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Research Article

Bacteriological and physicochemical characterization of campus waste water discharged into the drainage channels of Nigeria Police Academy, Wudil, Kano

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Abstract

Management and safe disposal of wastewater are the most critical environmental and public health challenges of the 21st century, particularly within developing nations. The overarching aim of this research was to characterize the bacteriological quality of wastewater discharged from the Nigeria Police Academy, Wudil, into its drainage channels and evaluating its potential environmental and public health risks. This study assessed the physicochemical and microbiological quality of wastewater across three sampling points (A, B, C) on Nigeria Police Academy Kano campus, where wastewater samples were collected and analyzed according to standard APHA methods for key parameters. Results indicated a progressive deterioration in water quality from point A to C. Physicochemical analysis revealed that parameters significantly exceeded permissible limits (WHO/NSDWQ) downstream ($p < 0.05$), with dissolved oxygen (1.9 – 3.2 mg/L) falling below the standard (≥5.0 mg/L), while BOD (42.5 – 63.7 mg/L) and COD (98.7–138.6 mg/L) increased significantly. Microbiologically, all bacterial counts (total heterotrophic bacteria, total coliforms, fecal coliforms, enterococci) showed a significant increasing trend from point A to C, ($p < 0.05$) with fecal indicators (E. coli, Enterococci) far exceeding the WHO standard of 0 cfu/100mL. Four predominant bacterial isolates were identified: *Escherichia coli,(25), Klebsiella pneumoniae,(15),Pseudomonas aeruginosa,(10)* and *Enterococcus faecalis* (8).Antibiotic susceptibility testing revealed high resistance rates among these isolates, particularly to ampicillin (70 - 80%) and other tested antibiotics. The study revealed that the campus wastewater was of poor quality, constituted a pollution source, and harbored multidrug-resistant bacteria, posing a significant health risk and highlighting a critical need for improved wastewater treatment before discharge.

Keywords: Antibiotic, bacteriological, coliforms, physicochemical, wastewater.

1. Introduction

The management and safe disposal of wastewater represent critical environmental and public health challenges today within developing nations. In institutional settings such as universities and academies with large, concentrated populations, the generation of significant volumes of domestic wastewater is inevitable. The effluent, if not properly treated and managed, poses a profound risk to campus community and the surrounding ecosystem. The Nigeria Police Academy (POLAC) in Wudil, Kano State, is a premier institution tasked with the training of future officers of the Nigerian Police Force. Like any large academic community, its daily operations encompassing student hostels, staff quarters, cafeterias, hospitals, and administrative blocks generate substantial quantities of domestic wastewater. This effluent, a complex mixture of organic matter, nutrients, and, most critically, pathogenic microorganisms, is typically discharged into the environment through drainage channels.

The central problem underpinning this research is the lack of empirical data on the bacteriological quality of this discharged wastewater. It is unknown which specific pathogenic bacteria are present, in what concentrations they exist, and what level of threat they pose as they move through the drainage systems (Michael-Kordatou et al., 2018). These channels are not isolated; they ultimately connect to larger water bodies or seep into the groundwater, which may be used for irrigation or even as a source of water by downstream communities (Akanbi et al., 2019). Furthermore, the open drainage systems common in such settings facilitate direct human contact, insect vector breeding, and environmental contamination (Abdullah et al., 2024).

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The absence of a functional wastewater treatment plant within the academy, a common issue in many Nigerian tertiary institutions as noted by Osuolale and Okoh (2017), Therefore, the core research problem is the uncharacterized and potentially hazardous bacteriological load of POLAC's wastewater effluent and its subsequent pathway into the local environment, creating a nexus of health risks that remain unquantified and unaddressed.

The justification for this research is multifactorial, spanning public health, environmental integrity, institutional accountability, and policy development. Primarily, the health implications are severe and immediate. Wastewater is a known reservoir for a plethora of enteric pathogens, including *Escherichia coli, Salmonella spp., Shigella spp.,* Vibrio cholerae, and Campylobacter jejuni (Odonkor & Ampofo, 2013; Grassly et al., 2024).

