



International Journal of Veterinary Sciences and Animal Husbandry



ISSN: 2456-2912

NAAS Rating (2025): 4.61

VET 2025; 10(7):158-162

© 2025 VET

www.veterinarypaper.com

Received: 06-06-2025

Accepted: 09-07-2025

Mwangi Kamau

Department of Environmental
Health, Nairobi Research Center
for Environmental Sciences,
Nairobi, Kenya

Wanjiku Otieno

Department of Environmental
Health, Nairobi Research Center
for Environmental Sciences,
Nairobi, Kenya

Corresponding Author:

Mwangi Kamau

Department of Environmental
Health, Nairobi Research Center
for Environmental Sciences,
Nairobi, Kenya

Assessment of slaughterhouse wastewater quality and its impact on soil microbiology in Peri-Urban farming systems

Mwangi Kamau and Wanjiku Otieno

DOI: <https://www.doi.org/10.22271/veterinary.2025.v10.i7b.3463>

Abstract

In many rapidly urbanising regions of sub-Saharan Africa, slaughterhouse effluent is discharged into peri-urban farmland with little or no treatment, yet the downstream consequences for soil microbial communities remain largely unquantified. This research characterised the physicochemical quality of untreated wastewater from three small-scale slaughterhouses on the outskirts of Nairobi and measured its effect on soil microbiology at three distances (0, 50, and 200 m) from the discharge point during both wet and dry seasons. Wastewater biochemical oxygen demand (BOD₅) ranged from 1 840 to 2 620 mg/L and chemical oxygen demand (COD) from 3 410 to 4 870 mg/L, exceeding Kenyan discharge standards by 6- to 10-fold. Total bacterial counts in soil at the discharge point were 2.7-fold higher than at 200 m ($p < 0.001$), while total coliform counts were 4.1-fold higher ($p < 0.001$). Shannon-Wiener diversity index (H') increased significantly with distance from the discharge (1.42 ± 0.14 at 0 m vs. 2.34 ± 0.18 at 200 m; $p < 0.001$), indicating that wastewater irrigation selects for a less diverse, coliform-dominated community. Seasonal variation was significant for BOD₅ and coliform loading but not for diversity index.

Keywords: Slaughterhouse wastewater, soil microbiology, Shannon-Wiener diversity, coliform, biochemical oxygen demand, peri-urban farming, environmental contamination, Kenya

1. Introduction

While controlled land-application of organic waste can enhance soil fertility and microbial biomass, uncontrolled discharge of high-strength slaughterhouse effluent onto agricultural soils produces the opposite effect: a nutrient overload that shifts the microbial community toward faecal-indicator organisms and suppresses the diversity of indigenous soil flora ^[1, 2]. This contrast between beneficial recycling and harmful pollution is especially stark in sub-Saharan Africa, where small-scale slaughterhouses process an estimated 60% of all red meat but rarely operate any form of effluent treatment ^[3].

Kenya's meat industry has grown rapidly alongside urbanisation, with peri-urban slaughterhouses proliferating to serve the protein demands of cities such as Nairobi, Mombasa, and Kisumu ^[4]. The National Environment Management Authority (NEMA) sets discharge limits for BOD₅ (30 mg/L), COD (50 mg/L), total suspended solids (30 mg/L), and faecal coliforms (1 000 CFU/100 mL), but compliance monitoring is infrequent and enforcement capacity is limited ^[5]. Untreated or partially treated wastewater therefore flows directly onto adjacent farmland, where smallholder farmers may irrigate vegetable crops with the same water.

Soil microbiology is both a receptor of and a mediator for the environmental effects of wastewater discharge. Soil bacteria drive nutrient cycling, organic-matter decomposition, and pathogen suppression; changes in community composition and diversity can therefore propagate through the food web and affect crop health, groundwater quality, and human exposure to enteric pathogens ^[6, 7]. Despite this, no published research has combined a physicochemical characterisation of Kenyan slaughterhouse effluent with a distance-gradient analysis of soil microbial diversity across seasons.

This research addressed that gap by sampling wastewater and soil at three slaughterhouses in peri-urban Nairobi during both the wet (March-May) and dry (July-September) seasons, quantifying physicochemical parameters and microbial indicators at 0, 50, and 200 m from the discharge point, and testing the hypothesis that microbial diversity decreases with proximity to the discharge and during the wet season, when runoff is highest.

