



Pollution of Mpanga River by Kabundaire Abattoir Effluents, Fort Portal Tourism City, Uganda

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Authors' contributions

This work was carried out in collaboration among all authors. Authors FB, TO and CA designed the study. Author FB performed analytical work. Authors SK, TO and CA performed literature search and analyzed the collected data. Authors FB, SK and TO wrote the first draft of the manuscript. Author CA managed the literature searches. All authors read and approved the final manuscript.

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Short Communication

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ABSTRACT

Aim: Abattoirs are one of the most pronounced but yet ignored sources of highly recalcitrant wastewater that has significant impacts on the environment. The aim of this study was to assess the impacts of Kabundaire abattoir effluents on the quality of water in the receiving Mpanga river, Fort Portal tourism city of Uganda. The study also estimated the amount of water used and wastewater generated in the facility between December 2018 and December 2019, and the number of animals slaughtered per month in the abattoir.

Study Design: This research employed a quantitative research design.

Place and Duration of Study: Samples were collected from six different sites of Mpanga river at intervals of 2 km from Fort Portal town: upstream (Kahungabunyoni and Kagote A), midstream/

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effluent discharge point (Kabundaire and Mpanga market) and downstream (Rwabuhinga and Kitumba) along Mpanga river stretch in the morning and evening hours. The analyses were done at National Water & Sewerage Corporation, Fort Portal, Uganda. The sampling and experimental work was done between May 2019 and August 2019.

Methodology: The physicochemical properties (pH, temperature, dissolved oxygen, total nitrates and total phosphates) and microbiological (*Escherichia coli* and total coliform) profile of the water samples were determined following standard methods. To quantify the amount of water used and wastewater generated, the number of cattle, goats and sheep slaughtered per day between December 2018 and April 2019 were retrieved from abattoir records and extrapolated.

Results: Analytical results indicated that the evaluated water quality parameters were in the range of 6.93 ± 0.02 to 7.90 ± 0.16 , 22.0 ± 0.14 °C to 23.6 ± 0.26 °C, 0.01 ± 0.00 mg/L to 0.26 ± 0.02 mg/L, 6.30 ± 0.03 mg/L to 10.00 ± 0.03 mg/L, 4.20 ± 0.05 mg/L to 9.70 ± 0.02 mg/L, 4×10^2 CFU/mL to 48×10^3 CFU/mL, 1.4×10^4 CFU/mL to 6.6×10^6 CFU/mL for pH, temperature, dissolved oxygen, total phosphates, total nitrates, *Escherichia coli* and total coliforms, respectively. Most of the parameters were above permissible limits except pH, temperature and total nitrates. An average of 133 cattle, 78 goats and 33 sheep are slaughtered in Kabundaire abattoir every month. The actual number varies by month, depending on the demand for meat. The amount of water used, and the wastewater generated were estimated at 15,768 m³/year and 18,396 m³/year, respectively.

Conclusion: Discharge of effluents from Kabundaire abattoir into Mpanga river negatively affects its water quality. Mpanga river water is not safe for domestic use without further treatment/purification. We recommend that an anaerobic wastewater treatment facility should be installed at Kabundaire abattoir to enhance environmental conservation. Further studies should determine the actual amount of water used and wastewater generated at the facility.

Keywords: Abattoir; effluents dissolved oxygen; *Escherichia coli*; Kabarole district; Lake George; Rwenzori mountains.

1. INTRODUCTION

Abattoirs (slaughter houses) are one of the most pronounced but yet ignored sources of highly recalcitrant wastewater that has significant impacts on the environment [1-3]. Wastewater from abattoirs contains untreated wastes that are discharged directly into nearby watercourses. They have been reported to have a bad odor, houses high oxygen demand materials such as blood, bones, hides and carcasses with high levels of suspended solids, detergents as well as waterborne pathogens [4, 5].

In continuity of our environmental monitoring assessments [6-13], we report on the profile of water from Mpanga river which receives effluents from Kabundaire abattoir, Fort Portal, Uganda.