The discharge of water laden with these pathogens into open drains creates a significant point source for the spread of waterborne diseases such as typhoid fever, dysentery, cholera, and severe gastroenteritis. The population at risk includes not only the cadets and staff of the academy but also the residents of Wudil town who live in proximity to these drainage channels and may rely on contaminated water sources for domestic use. Children playing near these drains are particularly vulnerable.

From an environmental perspective, the uncontrolled discharge of high-strength organic and bacterial pollutants leads to the eutrophication of receiving water bodies, degradation of aquatic life, and contamination of soil and groundwater resources (Ugochukwu & Onuorah, 2018). This research will provide baseline data on the pollution load, which is the first step in advocating for and designing appropriate remediation strategies.

Furthermore, the findings of this study hold significant institutional value. As a law enforcement training facility, the Nigeria Police Academy has a duty of care to its inhabitants and a responsibility to be a model of best practices. Empirical evidence from this research will serve as a powerful advocacy tool for the academy's administration and stakeholders to prioritize and invest in sustainable wastewater management infrastructure, such as constructing or rehabilitating a sewage treatment plant. It aligns with the United Nations Sustainable Development Goal 6, which aims to ensure availability and sustainable management of water and sanitation for all (United Nations, 2018). Without scientific data, the urgency of the situation may be overlooked.

Finally, on a broader scale, this study will contribute to the sparse body of knowledge regarding wastewater quality from institutional settings in Northern Nigeria. The data generated will be invaluable for public health officials, environmental regulators, and policymakers in crafting localized regulations and monitoring frameworks. It will also serve as a reference point for similar studies in other institutions, fostering a culture of environmental surveillance and evidence-based public health intervention. The overarching aim of this research is to characterize the bacteriological quality of wastewater discharged from the Nigeria Police Academy, Wudil, into its drainage channels and to assess the potential public health and environmental risks associated with it.

2. Materials and Methods

2.1. Study Area and Sampling points

The study was conducted within the premises of the Nigeria Police Academy, Wudil, Kano State, Nigeria. Three (3) strategic sampling points along the campus wastewater drainage channels were selected to represent a gradient of pollution, from a point of origin (Point A) to a point just before discharge into the external environment (Point C). Sampling point A: located near the Cadets hostels and academic blocks, representing the initial point of wastewater confluence; Sampling point B: situated downstream, after the wastewater flow had passed through the lecture halls and administrative blocks; Sampling point C: located at the final discharge point at the periphery of the academy campus, just before the wastewater enters the public drainage system.

2.2. Sample collection and transportation

Samples were collected in triplicate from each point monthly over a period of three months; March (dry season) to June (raining season), between 8:00 and 10:00 am to reduce temporal variations in physicochemical and bacteriological parameters. Wastewater samples were collected aseptically following standard procedures (APHA, 2017). At each sampling point, 1 L sterile glass bottles were used to collect composite wastewater samples from a depth of approximately 15-20 cm below the surface. Prior to collection, the bottles were rinsed three times with the water from the sampling point. For bacteriological analysis, separate 500mL sterile bottles containing 0.1mL of 10% sodium thiosulfate (to neutralize any residual chlorine) were used. All samples were immediately placed in a cooler box containing ice packs maintained at approximately 4°C and transported to the laboratory of the Department of Biological Sciences for analysis within 4 hours of collection (Cheesbrough, 2006).

2.3. Physicochemical analysis

The physicochemical parameters of the wastewater samples were analyzed using standard methods (APHA, 2017). Temperature and *pH* were measured in situ at the time of sample collection using a calibrated portable *pH* meter (Model: HI98107, Hanna Instruments) and a mercury-in-glass thermometer to prevent changes due to atmospheric exposure.

2.3.1 Determination of dissolved oxygen (DO)

The water sample was carefully collected in a 300 mL BOD bottle that was submerged in the water body, and filled from the bottom to minimize turbulence. The sample was fixed immediately upon collection; 2 mL of manganous sulfate solution was added to each of the sample. 2 mL of alkaline iodide-azide reagent was also added in the same manner, the contents were mixed vigorously. The resulting precipitate was allowed to settle below then 2 mL of concentrated sulfuric acid had been introduced. The bottle was restoppered and inverted several times until the precipitate had completely dissolved, liberating iodine equivalent to the DO present. A yellow-brown color was

observed. A 203 mL aliquot of the acidified sample was transferred to an Erlenmeyer flask and titrated with standardized sodium thiosulfate (0.025N) until a pale straw color had been reached. Several drops of starch indicator solution were added, producing a blue color. The titration had been continued until the blue color had disappeared. The concentration of DO in mg/L was calculated based on the volume of titrant used.

