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Impact of hospital wastewater on the rivers' quality: Case of Byumba hospital

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ABSTRACT

Hospital wastewater may pose chemical, biological, and physical threats to public and environmental health. This study's objective was to evaluate the effects of hospital wastewater on waterways' quality through physico-chemical parameters' analysis where samples were collected on-site between July and November 2021, and then using EPA and Hash procedures, they were preserved, prepared, and measured in the Environmental Research Laboratory at the University of Lay Adventists of Kigali (UNILAK-ERL). According to the findings, both receiving streams were contaminated to the following degrees: pH (88.51%), TDS (55.98%), COND (55.92%), TP (10.14%), TN (39.70%), COD (25%), Cr (9.90%), Zn (20%), Mn (4.28%) for Ruhashya stream and pH (48.43%), TDS (26.75%), COND (26.73%), TP (20.83%), TN (13.33%), COD (5.55%), Cr (19.49%), Zn (30%), Mn (4.33%) for Rwiminsi stream respectively. The findings demonstrated that Byumba hospital effluent has the potential to contaminate the ecosystem if improperly managed. Therefore, Byumba Hospital should improve the effectiveness of its hospital and routinely examine the effluent quality originating from its wastewater treatment facility; in addition, People should not be allowed to drink water from streams that receive Byumba Hospital effluents; finally, local government officials should enforce the polluter-pays principle, and environmental regulatory agencies should stiffen the penalties for institutions that fail to manage their wastes properly. Others studies on waste have been conducted, but there hasn't been any research on total dissolved solid particles (TDS), mercury (Hg), lead (Pb), and other heavy metals, BOD, and COD. So, this research fills the gap left behind by other researchers.

Contribution/Originality: This study is one of very few studies which have investigated liquid waste's chemical composition and documents essential records for water management. This paper is also free from any plagiarism and has not been submitted elsewhere for publication.

1. INTRODUCTION

The hospitals use large amounts of water each day and produce wastewater that contains chemical and biological components. Hospitals, medical facilities, cleaning services, laboratories, and other facilities all produce

hospital wastewater. As a result, it is recommended that the main elements are organic materials, antibiotics, disinfectants, and pathogenic microorganisms [1].

So Some hospital treatment facilities for liquid wastes (HWWTP) are not properly managed and slightly low removal capacities are achieved even for common parameters including BOD5, COD, TSS, TN, TP, TDS, heavy metals and coliforms [2]. Several studies had done by analyzing the composition and quality of municipal wastewater' effluents but there is a gap about analyzing hospital wastewater' effluents in Rwanda where some parameters like manganese, zinc and chromium and other heavy metals were left behind and Byumba makes part of this situation. Byumba hospital and various technical services in health-care centers has caused increasing changes in quantity and quality of wastewater.

After treatment trough wastewater Treatment Plant (WWTP), waste water released from Byumba hospital is dumped into environment and joined neighboring rivers where the first ones are Ruhashya and Rwiminsi. So, for the sake of the ecosystem, valuable and susceptible natural resources of this district such as rivers and agricultural lands, it is necessary to continuously assess and monitor the total quality of wastewater disposed by Byumba hospital because its total content is not yet known.

The aim of the study was to assess the impact of Byumba hospital wastewater on rivers' quality by analyzing some physico-chemical parameters and this overcame the gaps appeared on the analysis of hospital effluents and showed the current data of Byumba hospital' released effluents and improving the safety of receiving environments. Then after, the report will be used by Ministry of Health, local authorities, water and environment regulating agencies and Byumba hospital to improve the performance of wastewater Treatment Plant (WWTP) and the quality of released wastewater.