2. MATERIALS AND METHODS

2.1 Study Area

Kabundaire abattoir is one of the giant meat processing plants in the tourism city of Fort Portal. It is located in a densely populated area and its wastewater is discharged untreated into Mpanga river [14]. It is a one-hectare facility with

a lairage, administrative offices and two slaughterhouses (for cattle, and goats and sheep). In Kabundaire abattoir propinquity is Mpanga river, which emerges from Karagura hills of the Rwenzori mountains and run Eastwards for about 200 km covering an expanse of 4,700 km² through Kabarole, Bunyangabu, Kamwenge and Kyenjojo districts. It then turns South East after entering Kibale forest game park. In Kamwenge, Rushagwe river joins it from the East, and the river snake westwards to pour its water into Lake George [14-16]. Thus, the quality of Mpanga river has a contribution to the water quality and fish stock of Lake George [16].

2.2 Materials, Water Sampling and Analysis

Water samples were taken from six different sites at a distance of 2 km section in Fort Portal town: upstream (Kahungabunyoni (A), and Kagote A (B); $0^{\circ}39'55.3''$ N $30^{\circ}15'33.1''$ E), midstream/effluent discharge point (Kabundaire (C), and Mpanga market (D); $0^{\circ}39'25.7''$ N $30^{\circ}16'30''$ E) and downstream (Rwabuhinga (E), and Kitumba (F); $0^{\circ}39'30.5''$ N $30^{\circ}17'42.8''$ E). All samplings were done in duplicate on 13th May 2019 and then after a fortnight (on 27th May 2019)

between 08: 00 am and 10: 00 am (for morning samples) and then 4: 00 pm and 5: 00 pm for evening samples as described by Omara et al. [6]. Briefly, the samples were collected manually in 500 ml Teflon plastic bottles. The bottles, previously cleaned by washing in non-ionic detergent, were rinsed with tap water, soaked in 10% nitric acid for 72 hours and finally rinsed with deionized water before use. Each bottle was rinsed thrice with stream water at each sampling point, filled below the water surface and capped with airtight stoppers while still under water.

Non-conservable parameters (temperature and pH) of the water samples were determined on-site using a calibrated hand-held Jenway 370 pH/mV/Temperature meter (Jenway Gransmore Green, Felsted, Dunmow, Essex, England) precalibrated using pH 4, 7, 9.22 and 10 standard buffer solutions (manual override). The electrodes were thoroughly rinsed with distilled water between measurements of different water samples [7].

Total nitrates (TN), dissolved oxygen (DO), total phosphate (TP) levels and total coli form and *Escherichia coli* counts were determined following the APHA method [17].

2.3 Water and Wastewater Quantification

To quantify the amount of water used and wastewater generated, the number of cattle, goats and sheep slaughtered per day between December 2018 and April 2019 were retrieved from abattoir records. The total water consumption was calculated from daily water consumption records for the same period. This average was extrapolated to estimate the volume of water used for the period 2018 to 2019 [18]. To estimate the wastewater volume, we measured the amount of blood lost per animal slaughtered. The blood loss of 10 cattle, 10 goats and 10 sheep were measured with a recorded average bleeding time of 6.5 minutes. Blood drains before and after skinning/dressing were continuously recorded and the results were converted into flow measurements [18]. For cattle, the average blood loss per head killed was 8.4 liters while 6.1 litres was recorded in the case of goats and sheep. We asserted that 10% of the water used in the abattoir is lost in other processes, 8% in other uses like bathing, flashing toilets, cleaning offices and washing automobiles while 82% are used in the actual abattoir processes. Thus, the daily wastewater

generated was estimated as done by previous authors [18].

2.4 Quality Assurance of Data

All reagents used were of analytical grade. Equipment used were precalibrated and recalibrated between measurements. Quality control was achieved through analysis of samples in triplicate.

2.5 Statistical Analysis

Experimental data were captured in Excel for preliminary analysis. Data were checked for normality using the Kolmogorov-Smirnov test and where they did not follow a normal distribution, appropriate transformations were done. Statistical significance ($P = .05$) was assessed using independent sample *t*-tests and one-way ANOVA with the least significance difference for separation of means. The analyses were performed using Minitab Statistical Software (v17, Minitab Inc., USA).

3. RESULTS AND DISCUSSION

The analytical results for the investigated water quality parameters as compared with reports from global studies are shown in Table 1.