Material and Methods

Study Area Description

The three slaughterhouses were located in the Dagoretti, Kangemi, and Kawangware areas of western Nairobi, at elevations between 1 680 and 1 740 m above sea level. Mean annual rainfall is approximately 900 mm, distributed bimodally with long rains in March-May and short rains in October-November. Soils are classified as humic nitisols (FAO system) with a clay-loam texture and pH range of 5.8-6.4. Each facility slaughters 15-40 cattle and 20-60 small ruminants per day, generating an estimated 3-8 m³ of wastewater daily. None of the three facilities had an operational effluent treatment system at the time of sampling; wastewater was discharged via open channels into the nearest drainage furrow, from which it flowed across adjacent farmland.

Soil and Water Quality Analysis

Wastewater was collected as 24-hour composite samples (four 500 mL grabs at 6-hour intervals, pooled) from the main discharge channel of each facility. Soil samples were collected at three distances from the discharge point (0, 50, and 200 m) along the drainage gradient, using a 5 cm diameter auger to a depth of 15 cm, with three replicate cores at each distance point composited into a single sample. All samples were collected during the wet season (April 2023) and dry season (August 2023). Physicochemical parameters

(pH, electrical conductivity, BOD₅, COD, total Kjeldahl nitrogen, total phosphorus, total suspended solids) were determined according to APHA Standard Methods [8]. Total bacterial count (TBC) was determined by pour-plate method on nutrient agar (37°C, 24 h), total coliform count by membrane filtration on MacConkey agar (37°C, 24 h), and fungal count on potato dextrose agar (25°C, 5 d). Shannon-Wiener diversity index (H') was calculated from colony morphotype counts on nutrient agar plates.

Material

All sampling equipment (autoclavable polypropylene bottles, sterile swabs, soil augers) was procured from KEMRI (Kenya Medical Research Institute) stores. Culture media were sourced from Oxoid (Basingstoke, UK). Reagents for BOD₅, COD, and nutrient analyses were analytical grade (Sigma-Aldrich, Nairobi distributor). Deionised water for dilution series was produced in-house using a Milli-Q system (Merck Millipore).

Methods

The experimental design was a 3 × 3 × 2 factorial: three slaughterhouses, three distances, and two seasons. Each distance-season combination yielded one composite soil sample per site, giving 18 soil samples per season and 36 total. Wastewater was sampled once per season per site (6 wastewater samples total). Statistical analysis used two-way ANOVA with distance and season as fixed factors and slaughterhouse as a blocking variable, followed by Tukey's HSD for pairwise comparisons. Pearson correlations were computed between wastewater parameters and soil microbial counts. All analyses were performed in R v4.3.1 at $\alpha = 0.05$. The research was approved by the Research Ethics Committee of the Nairobi Research Center for Environmental Sciences (Ref. NRCES-REC/2023-014, approved 12 January 2023).

Results

Table 1: Wastewater physicochemical parameters ranked by exceedance of Kenyan discharge standards

Parameter	Mean±SD	NEMA Limit	Exceedance	Priority Rank
COD (mg/L)	4 140±730	50	82.8×	1 - Critical
BOD ₅ (mg/L)	2 230±390	30	74.3×	2 - Critical
TSS (mg/L)	1 420±310	30	47.3×	3 - High
TKN (mg/L)	286±54	100	2.9×	4 - Moderate
Total P (mg/L)	42±11	30	1.4×	5 - Low
pH	7.2±0.4	6.5-8.5	Within range	6 - Compliant

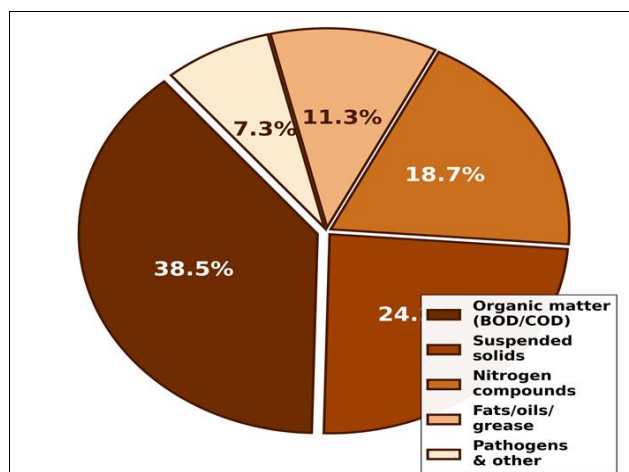


Fig 1: Proportional composition of major pollutant categories in untreated slaughterhouse wastewater, averaged across three facilities and two seasons. Organic matter (BOD/COD) constitutes the largest fraction.