2. MATERIALS AND METHODS

2.1. Description of Study Area

Gicumbi district is located in the Northern Province of Rwanda and is bordering with Uganda in the north, the City of Kigali on the South, Nyagatare and Gatsibo Districts on the Eastern side and finally Rulindo and Burera Districts in the West.Byumba hospital is located in Byumba sector which is the capital of Gicumbi district. The hospital was built in the early 1950s and it is one among 7 hospitals in Northern Province of Rwanda and it currently serves over 370.000 people mainly from Gicumbi district and the neighboring districts of Rulindo and Burera (Researcher,2021).

Wastewater from Byumba hospital is discharged into open drain system after treatment where it meets Ruhashya and Rwiminsi rivers about1 and 2.5km respectively from Byumba hospital WWTP.

2.2. Sampling Methods and Analysis

Five samples were collected respectively at Hospital Wastewater Treatment Plant(WWTP) outlet, Ruhashya stream water, mixture of Ruhashya and hospital effluent, Rwiminsi stream water and finally the mixture of both streams with hospital effluent as shown in Figure 1. These samples were taken during dry season (September 2021) and others were also taken during rainy season(November 2021).

Each sample has taken using washed and rinsed plastic bottle and all ten samples were kept in University of Lay Adventists of Kigali, Environmental Research Laboratory (UNILAK-ERL) in refrigerator at 40C before analysis where the following methods were used to analyze parameters: electrical conductivity (Hach 8160), Total dissolved solids (TDS) were examined using Hach 8160, pH(EPA 150.1), Chemical Oxygen Demand(COD) was measured using EPA 410.4, Hach 10072 was used for Total nitrogen (TN), Hach 10209 for total phosphorus (TP), Hach8023 for Chromium, Hach8009 for Zinc and Hach8149 for Manganese respectively.

3. RESULTS AND DISCUSSIONS

3.1. The Quality of Hospital Effluent during Dry Season

As indicated in Table 1, the results of Byumba hospital effluent during dry season were pH: 4.42; TDS:409 mg/l; Conductivity:819µS/cm; TP:19mg/l; TN:75mg/l; COD:COD:320mg/l; Cr:0.098mg/l; Zn:0.32mg/l and Mn:0.225mg/l respectively. The results show the higher values of some parameters such as pH, TDS, Conductivity, COD, TP and TN which exceeded the limits of standards recommended by World Health Organization. This situation can be caused by the higher concentration of chemicals in hospital effluent during dry season, inadequate monitoring and poor performance of Byumba Hospital WWTP in removing some chemical substances from its influents. The pH is an important factor in determining water quality since it affects a variety of biological and chemical activities within a water body. The alkalinity or acidity of wastewater always destroys and interrupts wastewater collection and treatment systems, causing the treatment process to fail.

