UN-OCHA (2010). The survey's results indicated that most of the boreholes in Juba are contaminated with *Escherichia coli (E coli)* (Total and fecal coliform).

4. Conclusion

Generally, the poor municipal solid waste management in most cities of the developing countries has resulted into many problems. The uncontrolled and un-scientific dumping of municipal solid wastes coupled with the poor sanitation status have brought about serious pollution problems; in which contamination of both surface and ground water which is in turn a threat to human health is very serious. The analysis results obtained from this study revealed that, the River Nile is highly contaminated with fecal coliform to the extent that it is unfit to be used as drinking water except for other purposes. The study also showed that the entire streams in Juba have abnormally high fecal coliform concentration thus; their water is not fit for any human use. For the boreholes and the well, the results also showed contamination. Out of the eleven boreholes tested, six of them were found to be clean thus; satisfying the USEPA and WHO recommended standard value for drinking water. The other five and the well were found to be contaminated but not as high as the surface water.

Consequently, the results of this study can be so useful to the general public and the government. It will alert those people who are currently using the contaminated water about the high risk of being affected by water-borne diseases and other water related diseases if they continue using it especially for drinking. Water-borne diseases such typhoid, diarrhea, dysentery, hepatitis A and occasionally cholera are currently a serious public health problem in Juba. This study will act as a guide for the government to take the necessary measures to tackle the municipal solid waste pollution in the city. More extensive surveys are needed to monitor the quality of the river water in order to reduce the level of water-borne diseases' incidence. Hence, the cities' authorities in the developing countries must heavily invest in municipal solid waste management in order to avoid the high risk to the environment and the loss of innocent lives.

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