2.3.2. Determination of 5-day biochemical oxygen demand (BOD_5)

The sample's pH was checked and adjusted to a range of 6.5-7.5 using sulfuric acid solution. Samples with high BOD were serially diluted using specially prepared dilution water. The dilution water was aerated to near-saturation with DO and was supplemented with phosphate buffer (pH 7.2), magnesium sulfate, calcium chloride, and ferric chloride to provide nutrients for microbial growth. Two BOD bottles were filled with the prepared sample (or dilution). The initial DO (D1) in one bottle was measured immediately using the Winkler method described above. The second bottle was then sealed with a ground-glass stopper to exclude air, and its lid was covered with a water seal to prevent evaporation. This bottle was incubated in a dark environment at 20°C ± 1°C for exactly five days. After five days of incubation, the final DO (D2) in the second bottle was measured. The BOD_5 in mg/L was calculated using the formula: BOD_5 (mg/L) = (D1 – D2) Dilution Factor (where the dilution factor for an undiluted sample is 1).

2.3.3. Determination of chemical oxygen demand (COD)

A representative sample was homogenized with 50 mL distilled water was transferred into a 500 mL refluxing flask and a magnetic stir bar was added. Concurrently, a blank was also prepared using 50 mL of distilled water. To each flask, 1 g of mercuric sulfate (added to complex chloride interferences) and 5.0 mL of sulfuric acid reagent were added, and the mixture was swirled to dissolve. Then, 25.0 mL of a standardized 0.0417M potassium dichromate ($K_2Cr_2O_7$) solution was carefully added. While swirling the flask continuously, 70 mL of sulfuric acid solution containing silver sulfate (a catalyst) was also added slowly to ensure thorough mixing. The flask was attached to a condenser, and the solution had been refluxed for 2 hours. After the reflux period, the system had been allowed to cool. The condenser had been washed down with distilled water into the flask. The contents of the flask had been quantitatively transferred to an Erlenmeyer flask. The solution had been diluted to approximately twice its volume with distilled water and allowed to cool to room temperature. Several drops of ferroin indicator was added. The excess potassium dichromate that had not been reduced by the organic matter in the sample had been titrated with standardized ferrous ammonium sulfate (FAS) titrant until the color had changed from a blue-green to a reddish-brown endpoint. The COD value in mg/L had been calculated using the formula: COD (mg/L) = [(A - B) M 8000] / mL of sample Where: A= volume of FAS used for the blank (mL), B = volume of FAS used for the sample (mL), M = molarity of the FAS titrant and 8000 = milliequivalent weight of oxygen (mg/L) 1000 mL/L.

2.3.4. Bacteriological analysis

(a) Enumeration of bacterial load

Serial dilutions (10^{-1} to 10^{-6}) of the wastewater samples were prepared in sterile normal saline (0.85% NaCl). Aliquots (0.1 mL) of appropriate dilutions were inoculated onto selective and non-selective agar media. The pour plate technique was used for the enumeration of bacteria (Cheesbrough, 2006). Total Heterotrophic Bacterial Count (THBC) was determined by plating appropriate dilutions on Plate Count Agar (PCA, Oxoid) and the plates were incubated aerobically at 35-37 °C for 24 hours.

Total Coliform Count was estimated using the most probable number (MPN) technique in Lauryl Tryptose Broth (LTB) with confirmation in Brilliant Green Bile Broth (BGBB) (APHA, 2017). Fecal Coliform (E. coli) Count was determined by sub-culturing positive LTB tubes into Escherichia coli (EC) Broth and incubating at 44.5°C in a water bath for 24 hours. Further confirmation was done on Eosin Methylene Blue (EMB) Agar. Enterococci Count was estimated by plating on Slanetz and Bartley Agar (Oxoid) and incubating at 37°C for 48 hours. Presumptive colonies were confirmed by catalase test and growth in bile aesculin azide medium. And colony counts were counted and expressed as colony-forming units per 100 milliliters (CFU/100mL).

