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Evaluation of the use of Effluent Released from a Wastewater Treatment Plant in Zaria, North-West, Nigeria for Irrigation of Vegetables

Ajala Fatima Adekemi[a], Machido Dauda Abdullahi[a], Tijjani Muhammad Bashir[a] and Yusuf Ado Adamu[b].
[a]Department of Microbiology, Faculty of Life Sciences, Ahmadu Bello University, Zaria, Nigeria
[b]Department of Soil Science, Faculty of Agriculture, Ahmadu Bello University, Zaria, Nigeria
*Correspondence author: fatimaadekemi16@gmail.com

Abstract

The use of Water daily accounts for the generation of wastewater requiring treatment. Influent, effluent (discharge point, 400m, 500m downstream), and soil and vegetable samples from fields of effluent-irrigated tomato, lettuce, and onion were sampled. Standard methods were used to analyse physicochemical properties and coliform counts. At the effluent discharge point, values of temperature (24°C), dissolved oxygen (100 mg/L), total dissolved solids (390 mg/L), and phosphate (3.7 mg/L) comply with WHO and NESREA standards for effluent discharge. However, biochemical oxygen demand (60 mg/L), chemical oxygen demand (1200 mg/L), total suspended solids (230 mg/L), nitrate (45 mg/L), and sulphate (480 mg/L) exceeded set limits. Statistical analysis showed no significant differences (P > 0.05) in pH as well as temperature across samples. Significant differences (P ≤ 0.05) occurred in dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, turbidity, total solids, total dissolved solids, total suspended solids, conductivity, nitrate, phosphate, and sulphate. The total coliform count at the point of effluent discharge was 1.0 x10^6 CFU/ml, at 400 m and 500 m downstream was 5.0 x10^5 and 2.4x10^5 CFU/ml, respectively. The faecal coliform count at the point of discharge was 4.1x10^5 CFU/ml, and 2.8x10^5 and 1.5x10^5 CFU/ml respectively at 400 m and 500 m along the effluent flow channel. Statistical analysis indicated significant differences (P ≤ 0.05) in total and faecal coliform counts for influent and effluent samples. However, coliform counts in both soil and vegetable samples exhibited no significant variation (P > 0.05) across plots. The wastewater treatment is inadequate, as seen in physicochemical parameters and high coliform counts. This, indicates the need for an improvement in wastewater management.
Keywords: Effluent, wastewater treatment, physicochemical, coliform.

INTRODUCTION

Water plays a critical role in the sustainability of life on the planet and performs several physiological functions in the maintenance of a healthy lifestyle (Kilic, 2020; WHO, 2022). Freshwater scarcity is one of the most critical challenges of the 21st century (United Nations World Water Development Report, 2023). This scarcity is not merely the lack of physical Water; it is also characterised by economic scarcity due to inadequate infrastructure and institutional scarcity as a result of poor governance (World Bank, 2023). Over the years, Nigeria's water resources have witnessed enormous pressure due to rising population growth of over 200 million people, climate change impacts and the absence of adaptive policy practices to harness the available water resources to meet human, industrial, agricultural and recreational needs (UNESCO, 2020). The agricultural sector is the largest water user globally, representing 70% of total global water withdrawals. Thus, enormous amounts of water are needed to feed the world's population, expected to be 9.7 billion by 2050 (FAO, 2020; UN DESA, 2022). Feeding more people requires more Water for crops, but Sustainable Development Goal 6 aims to protect Water for everyone's health and nature. Unless farming becomes much more water-efficient, these goals clash (FAO, 2020).

The rapid rate of urbanisation and the consequent rise in surface water pollution by wastewater discharge, combined with the scarcity of freshwater for irrigation in most cities, especially in arid areas, has led to a renewed interest in wastewater irrigation since the 1950s (Angelakis, 2015; Mateo-Sagasta, 2015). The annual wastewater production estimate is conservatively put at over 500,000 m^3 in the country (Olonade, 2016). Globally, only 8.4% of collected wastewater undergoes treatment of any kind. In low-income countries, this drops to <2%, while 48% of wastewater flows untreated into the environment (UN-Water, 2023). Most cities do not have adequate infrastructure and resources for wastewater management in an efficient and sustainable way. Thus, it is usually discharged into water bodies with little or no treatment (Corcoran, 2010; Qadir *et al.*, 2010). However, wastewater is a secondary water resource available throughout the year that could serve for crop irrigation if properly managed. Wastewater treatment helps in the reduction or removal of contaminants in wastewater to an acceptable level to prevent pollution in the environment after discharge of the effluent. The WHO (2006) guidelines for the use of wastewater in agriculture are to ensure safe use of treated wastewater in agriculture and good management practices for irrigating crops, particularly those consumed uncooked.