Pollution of Mpanga river from which water supplied to over 7,000 Ugandans is abstracted have been previously reported [14,16]. To assess the impacts of abattoir wastewater on the quality of Mpanga river, some physicochemical and bacteriological parameters of water samples taken from upstream, midstream and downstream of the river near Kabundaire abattoir were analyzed. The pH of all the samples were within 6.0-8.0 recommended by Uganda National Environmental Management Authority (NEMA) (Table 1). Similar pH values were reported in Rwanda [18], Ethiopia [19] and Nigeria [20-24]. The values were however, lower than those previously reported in Cameroon [25], Uganda [2,26] and Kenya [27]. Recently, Kakyoo [28] reported pH of 5.93-6.66 for a stretch of Mpanga river including Mpanga market and Kabundaire abattoir. Increase in pH of water at the discharge point could be because of the alkaline nature of the wastes. The reduction ($p > 0.05$) in pH recorded downstream could be due to dilution effects [2]. Because pH of water is a measure of its quality [29], the increment ($p < 0.05$) in pH

from 6.93 ± 0.02 at Kahungabunyoni to 7.90 ± 0.16 at Kabundaire, 7.00 ± 0.08 at Kagote A to 7.70 ± 0.01 at Mpanga market for morning samples suggest that the effluents negatively impact the water quality of Mpanga river. This can affect aquatic organisms because most of their metabolic activities are pH dependent.

The temperature ranged from 22.3 ± 0.18 °C at Kahungabunyoni to 23.6 ± 0.26 °C at Kabundaire for morning samples and 22.0 ± 0.14 °C at Kahungabunyoni to 22.9 ± 0.23 °C at Kabundaire for evening samples with a slight elevation recorded for midstream samples.

Similar marginal differences in temperature of Mpanga river water was previously reported [28]. The temperatures recorded were corroborant with those recorded in other studies (Table 1). The temperatures were within national limits for dischargeable wastewater. The slight elevation in temperature recorded for samples collected from the effluent discharge points could be attributed to the use of warm and hot water at about 43 °C and 65 °C respectively for sterilizing abattoir devices such as knee-operated hand washers, gut barrow, knives, horn saws, splitting saw and rod sterilizers [30].

Discharge of raw high-strength wastewater into water bodies depletes their dissolved oxygen (DO) [31]. The DO in upstream water samples were significantly different ($P < 0.05$) from those of midstream and downstream samples. A plausible explanation of this could be because of the high oxygen demand of abattoir effluents [4,5,31]. Comparable DO levels to our results were reported for abattoir waste-impacted water in Nigeria [20,21]. In contrast, higher DO values were earlier reported for abattoir wastewater in Uganda [26], Kenya [27] and Nigeria [23,32]. The low DO recorded for midstream and downstream morning samples indicate that during peak hours of abattoir operations (midnight to 10:00 am), there is a higher volume of wastewater discharged into the river than during evening hours. This agreed with the observation recorded for Kalerwe abattoir in Kampala, Uganda [2]. The low DO levels recorded downstream could also be attributable to the external input of organic loads from domestic wastes, sewage discharge, laundry and car washing activities cited along the banks of the river which causes a build-up of sludge and triggers mineralization processes

which consume DO from the water column [33]. Though DO was drastically reduced midstream, the insignificant increase ($P < 0.05$) in DO recorded downstream indicated that the river has little capacity for self-purification possibly due to input of other high oxygen demanding wastes along its flow path. Like pH, DO in natural water tend to fluctuate on a diurnal basis, but strong deviations from its natural average as in this study usually point to an external cause. As advanced previously [34,35], the studied sites of Mpanga river may not support aquatic life and the water from them is equally unsuitable for use without treatment.

Total phosphate (TP) and total nitrate (TN) concentrations of the samples increased ($p < 0.05$) at the effluent discharge point and then decreased downstream. The increment could be due to the high concentration of phosphates and nitrates in the effluents. However, all the TP (except at Kabundaire) and TN levels were within NEMA limits. These values though comparable to those reported in Nigeria [21,24] were lower than reported by other preceding studies [18,19, 23,25,26]. Increase in TP and TN levels could also be due to the use of detergents for cleaning in the facility. A previous study [16] reported that TN concentrations were elevated in Mpanga river headwaters but declined exponentially in the urban area of Fort Portal and rose again downstream until Kamwenge district. Nitrates in water may cause Blue Baby syndrome [23]. In tandem with phosphates, nitrates can at high concentrations be harnessed by microorganisms and algae, triggering eutrophication and algal bloom [23].