(b) Isolation and Biochemical Characterization of Bacteria

After colony counting, representative isolates from dominant colony types based on morphology, colour, and appearance were sub-cultured onto fresh nutrient agar plates to obtain pure isolates. Pure cultures were stored on nutrient agar slants at 4°C for further characterization. The predominant bacterial isolates were identified based on their cultural morphology, Gram staining reaction, and a series of biochemical tests; catalase test, oxidase test, indole production test, methyl red (MR) test, citrate utilization test, urease test, triple sugar Iron (TSI) agar test, and motility test were carried out to identify isolates to genus or species level, as described by Cheesbrough (2006) and Forbes et al. (2007).

(c) Antibiotic Susceptibility Testing

The antibiotic susceptibility patterns of the predominant bacterial isolates were determined using the Kirby-Bauer disk diffusion method on Mueller-Hinton Agar (MHA) as recommended by the Clinical and Laboratory Standards Institute (CLSI, 2023). A standardized inoculum (0.5 McFarland standard) of each test isolate was swabbed onto the surface of MHA plates. Commercially available antibiotic discs (Oxoid) were aseptically placed on the inoculated plates. The plates were incubated at 37°C for 18-24 hours. The zones of inhibition were measured (diameter in millimetres) and compared with CLSI standard tables to

categorize isolates as Resistant (R), Intermediate (I), or Susceptible (S). The percentages of isolates in each category were calculated according to CLSI guidelines. The antibiotics tested used included; ampicillin (10µg), ceftazidime (30µg), and erythromycin (15µg).

2.3.4. Data Analysis

All measurements (physicochemical and bacteriological counts) were recorded in triplicates, and results expressed as mean ± standard deviation (SD). The data were subjected to a one-way analysis of variance (ANOVA) to determine significant differences in the mean values of parameters across the three sampling points, where significant differences were observed ($p < 0.05$), post-hoc comparisons were performed using Tukey's honest significant difference (HSD) test. Statistical analyses were carried out using the IBM SPSS Statistics version 28.0. Antibiotic resistance data were summarized as percentage of isolates showing resistance, intermediate resistance, or susceptibility for each antibiotic, for each bacterial species.

3. Results

3.1. Physicochemical Parameters of wastewater

Table 1 presents the physical and chemical characteristics of the wastewater, which are key indicators of pollution levels, particularly from organic matter around the area.

Table 1. Physicochemical parameters of campus wastewater at different sampling points

Parameter (Unit)	Sampling point A (Mean ± SD)	Sampling point B (Mean ± SD)	Sampling point C (Mean ± SD)	WHO/NSDWQ Limit
Temperature (°C)	28.4 ± 0.6^{a}	29.2 ± 0.4^{b}	30.1 ± 0.5^{b}	25–30
pH	6.8 ± 0.3^{a}	6.4 ± 0.2^{a}	5.9 ± 0.3^{b}	6.5–8.5
Dissolved Oxygen (mg/L)	3.2 ± 0.4^{b}	2.8 ± 0.3^{b}	1.9 ± 0.2^{c}	≥5.0
BOD (mg/L)	42.5 ± 3.1^{a}	55.3 ± 4.0^{b}	63.7 ± 3.8^{c}	≤30
COD (mg/L)	98.7 ± 6.5^{a}	122.4 ± 7.0^{b}	138.6 ± 5.4^{c}	≤60

Mean values in the same row with different superscripts differ significantly at $p < .05$.

The results revealed that, the temperature of the campus wastewater ranged from 28.4 °C at point A to 30.1 °C at point C, showing a slight but significant increase downstream. These values fell within the WHO/NSDWQ guideline range of 25–30 °C for surface waters. The rising temperature toward point C may reflect cumulative exposure to sunlight and increased organic loading from additional discharges, which can enhance microbial activity and biochemical reactions.