The irrigation of vegetables consumed raw (lettuce, tomato, and onion), with effluent from a wastewater treatment plant, raises significant concerns regarding public health and environmental safety. There is a need to determine the efficacy of wastewater treatment in reducing coliform levels and other risk factors to assess the suitability of the released effluent for the irrigation of vegetables.

MATERIALS AND METHODS

Study Site

The study was carried out in a wastewater treatment plant (located between Latitude 11 °8’N, 11 °10’N and Longitude 7 °41’E, 7 °42’E)that makes use of a waste stabilisation pond system to treat wastewater generated within the community. The ponds have a limited retention capacity. Inflow of wastewater beyond their carrying capacity leads to premature discharge of effluent. During the dry season, farmers with farmlands along the effluent flow channel use the effluent for irrigation of vegetables.

Sampling Points and Sample Collection

One litre (1 L) sample each of influent at the point of entry into the waste stabilisation pond, effluent at the point of discharge from the waste stabilisation pond, effluent samples at points where farmers obtain the effluents for irrigation (400m and 500m along the effluent flow channel after discharge from the waste stabilisation pond) were collected by grab sampling. One hundred grams (100 g) of soil was collected from 0-10 cm depth using a clean hand trowel at five different spots on the fields of lettuce, onion, and tomato irrigated with the effluent using a composite sampling method. Each of the samples obtained from each field was mixed to make a 500 g composite sample representative of each field. Samples were collected monthly from the fields of each of the selected vegetables. Fifty grams (50 g) each of tomato fruits, lettuce leaves, and onion bulbs irrigated with the released effluent were collected at five different spots to make 250 g of composite sample representative of each field of tomatoes, lettuce and onions from each of the selected fields. Samples of vegetables were obtained during the harvest period of the vegetables irrigated with the effluent.

Determination of Physicochemical Properties of Influent and Treated Effluent

The Biochemical Oxygen Demand (BOD), Dissolved Oxygen, Chemical Oxygen Demand (COD), Turbidity, Total Dissolved Solids, Total Suspended Solids, Nitrate, Phosphate, Sulphate of the influent and effluent were determined using standard methods (APHA, 2017). The pH, temperature, and electrical conductivity of the influent and effluent were determined at the point of sample collection using a portable multifunction water quality tester (model EZ-9909-SP).

Determination of Coliform Counts.

The total and faecal coliform count of the influent, effluent, soil and vegetable samples was carried out using the most probable number method as described by Alexander (1983). A serial dilution of the samples from 10^{-1} to 10^{-6} was carried out. Lauryl sulphate broth was prepared according to the manufacturer’s specification, and 9ml was dispensed into 15 test tubes containing inverted Durham’s tubes. The test tubes were arranged in 3 sets of 5 test tubes containing the prepared broth, to inoculate three consecutive dilutions of each of the samples. An aliquot of 1.0 ml of each dilution of 10^{-4}, 10^{-5} and 10^{-6}, respectively, was used to inoculate each of the set of tubes containing Lauryl sulphate broth. The inoculated tubes were incubated aerobically at 35 °C for total coliform and 45 °C for faecal coliform for 24 hours. After 24 hours, the inoculated tubes were examined for evidence of growth indicated by turbidity of the broth and/or the collection of gas in inverted Durham’s tubes. To estimate the total and faecal coliform density, the pattern of positives and negatives was noted and a standardised MPN table was consulted to determine the most probable number of organisms.

Statistical Analysis

Data on physico-chemical properties of influent and effluent samples, and total and faecal coliform counts of all the samples were subjected to analysis of variance (ANOVA) at 95% confidence interval on IBM SPSS version 20. Factors with P-value ≤ 0.05 were considered statistically significant.