Microbial examination confirmed the presence of coliforms which are indicators of fecal contamination. This was in tandem with the poor sanitation observed in the area. The gross increase in coliform counts at the discharge point and downstream is attributable to fecal contamination by abattoir wastewater. Total coliform counts recorded were comparable to those reported previously [18,19] but several folds lower than was reported for Kalerwe abattoir in Uganda [2]. The high coliform counts observed in samples taken after Mpanga market could be due to additional sewage it receives from market latrines located directly on the banks and from the heavily polluted Nyakimya stream that joins Mpanga river [16].

Table 1. Quality parameters of water samples from selected sites on Mpanga river in Kabundaire abattoir propinquity, Uganda in comparison with previous studies done in other developing countries

Country	Study site (abattoir)	pH	Temperature (°C)	Dissolved oxygen (mg/L)	Total phosphates (mg/L)	Total Nitrogen (mg/L)	<i>E. coli</i> ($\times 10^3$)	Total coliforms ($\times 10^4$)	Authors
Uganda	A	6.93 \pm 0.02 (7.10 \pm 0.14)	22.3 \pm 0.18 (22.0 \pm 0.14)	0.24 \pm 0.03 (0.22 \pm 0.01)	7.70 \pm 0.14 (6.90 \pm 0.02)	4.20 \pm 0.05 (6.00 \pm 0.02)	2.0 \pm 0.5 (1.1 \pm 0.1)	6.2 \pm 0.7 (2.6 \pm 0.1)	This Study
	B	7.00 \pm 0.08 (7.30 \pm 0.01)	22.6 \pm 0.14 (22.2 \pm 0.14)	0.26 \pm 0.02 (0.23 \pm 0.01)	7.10 \pm 0.00 (6.70 \pm 0.02)	4.00 \pm 0.22 (6.30 \pm 0.04)	0.4 \pm 0.0 (1.1 \pm 0.2)	1.4 \pm 0.2 (2.4 \pm 0.3)	
	C	7.90 \pm 0.16 (7.30 \pm 0.02)	23.6 \pm 0.26 (22.9 \pm 0.23)	0.01 \pm 0.00 (0.07 \pm 0.02)	10.00 \pm 0.03 (6.70 \pm 0.05)	9.70 \pm 0.02 (6.20 \pm 0.03)	12.0 \pm 2.0 (5.4 \pm 0.1)	480.0 \pm 33.6 (3.6 \pm 0.2)	
	D	7.70 \pm 0.01 (7.40 \pm 0.00)	23.0 \pm 0.29 (22.7 \pm 0.22)	0.02 \pm 0.01 (0.01 \pm 0.00)	9.10 \pm 0.05 (6.40 \pm 0.18)	8.00 \pm 0.26 (6.25 \pm 0.52)	2.0 \pm 2.6 (3.5 \pm 1.8)	58.0 \pm 1.3 (3.0 \pm 0.1)	
	E	7.46 \pm 0.01 (7.00 \pm 0.18)	22.8 \pm 0.15 (22.2 \pm 0.15)	0.03 \pm 0.01 (0.08 \pm 0.03)	7.90 \pm 0.02 (6.40 \pm 0.08)	6.50 \pm 0.00 (6.10 \pm 0.08)	30.0 \pm 1.6 (4.8 \pm 0.1)	660.0 \pm 25.8 (6.1 \pm 0.1)	
	F	7.50 \pm 0.04 (7.40 \pm 0.03)	22.5 \pm 0.14 (22.1 \pm 0.19)	0.03 \pm 0.01 (0.09 \pm 0.01)	7.60 \pm 0.03 (6.30 \pm 0.03)	6.30 \pm 0.03 (6.10 \pm 0.08)	6.6 \pm 2.4 (48.0 \pm 1.8)	48.1 \pm 1.9 (6.0 \pm 0.3)	
Cameroon	Ekona	7.41-7.55	22.6-23.7	Not determined	Not determined	12.90-27.45	Not determined	Not determined	[25]
	Mutegene	8.13-8.36	22.2-22.6	Not determined	Not determined	12.6-29.2	Not determined	Not determined	
	Muea	7.51-7.72	21.70-21.95	Not determined	Not determined	12.3-15.75	Not determined	Not determined	
Uganda	Nsooba channel	8.21-9.05	21.98- 22.18	Not determined	8.77-241.03	0.61-4.16	Not determined	4.4 x 10 ⁸ -5.7x 10 ⁹	[2]
Ethiopia	Kera abattoir	7.30	26.55	Not determined	67.33	1450.0	Not determined	4.40 x 10 ²	[19]
	Luna abattoir	7.24	28.12	Not determined	13.00	615.00	Not determined	6.61 x 10 ¹	
Uganda	Kampala city abattoir	7.48 \pm 0.08 (8.41 \pm 0.16)	26.91 \pm 0.55 (25.16 \pm 0.82)	3.78 \pm 0.31 (6.18 \pm 1.48)	33.37 \pm 3.84 (28.14 \pm 3.72)	63.8 \pm 19.6 (58.6 \pm 18.70)	Not determined	Not determined	[26]
Kenya	Kavuthi stream	6.66-9.14	17.88- 23.83	3.70-6.80	Not determined	Not determined	Not determined	Not determined	[27]