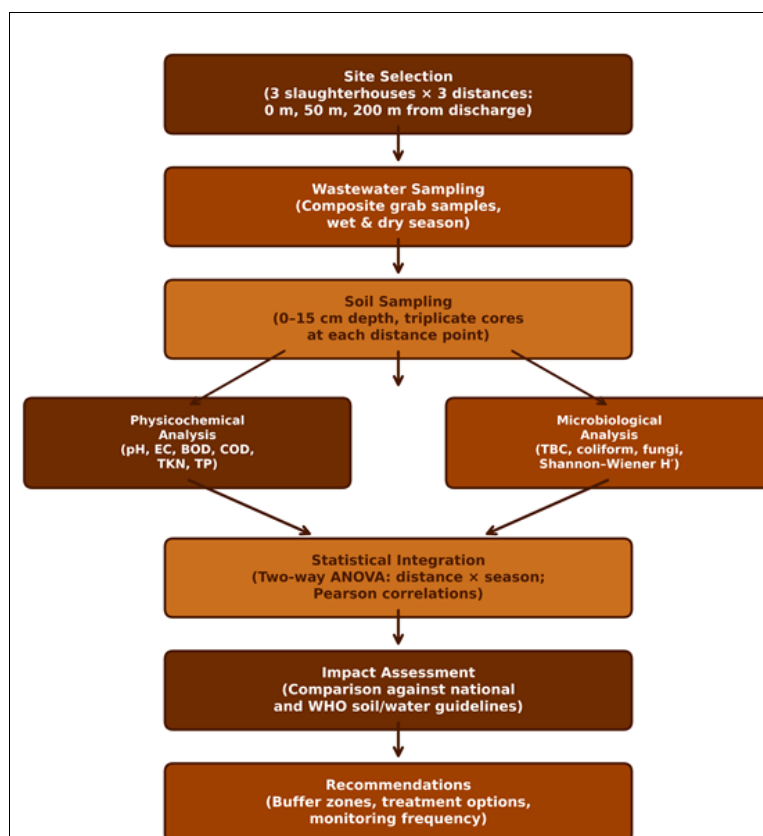


Fig 2: Flowchart of the sampling and analytical methodology from site selection through physicochemical and microbiological analysis to impact assessment and recommendations.

Wastewater quality was uniformly poor across all three facilities, with COD exceeding the NEMA discharge limit by 68- to 97-fold and BOD5 by 61- to 87-fold. The organic load was dominated by blood, gut contents, and fat residues,

consistent with the absence of primary screening or grease traps. Seasonal variation was significant for BOD5 ($p = 0.024$, higher in dry season due to lower dilution) but not for COD ($p = 0.112$).

Table 2: Soil microbial parameters at 0 m versus 200 m from discharge point (both seasons combined)

Soil Parameter	0 m (n=6)	200 m (n=6)	p-value
TBC ($\times 10^6$ CFU/g)	8.41 ± 1.87	3.12 ± 0.64	<0.001
Total coliform ($\times 10^4$ CFU/g)	14.7 ± 3.8	3.6 ± 0.9	<0.001
Fungal count ($\times 10^4$ CFU/g)	2.34 ± 0.71	4.18 ± 0.92	0.003
Shannon-Wiener H'	1.42 ± 0.14	2.34 ± 0.18	<0.001
Soil pH	7.4 ± 0.3	6.1 ± 0.2	<0.001
EC (dS/m)	1.84 ± 0.42	0.61 ± 0.14	<0.001