RESULTS

The physico-chemical properties of influent and effluent obtained from the wastewater treatment plant are shown in Table 1. Statistical analysis of data showed that there were no significant differences(P > 0.05) between the pH and temperature of the samples obtained from the study area. However, the mean values of DO, BOD, COD, turbidity, total solids, TDS, TSS, conductivity, nitrate, phosphate and sulphate varied significantly (P≤ 0.05) in the samples. There was a reduction in the total coliform count in released effluent (1.0×10^6 CFU/ml) compared to the influent, which was 9.2×10^6 CFU/ml (Table 2). The ANOVA showed significant differences (P ≤ 0.05) in the total coliform counts of influent and effluents. Table 3 shows the faecal coliform counts of influent and effluent samples. A decline in the faecal coliform count in released effluent (4.1×10^5 CFU/ml) was observed compared to the influent (1.6×10^6 CFU/ml). The ANOVA showed significant differences (P ≤ 0.05) in the faecal coliform counts of influent and effluents. There were no significant differences (P > 0.05) in the total coliform counts of soil samples across the plots. The total coliform count of lettuce plot, tomato plot and onion plot recorded from the study site were high (Table 4). The faecal coliform count of lettuce plot, tomato plot and onion plot recorded from the study site were also high (Table 5). There were no significant differences (P > 0.05) in the faecal coliform counts of soil samples across the plots as well as in the total coliform counts of vegetable samples across the plots (Table 6). There were no significant differences (P > 0.05) in the faecal coliform counts of vegetable samples across the plots. Faecal coliforms were detected on the surfaces of lettuce leaves, tomato fruits and onion bulbs from the study site (Table 7).

Table 1: Physico-chemical Properties of Influent and Effluent Obtained from the Wastewater Treatment Plant

Parameters (Unit)	Experimental Values				Effluent Quality Standard	
	IF	EF1	EF2	EF3	NESREA	WHO
pH	7.5±0.92^{a}	7.6±0.90^{a}	7.4±1.11^{a}	7.4±1.07^{a}	6.5-8.5	6.5-8.5
T (°C)	26±2.45^{a}	24±1.53^{a}	22±1.75^{a}	23±1.16^{a}	Max 40	Max 40
DO (mg/L)	150±5.23^{a}	100±4.78^{b}	95±4.45^{b}	95±3.05^{b}	NS	Min 2
BOD (mg/L)	110±14.14^{a}	60±7.02^{b}	25±7.56^{c}	25±2.82^{c}	50	30
COD (mg/L)	2900±45.5^{a}	1200±30.05^{b}	1000±31.32^{b}	900±24.76^{b}	100	NS
Turbidity	129.4±10.47^{a}	96.6±24.18^{ab}	46.2±4.24^{b}	52.0±2.82^{b}	5	5
TSS (mg/L)	330±4.97^{a}	230±12.72^{ab}	150±15.55^{b}	180±12.21^{b}	100	30
TDS (mg/L)	411±12.72^{a}	390±5.36^{a}	200±4.26^{b}	190±4.34^{b}	2100	2000
C (µS/cm)	815±32.04^{a}	718±21.97^{b}	388±15.65^{c}	392±13.25^{c}	NS	2000
N (mg/L)	50±7.07^{a}	45±8.48^{ab}	25±4.24^{b}	24±1.41^{b}	10	10
P (mg/L)	3.9±0.57^{a}	3.7±0.28^{a}	2.4±0.43^{ab}	2.0±0.14^{b}	NS	10
S (mg/L)	560±22.62^{a}	480±16.97^{b}	290±9.89^{c}	320±4.24^{c}	250	400

Keys: C: Conductivity; T: Temperature; N: Nitrate; P: Phosphate; S: Sulphate; IF: Influent; EF1: Effluent at the point of discharge; EF2: Effluent along the effluent flow channel (400 m away from EF1); EF3: Effluent along the effluent flow channel (500 m away from EF1); pH: Hydrogen ion; TSS: Total Suspended Solids; TDS: Total Dissolved Solids; DO: Dissolved oxygen;BOD: Biochemical Oxygen Demand; NS: Not Stated; COD: Chemical Oxygen Demand; NTU: Nephelometric Turbidity Unit; WHO: World Health Organization; Max: Maximum; Min: Minimum; NESREA: National Environmental Standards and Regulations Enforcement Agency