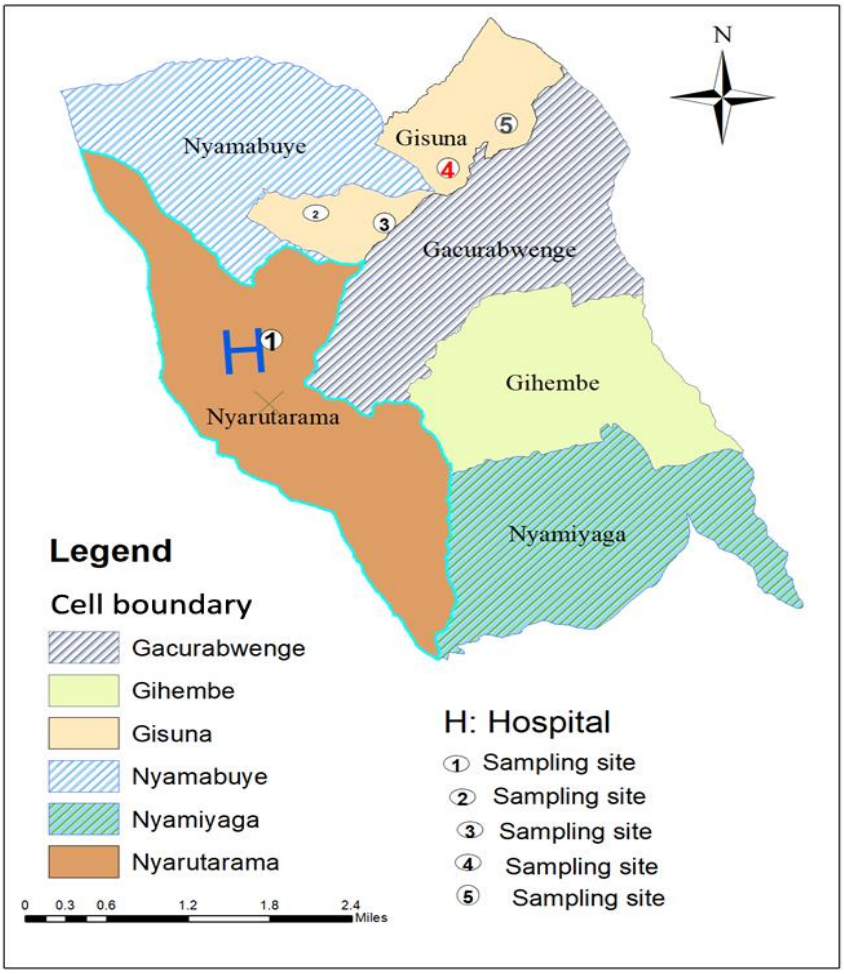

Figure 1. Hydrological map of Byumba hospital drain system towards Ruhashya.

Table 1. The quality of hospital effluent during dry season.

Parameter	Results	Unit	WHO standards
pH	4.42	-	5-9
TDS	409	mg/l	100
Conductivity	819	µS/cm	200-800
TP	19	mg/l	6-10
TN	75	mg/l	10
COD	320	mg/l	250
Cr	0.098	mg/l	0.05
Zn	0.32	mg/l	5.0
Mn	0.225	mg/l	0.3

Where Ph stands for Potential of Hydrogen ions, TDS (Total Dissolved Solids), TP (Total Phosphorus), TN (Total Nitrogen), COD (Chemical Oxygen Demand), Cr (Chromium), Zn (Zinc), Mn (Manganese) and WHO (World Health Organization).

During the dry season, the pH of the effluent (4.42) was indicated below the permissible range (5-9).As a result, the water body, its ecosystems, and the surrounding environment are all at risk. TDS was another characteristic we looked at in our samples since certain components including chlorides, sulfates, magnesium, calcium, and carbonates can cause corrosion or encrustation in water distribution systems [3]. Excessive scaling occurs in water pipelines, water heaters, boilers, and home appliances such as kettles and steam irons when TDS levels are high (>500 mg/litre).These appliances' service life may be shortened as a result of this scaling [4]. If the excess TDS in the Byumba hospital wastewater is not appropriately handled, it can lead to the above-mentioned dangers. Total phosphorus is one of the most important markers of nutrient weight in any receiving environment; larger concentrations stimulate fast growth of plants on the water surface and a reduction in oxygen, which can lead to suffocation of aquatic life. The excess concentration of total phosphorus detected at Byumba hospital wastewater treatment plant (WWTP) outlet during the dry season was 19 mg/l, indicating that the effluent quality of Byumba hospital effluents is not good for the receiving environment.

3.2. The Quality of Hospital Effluent during Rainy Season

During rainy season, the results were: pH:6.24; TDS:139.4mg/l; Conductivity:278.5µS/cm; TP:7.1mg/l; TN:27mg/l;192mg/l; Cr:0.101mg/l; Zn:0.2mg/l and Mn:0.042mg/l respectively. Among all parameters only TDS and TN had exceeded the limits recommended by WHO, the results of other parameters are prescribed within the limits recommended by World health organization standards.