The pH values, 6.8 at point A; 6.4 at point B; 5.9 at point C indicated a gradual shift from near-neutral to slightly acidic conditions. Meanwhile, points A and B remained within the acceptable WHO range of 6.5–8.5, whereas point C dropped below the limit, suggesting acidification due to higher organic decomposition and release of acidic intermediates downstream, which may alter metal solubility and also favor the proliferation of certain pathogenic bacteria. Dissolved oxygen (DO) levels were critically low at all points, decreasing from 3.2 mg/L (point A) to 1.9 mg/L (Point C). These values fell well below the recommended minimum of 5.0 mg/L for aquatic life. Such low DO indicates heavy organic pollution and high microbial respiration, which depletes oxygen and can lead to anaerobic conditions downstream. Both BOD and COD showed a marked and significant ($P<0.05$) increase downstream, BOD rose from 42.5 mg/L to 63.7 mg/L; COD from 98.7 mg/L to 138.6 mg/L, these far exceeded the WHO permissible limits of ≤30 mg/L for BOD and ≤60 mg/L for COD, confirming strong organic and chemical contamination. High BOD/COD indicated large amounts of biodegradable and non-biodegradable substances, consistent with domestic sewage mixed with kitchen and institutional wastewaters. The progressive rise downstream suggests accumulation of pollutants and insufficient self-purification within the drainage channel.

3.2. Bacteriological Counts of campus wastewater

Table 2 presents the microbial population in the wastewater, specifically focusing on indicator organisms whose presence signals fecal contamination and potential health risks.

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Table 2. Bacterial counts of campus wastewater at different sampling points

Parameter (cfu/100 mL)	Sampling point A (Mean ± SD)	Sampling point B (Mean ± SD)	Sampling point C (Mean ± SD)	WHO Standard (cfu/100 mL)
Total Heterotrophic Bacteria	$3.2\times10^5 \pm 0.5^a$	$4.5\times10^5 \pm 0.7^b$	$6.1\times10^5 \pm 0.6^c$	–
Total Coliforms	$1.8\times10^4 \pm 0.3^a$	$2.7\times10^4 \pm 0.4^b$	$3.5\times10^4 \pm 0.5^c$	0.00
Fecal Coliforms (*E. coli)*	$1.2\times10^3 \pm 0.2^a$	$2.1\times10^3 \pm 0.3^b$	$3.0\times10^3 \pm 0.4^c$	0.00
Enterococci	$5.5\times10^2 \pm 0.1^a$	$7.2\times10^2 \pm 0.2^b$	$9.0\times10^2 \pm 0.2^c$	0.00

Mean values in the same row with different superscripts differ significantly at $p < .05$.

Total heterotrophic bacterial counts increased significantly ($P<0.05$) from 3.2×10^5 cfu/100 mL at Point A to 6.1×10^5 cfu/100 mL at Point C. Although there is no WHO limit for total heterotrophic bacteria in wastewater, such high counts are characteristic of untreated domestic effluents. Total coliforms, fecal coliforms (*E. coli*), and *Enterococci* all increased progressively downstream. Total coliforms ranged from 1.8×10^4 to 3.5×10^4 cfu/100 mL, fecal coliforms from 1.2×10^3 to 3.0×10^3 cfu/100 mL, and *Enterococci* from 5.5×10^2 to 9.0×10^2 cfu/100 mL. All these parameters grossly exceeded the WHO standard of 0 cfu/100 mL for potable water and recreational waters. Their high densities indicate intense fecal contamination and the likely presence of enteric pathogens (WHO, 2017). The increase downstream mirrors the trend in BOD and COD, supporting the view that untreated wastewater and runoff from additional sources are being discharged into the drainage.

The high counts at point C showed a considerable public health risk to communities or livestock exposed downstream.

3.3. Biochemical and Antibiotic Susceptibility Profiles

Table 3 identified the specific pathogenic bacteria and their susceptibility to some selected antibiotics. The result of the biochemical tests confirmed the presence of four predominant isolates (enteric and opportunistic pathogens): *Escherichia coli,* (25 isolates); *Klebsiella pneumoniae,* (15 isolates) *Pseudomonas aeruginosa,* (10 isolates) and *Enterococcus faecalis* (8 isolates). *E. coli* isolates were indole- and methyl-red–positive but citrate- and urease-negative, consistent with classical identification, K. pneumoniae was indole-negative but citrate- and urease-positive. *P. aeruginosa* showed oxidase-, catalase-, and citrate-positive reactions. *E. faecalis* was catalase-negative but PYR- and bile-esculin–positive.