Table 2: Total Coliform Counts of Influent and Effluent Samples at the Wastewater Treatment Plant

Samples Analysed	Mean (CFU / ml)	± SEM
Influent	9.20×10^{6}	0.0
Effluent at point of discharge	4.60×10^{5}	3.30×10^{5}
Effluent at 400m away from point of discharge	5.05×10^{5}	2.85×10^{5}
Effluent at 500m away from point of discharge	2.45×10^{5}	2.50×10^{4}
ANOVA (F)	1518.163	
Df	6	
P-value	0.000	

Table 3: Faecal Coliform Counts of Influent and Effluent Samples at the Wastewater Treatment Plant

Samples Analysed	Mean (CFU / ml)	± SEM
Influent	1.60×10^{6}	0.0
Effluent at point of discharge	4.10×10^{5}	8.00×10^{4}
Effluent at 400m away from point of discharge	2.80×10^{5}	5.00×10^{4}
Effluent at 500m away from point of discharge	1.58×10^{5}	1.33×10^{5}
ANOVA (F)	133.881	
df	6	
P-value	0.000	

Table 4: Total Coliform Counts of Soil Samples Irrigated with Effluent for Vegetable Cultivation

Vegetable farm	Mean(CFU / ml)	± SEM
Lettuce Plot-1	1.09×10^{5}	6.15×10^{4}
Lettuce Plot-2	7.15×10^{5}	3.85×10^{5}
Lettuce Plot-3	4.95×10^{6}	4.25×10^{6}
Tomato Plot-1	7.15×10^{5}	3.85×10^{5}
Tomato Plot-2	9.45×10^{5}	1.55×10^{5}
Tomato Plot-3	4.95×10^{6}	4.25×10^{6}
Tomato Plot-4	1.19×10^{4}	5.10×10^{3}
Onion Plot-1	6.20×10^{5}	1.7×10^{5}
Onion Plot-2	2.50×10^{5}	8.00×10^{4}
Onion Plot-3	1.55×10^{5}	1.50×10^{4}
Onion Plot-4	3.00×10^{5}	1.60×10^{5}
ANOVA (F)	0.783	
df	19	
P-value	0.471	

DISCUSSION

The optimal pH range for most biological wastewater treatment processes is between 6.5 and 8.5. If the pH of the effluent is outside of this range, it can affect the growth and activity of microorganisms involved in the treatment process, leading to a decrease in treatment efficiency (Kodukula *et al.*, 2018). The effluent pH at the point of discharge (7.6) was within acceptable limits (6.5-8.5) set by NESREA (2009) and WHO (2006). This effluent pH is not toxic to the soil and suggests that the recorded neutral pH of the effluent is safe for use in irrigation. Most biological processes operate within a certain temperature range, and low temperatures slow microbial metabolism and high temperatures cause enzyme denaturation (Egilmez and Haspolat, 2024). As the temperature of water increases, the amount of dissolved oxygen decreases (Danladi *et al.*, 2017). The temperature of the effluent at the point of discharge (24 °C) was below the maximum limit (40°C) set by NESREA (2009) and WHO (2006). This is similar to the findings of Balogun and Ogwueleka (2021), who obtained an effluent temperature of 26.5°C from the effluent of the Wupa wastewater treatment plant in Abuja. The temperature values obtained in this study showed that the effluent could be safely used for irrigation.

The influent from the wastewater treatment plant had an appreciable high dissolved oxygen and consequently, the dissolved oxygen of the effluent was within the permissible limit of a minimum of 2 mg/L set by WHO (2006). The reduction in the dissolved oxygen content of the effluent could be due to the use of oxygen by aerobic microorganisms present in the wastewater treatment plant to break down organic matter and nutrients. The growth and decay of algae during the treatment process could also lead to a decrease in the dissolved oxygen of the effluent. In nutrient-rich wastewater, algae and microorganisms grow fast; they eventually die, and oxygen is used up for their decomposition (Boyd and Boyd, 2020). The dissolved oxygen level reported in this study suggests that the Water is not depleted of oxygen and is able to support a healthy aquatic environment. This finding contrasts with that of Oluwaseun (2018), who reported dissolved oxygen of 0.00mg/l in domestic wastewater.