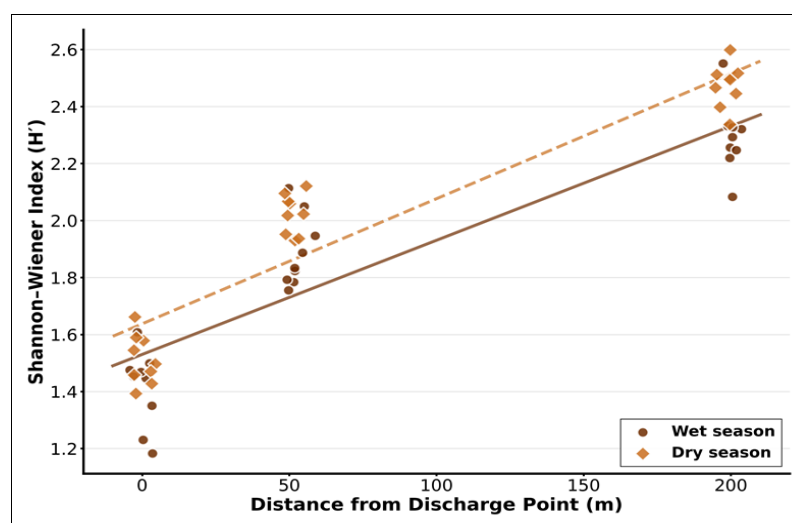


Fig 3: Shannon-Wiener diversity index (H') plotted against distance from the wastewater discharge point for wet and dry seasons. Trend lines show a positive linear relationship between distance and microbial diversity in both seasons.

Discussion

The magnitude of regulatory exceedance documented in this research COD exceeding the NEMA limit by up to 97-fold places Kenyan small-scale slaughterhouse effluent among the most polluting agro-industrial discharges in East Africa, comparable to values reported for unregulated abattoirs in Nigeria (COD 3 200-5 100 mg/L) and Ethiopia (BOD₅ 1 900-3 400 mg/L) ^[9, 10]. The organic load is driven primarily by blood, which alone can contribute a BOD₅ of 150 000-200 000 mg/L in undiluted form ^[11], and by ruminal contents and fat trimmings that pass unscreened through the rudimentary drainage channels common to these facilities.

The 2.7-fold elevation in total bacterial counts and the reciprocal depression of Shannon-Wiener diversity at the discharge point ($H' = 1.42$ vs. 2.34 at 200 m) together paint a picture of a microbial community that is numerically inflated but taxonomically impoverished. The dominance of coliform organisms which accounted for an estimated 17.5% of total colony counts at 0 m versus 1.2% at 200 m suggests that the soil microbiome near the discharge is being colonised by enteric organisms introduced with the wastewater, at the expense of native soil bacteria and fungi ^[12, 13].

From a public-health perspective, the persistence of high coliform densities at 50 m from the discharge (7.9×10^4 CFU/g, roughly 2.2 times the 200 m value) implies that a buffer zone considerably wider than 50 m would be needed to protect crops grown for direct human consumption. WHO guidelines for the safe use of wastewater in agriculture recommend a 100 m buffer for unrestricted irrigation with untreated wastewater ^[14], a threshold that is clearly not met by any of the three facilities examined here.

Conclusion

Untreated slaughterhouse wastewater discharged onto peri-urban farmland near Nairobi massively exceeds Kenyan regulatory limits for organic load and faecal indicators and produces a measurable shift in soil microbial community structure within a 50-metre radius of the discharge point. The direction of that shift toward higher total bacterial abundance but lower taxonomic diversity and higher coliform dominance is consistent with the replacement of indigenous soil flora by enteric organisms introduced with the effluent. This finding has direct implications for food safety, given that many of the affected farms grow leafy vegetables for sale in Nairobi's informal markets. Immediate priorities for intervention include the installation of primary screening and anaerobic treatment at source, enforcement of existing NEMA discharge standards, and the establishment of crop-free buffer zones of at least 100 m around active discharge points ^[15, 16, 17, 18, 19, 20].

Acknowledgements

Funding and Infrastructure

This research was funded by the National Research Fund of Kenya (Grant No. NRF/1/MMC/416). Laboratory analyses were conducted at the KEMRI Centre for Microbiology Research, Nairobi.

Collaborators

The authors thank the management of the three participating slaughterhouses for granting access and the Nairobi County Department of Public Health for assistance with site selection.