Table 3. Biochemical and Antibiotic susceptibility profiles of predominant isolates

Isolate (n)	Key Biochemical Tests (Result)	Resistance (%)	Intermediate (%)	Susceptible (%)
Escherichia coli (25)	Indole +, Methyl Red +, Citrate –, Urease –	Ampicillin 80	10	10
Klebsiella pneumoniae (15)	Indole –, Methyl Red +, Citrate +, Urease +	Ampicillin 70	15	15
Pseudomonas aeruginosa (10)	Oxidase +, Catalase +, Citrate +	Ceftazidime 60	20	20
Enterococcus faecalis (8)	Catalase –, PYR +, Bile Esculin +	Erythromycin 65	20	15

Antibiotic susceptibility tests revealed high resistance rates among the isolates. *E. coli* showed 80 % resistance to Ampicillin with only 10 % susceptible.

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K. pneumoniae displayed 70 % resistance to ampicillin. *P. aeruginosa* demonstrated 60 % resistance to ceftazidime, a third-generation cephalosporin often used for this species. *E. faecalis* showed 65 % resistance to erythromycin. These resistance rates far exceed typical environmental strains and reflect selective pressure from antibiotic use in the surrounding community. The presence of multidrug-resistant bacteria in untreated wastewater poses significant risks for dissemination of antimicrobial resistance genes into the environment.

4. Discussion

The analysis of wastewater from Police academy campus had provided critical insights into the environmental impact of human activities within an academic community. The data presented in the study revealed a concerning pattern of pollution, characterized by significant organic loading, severe oxygen depletion, and high levels of pathogenic and antibiotic-resistant bacteria, which intensified as the wastewater moves through the collection system from sampling point A to C. The physicochemical parameters assessed during the study indicated a clear and statistically significant ($p < 0.05$) trend of deteriorating water quality from sampling point A to C. This progression suggested that, point A was likely an early collection point, point B was mid-stream, and point C was a point just before or at the final discharge, having accumulated waste from a larger section of the campus.

Temperature, while within the typical range for wastewater in tropical or subtropical climates as reported by Abdullahi et al., 2021, shows a slight but significant increase from A to C. This could be attributed to the cumulative effect of microbial activity and biochemical oxidation processes, which are exothermic (release heat), as the wastewater travels further along the sewer line. The pH values showed a significant decrease, becoming increasingly acidic from point A to Point C. This acidification fell outside the WHO/NSDWQ permissible range (6.5–8.5) at Point C, this trend was a classic indicator of ongoing anaerobic processes, hence, the microbial degradation of organic matter produces organic acids and carbon dioxide, which dissolves in water to form carbonic acid (H_2CO_3), thereby lowering the pH (Tchobanoglous et al., 2014; Maldonado Rivera, 2025). This acidic environment may be corrosive to infrastructure in the academy and stressful for aquatic life if discharged without treatment.

The most critical indicators of organic pollution are Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD). The DO levels were critically low and decrease significantly ($P<0.05$) from point A to a near-anoxic at point C, far below the ≥5.0 mg/L standard. This oxygen depletion was a direct consequence of the high BOD and COD values. BOD and COD measure the amount of oxygen required by microorganisms to break down organic matter; high values recorded in this study indicated severe organic pollution from sources like food waste, sewage, and detergents (Akaninwor & Wegwu, 2018). The significant rise in BOD and COD from point A to C confirmed the continuous input of organic pollutants. All values exceed permissible limits, indicating that, the wastewater was heavily laden with organic material that rapidly deplete oxygen in a receiving water body, leading to eutrophication and the death of aerobic aquatic organisms.