Table 5: Faecal Coliform Counts of Soil Samples Irrigated with Effluent for Vegetable Cultivation

Vegetable farm	Mean (CFU / ml)	± SEM
Lettuce Plot-1	3.25×10^4	1.25×10^4
Lettuce Plot-2	4.50×10^4	2.50×10^4
Lettuce Plot-3	8.15×10^5	4.85×10^5
Tomato Plot-1	1.38×10^4	9.25×10^3
Tomato Plot-2	4.05×10^4	2.05×10^4
Tomato Plot-3	2.77×10^6	2.73×10^6
Tomato Plot-4	6.5×10^4	4.50×10^4
Onion Plot-1	6.15×10^4	1.65×10^4
Onion Plot-2	1.90×10^5	2.00×10^4
Onion Plot-3	1.19×10^4	5.10×10^3
Onion Plot-4	2.75×10^5	5.5×10^4
ANOVA (F)	0.505	
df	19	
P-value	0.611	

Table 6: Total Coliform Counts of Vegetables Irrigated with the Effluent from the Wastewater Treatment Plant

Vegetable	Farm	Mean (CFU / ml)	± SEM
Lettuce	Plot 1	7.15×10^5	3.85×10^5
	Plot 2	5.60×10^5	5.4×10^5
	Plot 3	6.6×10^5	4.4×10^5
Tomato	Plot 1	8.95×10^5	5.05×10^5
	Plot 2	1.60×10^5	1.21×10^5
	Plot 3	1.45×10^5	1.06×10^5
	Plot 4	2.50×10^6	3.00×10^5
Onion	Plot 1	9.00×10^5	7.00×10^5
	Plot 2	9.00×10^5	7.00×10^5
	Plot 3	1.6×10^6	2.00×10^5
	Plot 4	7.30×10^6	1.90×10^6
ANOVA (F)		2.249	
	df	19	
P-value		0.133	

The biochemical oxygen demand (BOD) observed in EF1 was above the permissible limit (30 mg/l) set by WHO (2006) and (50 mg/l) set by NESREA (2009). This is similar to the report of Oluwaseun (2018), who reported BOD of 566.4 mg/l in an industrial wastewater and in contrast to the findings of Letshwenyo and Mokokwe (2020), who reported BOD of 5mg/l from treated effluent obtained from a waste stabilisation pond in Botswana. However, along the effluent flow channel, at sampling points EF2 and EF3, there was a reduction in the BOD of the effluent. Thus, the BOD was within the permissible limit set by WHO (2006). The improvement observed in the BOD of samples implies that as the effluent travelled along the effluent flow channel, it received further treatment. The finding in this study is in line with the finding of Balogun and Ogwueleka (2021), who obtained a BOD of 47 mg/l from the effluent of the Wupa wastewater treatment plant. The COD of the effluents were above the permissible limit of 100 mg/l set by NESREA (2009). Nonetheless, there was a significant reduction from IF (2900 mg/L) to EF3 (900 mg/L), which is an indication of improved degradation of pollutants. The high COD of the effluents could be due to the presence of a high level of organic and inorganic matter. This is in contrast with the findings of Balogun and Ogwueleka (2021) and of Letshwenyo and Mokokwe (2020), who obtained low COD of 15 mg/l and 9 mg/l, respectively, from the effluent of the Wupa wastewater treatment plant and from treated effluent obtained from a waste stabilisation pond in Botswana. There were statistically significant differences in the turbidities of the samples; nonetheless, the treated effluents' turbidities were still above the permissible limit of 5 NUT set by WHO (2006) and NESREA (2009). This is in contrast to the findings of Letshwenyo and Mokokwe (2020), who reported turbidity of 5 NTU from treated effluent, and similar to the findings of Oluwaseun (2018), who obtained turbidity of 50.47 NUT from wastewater obtained from FUTA, Akure. The high level of turbidity can affect the performance of the irrigation facility (Jeong *et al.*, 2016).