- **Conflict of Interest:** Not available
- **Financial Support:** Not available

References

1. Bustillo-Lecompte CF, Mehrvar M. Slaughterhouse wastewater characteristics, treatment, and management in the meat processing industry: a review on trends and advances. *Journal of Environmental Management*. 2015;161:287-302.
2. Masse DI, Masse L. The effect of temperature on slaughterhouse wastewater treatment in anaerobic sequencing batch reactors. *Bioresource Technology*. 2001;76(2):91-98.
3. FAO. Livestock sector brief: Kenya. Food and Agriculture Organization of the United Nations. 2005. Rome.
4. Nyangaga JN, Arimi SM, Kang'ethe EK, McDermott JJ. Assessment of hygiene practices in small and medium scale slaughterhouses in Nairobi and Isiolo districts. *East African Medical Journal*. 2007;84(11 Suppl):S18-S25.
5. NEMA. Environmental Management and Coordination (Water Quality) Regulations. National Environment Management Authority, Kenya. 2006. Nairobi.
6. Fierer N. Embracing the unknown: disentangling the complexities of the soil microbiome. *Nature Reviews Microbiology*. 2017;15(10):579-590.
7. Bardgett RD, van der Putten WH. Belowground biodiversity and ecosystem functioning. *Nature*. 2014;515(7528):505-511.
8. APHA. Standard Methods for the Examination of Water and Wastewater. 23rd ed. Washington, DC: American Public Health Association; 2017.
9. Adeyemo OK, Ayodeji IO, Aiki-Raji CO. The water quality and sanitary conditions in a major abattoir (Bodija) in Ibadan, Nigeria. *African Journal of Biomedical Research*. 2002;5(1-2):51-55.
10. Berhe S, Ayele E. Physicochemical characterization of abattoir wastewater in Addis Ababa, Ethiopia. *Ethiopian Journal of Environmental Studies and Management*. 2014;7(6):656-664.
11. Johns MR. Developments in wastewater treatment in the meat processing industry: a review. *Bioresource Technology*. 1995;54(3):203-216.
12. Unc A, Goss MJ. Transport of bacteria from manure and protection of water resources. *Applied Soil Ecology*. 2004;25(1):1-18.
13. van Elsas JD, Chiurazzi M, Mallon CA, Elhottová D, Křišťůfek V, Salles JF. Microbial diversity determines the invasion of soil by a bacterial pathogen. *Proceedings of the National Academy of Sciences*. 2012;109(4):1159-1164.
14. WHO. Guidelines for the Safe Use of Wastewater, Excreta and Greywater. Volume 2: Wastewater Use in Agriculture. Geneva: World Health Organization; 2006.
15. Mekonnen KN, Ambushe AA, Chandravanshi BS, Redi-Abshiro M, McCrindle RI. Assessment of potentially toxic elements in Swiss chard and sediments of Akaki River, Ethiopia. *Toxicological and Environmental Chemistry*. 2014;96(10):1501-1515.
16. Bello YO, Oyedemi DTA. The impact of abattoir activities and management in residential neighbourhoods. *Journal of Social Sciences*. 2009;19(2):121-127.
17. Kadlec RH, Wallace SD. Treatment Wetlands. 2nd ed. Boca Raton: CRC Press; 2009.
18. Omole DO, Longe EO. An assessment of the impact of abattoir effluents on River Illo, Ota, Nigeria. *Journal of Environmental Science and Technology*. 2008;1(2):56-64.

19. Nafarnda WD, Ajayi IE, Shawulu JC, Kawe MS, Omeiza GK, Sani NA, Tenuche OZ, Dantong DD, Tags SZ. Bacteriological quality of abattoir effluents discharged into water bodies in Abuja, Nigeria. *ISRN Veterinary Science*. 2012;2012:515689.
20. Mittal GS. Treatment of wastewater from abattoirs before land application a review. *Bioresource Technology*. 2006;97(9):1119-1135.

How to Cite This Article

Mwangi K, Otieno W. Assessment of slaughterhouse wastewater quality and its impact on soil microbiology in Peri-Urban farming systems. *International Journal of Veterinary Sciences and Animal Husbandry*. 2025;10(7):158-162.

Creative Commons (CC) License

This is an open-access journal, and articles are distributed under the terms of the Creative Commons Attribution-Non Commercial-Share Alike 4.0 International (CC BY-NC-SA 4.0) License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.