The differences in variability of parameters during dry and rainy season showed the dilution by rain, chemical reactions during rainy season and biological processes which affected mainly pH, TDS, TN and COD. TN is sometimes regulated as an effluent parameter for municipal and industrial wastewater treatment plants, but it is more common for limits to be placed on an individual nitrogen form, such as ammonia. Treatment plants that have a TN limit will usually need to nitrify and denitrify in order to achieve the TN limit.

Table 2. The quality of hospital effluent during rainy season.

Parameter	Results	Unit	WHO standards
pH	6.24	-	5-9
TDS	139.4	mg/l	100
Conductivity	278.5	µS/cm	200-800
TP	7.1	mg/l	6-10
TN	27	mg/l	10
COD	192	mg/l	250
Cr	0.101	mg/l	0.05
Zn	0.02	mg/l	5.0
Mn	0.042	mg/l	0.3

Table 2 shows the pollution caused by excess total nitrogen and total dissolved solids thus, like Phosphorus, too much Nitrogen in water causes algal blooms and they can severely reduce or eliminate oxygen in the water, leading to illnesses in fishes and the death of large numbers of fishes. Some algal blooms are also harmful to human beings because they produce higher toxins and bacterial growth that can make people sick if they come into contact with polluted water, consume tainted fishes or shellfishes, or drink contaminated water. Infants are vulnerable to a nitrogen-based compound called nitrates in drinking water. In our samples, 75 and 27mg/l values were respectively found. These values exceed the required accepted values recommended by WHO (10mg/l), therefore it's a threat to aquatic organisms and for human beings who can drink this contaminated water. Chemical Oxygen Demand or COD is a measurement of the oxygen required to oxidize soluble and particulate organic

matter in water and it is an important water quality parameter because it provides an index to assess the effect by which the discharged wastewater will have on the receiving environment. Higher COD levels mean a greater amount of oxidizable organic material in the sample, which will reduce dissolved oxygen (DO) levels. A reduction in DO can lead to anaerobic conditions, which is lethal to higher aquatic life forms. The results were 192 and 320 mg/l respectively. This variability shows the increase of COD during rainy season and this high level in hospital effluent indicates the poor performance of Byumba hospital WWTP in removing decaying organic matter from its influent during rainy season where the values exceeded the accepted limits of standards recommended by WHO (250 mg/l).

Many studies on hospital wastewater have been carried out across the World. In Rwanda especially in Kigali city, the findings obtained from the research carried out by Bimenyimana, et al. [5] on Phyisico-Chemical and Bacteriological Analysis on wastewater from Hospital, Case of Centre University Teaching Hospital of Kigali in Rwanda were: pH: 7.25, COD: 215.5mg/l, TN: 7.46mg/l and TP: 1.05mg/l respectively. So, by comparing those results with those of Byumba hospital WWTP, it seems that the results of effluent of Byumba hospital are higher and this indicates the poor performance of Byumba hospital WWTP.

3.3. The Quality of Rivers during Dry Season

Results obtained after analyzing the composition of receiving streams during dry season were:pH:7.04,TDS:30.4mg/l;COND:61.1µS/cm;TP:0.3mg/L;TN:15;TP:0.3mg/L;COD:160 mg/L;Cr:0.108 mg/L;Zn:0.02mg/L and Mn:0.109mg/L respectively for Ruhashya stream whereas pH:7.07,TDS:27.4mg/l;COND:55.1µS/cm;TP:0.5mg/l;TN:31mg/l;TP:0.3mg/l;COD:112mg/L;Cr:0.096;Zn:0.02mg /l and Mn:0.254mg/l values have been found respectively for Rwiminsi stream.

Apart from total Nitrogen other parameters values 'are prescribed within the recommended limits by WHO and water is suitable for use but it is prohibited for drinking it because it can cause illness and toxicity for human being because of high level of TN. The values of TN (15 and 31mg/l>10mg/l) exceeded the limits recommended by WHO. This indicates that apart from hospital effluent other anthropogenic activities of neighboring community pollutes surrounding rivers during dry season.