Country	Study site (abattoir)	pH	Temperature (°C)	Dissolved oxygen (mg/L)	Total phosphates (mg/L)	Total Nitrogen (mg/L)	<i>E. coli</i> ($\times 10^3$)	Total coliforms ($\times 10^4$)	Authors
Rwanda	Mpazi river (Nyabugogo)	7.2-8.2	22.3-25.8	Not determined	0.71– 937	3.2-676.6	Not determined	$0.00-33 \times 10^{-1}$	[18]
Nigeria	Omu-Aran wells	6.89-7.65	6.90-26.70	7.23-5.80	Not determined	2.71-1.93	Not determined	Not determined	[24]
	Ogun river (Kara)	5.74 - 5.93	27.3 - 27.6	3.09 - 5.09	0.34 – 109	6.8 - 2,395	Not determined	Not determined	[23]
	River Illo	6.2-6.9	Not determined	0.01-0.46	Not determined	0.1-0.22	Not determined	Not determined	[20]
	Wells (Minna)	8.4	26.2	0.86-1.50	0.60-2.04	0.60-1.00	Not determined	Not determined	[21]
	Oshunkaye stream	6.92– 8.18	32 – 34	Not determined	142– 180	62–159	Not determined	Not determined	[22]
NEMA standards		6.0 – 8.0	20.0-35.0	≥ 2.0	10.0	20.0	Not specified	Not specified	[2]

*Study sites on Mpanga river: A-Kahungabunyoni, B-Kagote A (Upstream); C-Kabundaire, D-Mpanga market (Point of effluent discharge); E-Rwabuhinga, and F-Kitumba (Downstream). Values in parenthesis are means \pm standard deviations for measurements taken in the evening hours. For [26], values are for inflow effluents while those in parenthesis are for out flowing effluents. Total coli forms and *E. coli* counts are reported in CFU/100 ml. NEMA-Uganda National Environmental Management Authority*

Coliforms indicate possible presence of *Salmonella*, rotaviruses, hepatitis E virus, *E. coli* O157:H7, *Yersinia enterocolitica*, *Campylobacter jejuni*, *Ascaris* species, *Giardia lamblia* and *Cryptosporidium parvum* in the effluents [23,36, 37]. Svanström [37] reported that Kampala city abattoir wastewater contained high levels of *E. coli*, *Enterococci*, *Citrobacter freundii* and *Shigella* than earthworms and Marabou stork faeces.

Overall, Mpanga river water parameters were higher ($P = .05$) for morning samples than evening samples. This is because peak hours of abattoir operations in Uganda are usually during morning hours (midnight to 10:00 am) and decreases in the evening [2].

The number of animals slaughtered in Kabundaire abattoir between December 2018 and April 2019 is depicted in Fig. 1. while Table 2 shows the volume of water used and wastewater generated in the same period.

About 133 cattle, 78 goats and 33 sheep are slaughtered in Kabundaire abattoir every month. The actual number varies by month as this depends on the demand for meat [18]. The

highest slaughter was in December 2018, corroborating a previous observation in Rwanda [18]. This could be because December houses the Christmas and new year celebrations which in Uganda are characterized by consumption of meat by nearly every family.