The bacteriological analysis revealed an alarmingly high and statistically significant ($p < 0.05$) increase in bacterial counts across all sampling points. The total heterotrophic bacterial count rise, reflecting a rich nutrient environment that supports extensive microbial growth more critically, the presence and increasing concentration of indicator organisms, total coliforms, fecal coliforms specifically *E. coli*, and *Enterococci* confirmed severe fecal contamination of the wastewater. The use of these bacteria as indicators of fecal pollution and potential pathogen presence was also well established by Odonkor & Ampofo, (2013). The values, which were orders of magnitude above the WHO standard of 0.00 cfu/100mL for potable water, represented a serious public health hazard. The progression from point A to C suggested that, human sanitary waste was the major component of the campus effluent. If this untreated or inadequately treated wastewater was discharged into the environment or used for irrigation, it poses a high risk of transmitting waterborne diseases such as cholera, typhoid, dysentery, and gastroenteritis (Ahmed et al., 2022).

This study identified the predominant bacterial isolates and their troubling antibiotic resistance profiles. The isolation of *Escherichia coli, Klebsiella pneumoniae,* Pseudomonas aeruginosa, and *Enterococcus faecalis* was significant as all were reported to be opportunistic pathogens commonly associated with hospital and community acquired infections. The biochemical test results were consistent with the standard identification criteria, for instance, the indole positive, methyl red positive, citrate negative profile was typical for *E. coli*, while *K. pneumoniae* was citrate and urease positive (Mahon et al., 2018).

The antibiotic susceptibility testing revealed a high prevalence rate of resistance among these environmental isolates, *E. coli* and *K. pneumoniae* showed high resistance to ampicillin, a common beta-lactam antibiotic. *P. aeruginosa* exhibited resistance to ceftazidime, a third-generation cephalosporin critical for treating serious infections caused by this organism. *E. faecalis* showed resistance to erythromycin, a macrolide antibiotic. These high resistance percentages were indicative of a significant environmental reservoir of antibiotic-resistant bacteria (ARB) and genes (ARGs) within the campus wastewater. Universities are known to be hotspots for antibiotic consumption (e.g., health clinics, student use), and the effluent from bathrooms and laboratories may contain antibiotic residues (Santra, & Bhadury, 2024). This creates a

selective pressure that favors the survival and proliferation of resistant strains (Karkman et al., 2018). The mixing of bacteria from many individuals in the sewer system facilitates the horizontal transfer of resistance genes, turning the wastewater infrastructure into a bioreactor for the development of multi-drug resistant pathogens (Bengtsson-Palme & Larsson, 2016; Shi, 2025). The discharge of such wastewater directly into the environment contributes to the global spread of antimicrobial resistance (AMR), severely compromising the effectiveness of essential medicines, (Dambrino, & Green, 2022).

5. Conclusion

In conclusion, the results from this study paint a clear picture of heavily polluted campus wastewater. The physicochemical analysis reveals a nutrient-rich, oxygen-depleted, and acidic effluent that violates international standards. The microbiological analysis confirms extreme fecal contamination with dangerously high levels of pathogenic indicator bacteria. Most alarmingly, the characterization of predominant isolates reveals a high prevalence of antibiotic resistance, identifying the wastewater system as a potential breeding ground for resistant pathogens. The findings underscore the critical necessity for an effective and functional wastewater treatment plant for the university campus. However, given the high levels of antibiotic resistance, advanced treatment options such as membrane filtration, ozonation, or UV disinfection may be necessary to effectively remove ARB and ARGs before the effluent is discharged or reused.

Recommendations:

Future studies should focus on quantifying specific antibiotic residues in the wastewater and using molecular techniques (e.g. metagenomics) to fully characterize the resistome present. Furthermore, implementing campus-wide awareness programs on the proper disposal of pharmaceuticals and chemicals is essential to mitigate this growing environmental and health crisis.

Abbreviations

UV	Ultraviolent
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolve oxygen
MPN	Most Probable Number
LTB	Technique in Lauryl Tryptose Broth
BGBB	Brilliant Green Bile Broth
ARB	Antibiotic Resistant Bacteria
ARGs	Antibiotic Resistant Genes
CLSI	Clinical Labortory Standard Institute
POLAC	Police Academy
WHO	World Health Organization

Author Contributions

H .A. Muhammad: Conceptualization, methodology, writing- original draft, **T.J. Hemen:** Methodology , analysis of result**, I.H. Rabia:** Proof Reading and Editing

Conflicts of Interest

The author(s) declare that they have no known competing financial interests, professional affiliations or personal relationships that could have appeared to influence the work reported in this paper,

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