3.3.1. The Quality of Rivers during Rainy Season

Tables 3 and 4 present the results of Ruhashya and Rwiminsi streams were pH:7.05;TDS:24.9mg/l; Conductivity:49.85µS/cm;TP:0.7mg/l;TN:6.8mg/l;COD:128mg/l;Cr:0.102mg/l;Zn:0.01mg/l and Mn:0.098mg/l and pH:7.04; TDS:23.1mg/l; Conductivity:46µS/cm; TP:0.12mg/l; TN:8.7mg/l; COD:288mg/l; Cr:0.059mg/l; Zn:0.01mg/l and Mn:0.210mg/l respectively. Therefore, results in Table 4 show the high value of COD (288 mg/l) at Rwiminsi stream which exceeded the limits recommended by WHO. This is due to other anthropogenic activities. So, apart from COD, other parameters' values obtained are accepted by WHO standards. Thus, during rainy season, rivers water is suitable for drinking and for using.

Table 3. The quality of rivers during dry season.

Parameter	Ruhashya stream	Rwiminsi stream	Unit	WHO standards
pH	7.04	7.07	-	5-9
TDS	30.4	27.4	mg/l	100
COND	61.1	55.1	µS/cm	200-800
TP	0.3	0.5	mg/l	6-10
TN	15	31	mg/l	10
COD	160	288	mg/l	250
Cr	0.108	0.096	mg/l	0.05
Zn	0.02	0.02	mg/l	5.0
Mn	0.109	0.254	mg/l	0.3

Table 4. The quality of rivers during rainy season.

Parameter	Ruhashya stream	Rwiminsi stream	Unit	WHO standards
pH	7.05	7.04	-	5-9
TDS	24.9	23.1	mg/l	100
COND	49.8	46	µS/cm	200-800
TP	0.7	0.12	mg/l	6-10
TN	6.8	8.7	mg/l	10
COD	128	112	mg/l	250
Cr	0.102	0.059	mg/l	0.05
Zn	0.01	0.01	mg/l	5.0
Mn	0.098	0.210	mg/l	0.3

3.4. The Extent at Which Hospital Effluents Affect Rivers' Water Quality during Dry Season

As shown in Table 5, during dry season the results from laboratory show the following contamination level values: pH (62.78%),TDS (13.45%),COND (13.40%), TP(63.33%),TN(50%), COD(12%), Cr(9.07%), Zn(16.00%), Mn(20.64%) respectively at Ruhashya stream whereas at Rwiminsi stream the results were : pH(90.94%),TDS(8.24%), COND(8.13%),TP(14.14%),TN (10.96%),COD(8.57%),Cr (8.33%), Zn(20.00%) and Mn (20.78%) respectively.

Table 5. The extent at which effluents affect rivers' water quality during dry season.

Para.	Byumba hospital effluent at WWTP outlet	Ruhashya Stream	Mixture of Ruhashya stream with Byumba hospital effluent	Contamination	Rwiminsi stream	Contamination
pH	4.42	7.04	6.43	62.78	7.07	90.94
TDS	409	30.4	223	13.45	27.4	8.24
COND	819	61.1	448	13.40	55.1	8.13
TP	19	0.3	7.07	63.33	0.5	14.14
TN	75	15	34	50.00	31	10.96
COD	192	160	96	12.00	112	8.57
Cr	0.098	0.108	0.080	9.07	0.096	8.33
Zn	0.32	0.02	0.04	16.00	0.02	20.00
Mn	0.225	0.109	0.528	20.64	0.254	20.78

Table 5 indicates that among all parameters, pH values have been increased vividly from receiving site to another and this contamination degree is considered to be high and it is very harmful to environment and for its components as well. For other parameters, generally, the contamination degree has been reduced from point 1 to point 2 (Ruhashya to Rwiminsi) and the level of contamination degree is negligeable and cannot cause a significant harm to any receiving environment and its components.