In this study, an attempt was also made to estimate the amount of water used and the wastewater generated in Kabundaire abattoir. This could be a preliminary step in planning for treatment of the effluents prior to discharge. The estimated average daily usage of water was 43.2 m³/day while wastewater generation rate was 50.4 m³/day (Table 2). Extrapolated, this translates into 15,768.0 m³/year and 18,396.0 m³/year of water used and wastewater generated for December 2018 to December 2019, respectively. Muhirwa et al [18]. reported water usage of 25,057.25 m³/year with wastewater generation of 26,120 m³ for Nyabugogo abattoir (Rwanda) where estimated 972 cattle and 2,592 sheep and goats were slaughtered between July 2006 to July 2007. At present, there is no economical, stable and efficient facility to stabilize, deodorize or recover usable energy from Kabundaire abattoir effluents.

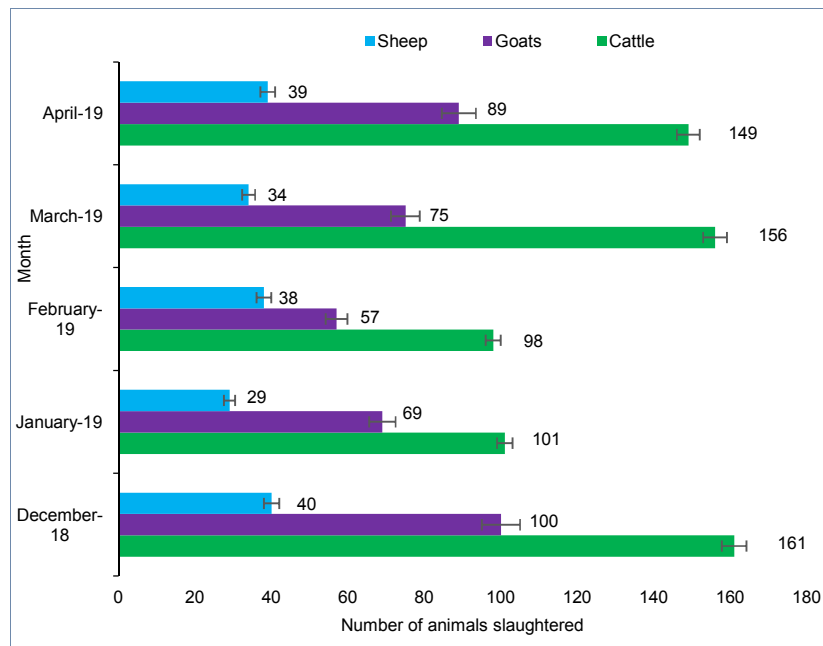


Fig. 1. Average number of animals slaughtered per day in Kabundaire abattoir between December 2018 and April 2019 (Data source: Kabundaire abattoir records)

Table 2. Average water consumption and wastewater produced at Kabundaire abattoir between December 2018 and April 2019

Month	Total water intake (m ³)*	Water usage (m ³ /day)	Total wastewater produced (m ³)	Wastewater released (m ³ /day)
December 2018	2,817.9	90.9	3,143.4	101.4
January 2019	1,097.4	35.4	1,354.7	43.7
February 2019	604.8	21.6	781.2	27.9
March 2019	895.9	28.9	1,023.0	33.0
April 2019	1,176.0	39.2	1,374.0	45.8
Monthly average	1,318.4	43.2	1,535.3	50.4
Annual rate		15,768.0		18,396.0

* Water intake estimated as per tap meter reading assuming that 82% of it is used in abattoir processes. Daily rates were computed by dividing the total volume of water used and wastewater generated by 31, 31, 28, 31 and 30 days that made up December 2018, January 2019, February 2019, March 2019 and April 2019 respectively. Annual rates were computed by multiplying daily volumes with 365 days which make up a calendar year (since the abattoir operates daily). 1 m³ = 1,000 liter

4. CONCLUSION

Discharge of effluents from Kabundaire abattoir into Mpanga river negatively affects its water quality. Mpanga river water is not safe for domestic use without further treatment/purification. We recommend that an anaerobic wastewater treatment facility should be adopted at the abattoir so as to blend industrialization with environmental conservation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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