3.5. The Extent at Which Hospital Effluents Affect Rivers' Water Quality during Rainy Season

The results in Table 6 show the following contamination degree in both receiving rivers: pH (88.51%), TDS (55.98%), COND (55.92%), TP (10.14%), TN (39.70%), COD (25%), Cr (9.90%), Zn (20%), Mn (4.28%) and pH (48.43%), TDS (26.75%), COND (26.73%), TP (20.83%), TN (13.33%), COD (5.55%), Cr (19.49%), Zn (30%), Mn (4.33%) respectively.

Table 6 indicates that pH contamination level decreased from 88.51 to 48.43%, TDS from 55.98 to 26.75%; TN from 39.70 to 13.33% and COD from 25 to 5.55% respectively while the contamination degree of the following parameters have been increased as follows: TP from 10.14 to 20.83%; Mn from 4.28 to 4.33%; Cr from 9.90 to 19.49%; and Zn from 20 to 30%. The contamination degree of some heavy metals such as Cr and Zn increased intensely during rainy season. Generally, the contamination degree during rainy season is lower than that of dry season.

Table 6. The extent at which hospital effluents affect rivers' water quality during rainy season.

Sampling point	Byumba hospital effluent at WWTP outlet	Ruhashya Stream	Mixture of Ruhashya stream with Byumba hospital effluent	Contamination	Rwiminsi stream	Contamination
pH	6.24	7.05	6.88	88.51	7.04	48.43
TDS	139.4	24.9	61.8	55.98	23.1	26.75
COND	278.5	49.8	123	55.92	46	26.73
TP	7.1	0.7	2.5	10.14	0.12	20.83
TN	27	6.8	11.6	39.70	8.7	13.33
COD	320	128	160	25.00	288	5.55
Cr	0.101	0.102	0.115	9.90	0.059	19.49
Zn	0.02	0.01	0.03	20.00	0.01	30.00
Mn	0.042	0.098	0.091	4.28	0.210	4.33

4. CONCLUSION

The physical and chemical parameters analyzed from Byumba hospital WWTP effluents released into water bodies especially in Ruhashya and Rwiminsi streams and the streams themselves were measured, analysed and interpreted in this research study. After data analysis and compared with the WHO and Rwanda Standards Board(RSB) standards, the effluent results during dry season were: pH: 4.42; TDS:409mg/l; COND:819µS/cm;TP:19mg/l;TN:75mg/l;COD:192mg/l;Cr:0.098mg/l;Zn:0.32mg/l and Mn:0.225mg/l respectively and pH:6.24; TDS:139.4mg/l; Conductivity:278.5µS/cm; TP:7.1mg/l; TN:27mg/l; COD:320mg/l; Cr:0.101mg/l; Zn:0.2mg/l and Mn:0.042mg/l respectively during rainy season. So apart from COD and analyzed heavy metals (Cr, Zn and Mn) which meet the limits of standards recommended by WHO and have no negative effects on the receiving environment, other parameters like (pH, TDS, COND, TP and TN) exceeded the limits of standards recommended by RSB and WHO and this increase in values shows the poor performance and ineffectiveness of Byumba hospital WWTP especially in dry season on one hand while for TP and TN on other hand where the streams were already contaminated before receiving hospital effluent, the increased values is due to other anthropogenic activities. Therefore, Byumba hospital effluent can damage receiving environment and its components as well if not controlled properly. Among all analyzed parameters pH shows the higher contamination level especially during dry season. The comparison of effluents results with the recommended standards showed that apart from COD and heavy metals (Cr, Zn and Mn) the results of other parameters namely pH, TDS, COND, TN and TP of Byumba hospital effluents exceeded the limits of standards recommended by WHO and Rwanda standard board, therefore Byumba Hospital can be a polluter to the environment and its component as well if there is no effort made to control the quality of its effluent especially during dry season.

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