Table 7 Faecal Coliform Counts of Vegetables Irrigated with the Effluent from the Wastewater Treatment Plant

Vegetable	Farm	Mean (CFU / ml)	± SEM
Lettuce	Plot 1	3.25×10^3	1.25×10^3
	Plot 2	3.50×10^4	3.30×10^4
	Plot 3	1.25×10^5	1.50×10^4
Tomato	Plot 1	1.76×10^4	8.40×10^3
	Plot 2	1.55×10^5	1.50×10^4
	Plot 3	1.55×10^5	1.50×10^4
	Plot 4	1.40×10^4	3.00×10^3
Onion	Plot 1	3.70×10^5	1.70×10^5
	Plot 2	2.20×10^5	2.00×10^4
	Plot 3	1.6×10^5	4.00×10^4
	Plot 4	1.32×10^4	3.85×10^3
ANOVA (F)		2.836	
	Df	19	
P-value		0.084	

The total suspended solids (TSS) of the effluent samples were above the permissible discharge limit of 30 mg/l and 100 mg/l set by WHO (2006) and NESREA (2009), respectively. The high TSS values may be due to the high presence of colloidal and non-settleable solids in the effluents. This is in line with the findings of Kanwar *et al*. (2021), who obtained TSS of 187 mg/l and in contrast with the findings of Balogun and Ogwueleka (2021), who obtained TSS of 11.7 mg/l. The high TSS values indicate that the water treatment process is not effectively removing the suspended solid materials present in the effluent. The total dissolved solids (TDS) of the influent were low and consequently, the effluents' TDS were within the permissible limit of 2000 mg/l and 2100 mg/l set by WHO (2006) and NESREA (2009), respectively. This suggests that the effluent may be suitable for irrigation. This is similar to the findings of Balogun and Ogwueleka (2021) and of Letshwenyo and Mokokwe (2020), who obtained TDS of 115 mg/l and 0 mg/l, respectively, from effluent. The conductivity of the influent was low and consequently, the effluents' conductivities were also within the permissible limit of 2000 µS/cm stipulated by WHO (2006). This is similar to the findings of Balogun and Ogwueleka (2021), who obtained a conductivity of 301 µS/cm. The conductivity values recorded in this study suggest that the effluent may be suitable for irrigation.

The effluent contains some nutrients such as nitrogen and phosphorous, which are important for plant growth and production; thus, it is used for the irrigation of vegetables to reduce fertiliser application. The nitrate content of the effluent was above the permissible limit of 10 mg/l stipulated by WHO (2006). The high concentration of nitrate in the effluent could be due to the high concentration of organic matter in the influent and inadequate retention time for treatment of the wastewater in the waste stabilisation pond. This is similar to the report of Ouansafi *et al*.(2022), who obtained a nitrate value of 21.8 mg/l in treated wastewater. The phosphate of the effluent was within the permissible limit of 10 mg/l stipulated by WHO (2006). This is in line with the findings of Balogun and Ogwueleka (2021), who obtained phosphate of 2.5 mg/l, and in contrast with the findings of Kanwar *et al*. (2021), who obtained phosphate of 15.4 mg/l. The sulphate of all the effluents was above the permissible limit of 250 mg/l set by NESREA (2009). This is similar to the findings of Ouansafi *et al*. (2022), who obtained a sulphate value of 275.7 mg/l in treated wastewater. Sulfate concentrations >250 mg/L in irrigation water are toxic to plants and may affect their productivity (FAO, 2023).

The reduction in the total coliform count in released effluent (1.0×10^6 CFU/ml) compared to the influent, which was 9.2×10^6 CFU/ml, could be a result of biological treatment of the influent in the waste stabilisation ponds. The decrease in the total coliform count in effluent as it moved along the effluent flow channel is an indication that the effluent also received treatment as it moved down the flow channel. The ANOVA showed significant differences ($P \leq 0.05$) in the total coliform counts of influent and effluents. Nonetheless, the total coliform counts in the effluent samples were above the WHO (2006) (1.0×10^3 CFU/ml) recommended standard for unrestricted irrigation of crops, especially those consumed uncooked. The World Health Organisation (WHO, 2006) recommended that vegetables to be eaten uncooked should be irrigated only with biologically treated effluent that has been disinfected to achieve a coliform level of not more than 1.0×10^2 /100 ml in 80% of the samples. The finding in this study is similar to the finding of Mojid and Wyseure (2013), who reported a total coliform count of $1.7\text{x}10^7$ CFU/mL in treated municipal wastewater and in contrast to the findings of Sacks and Bernstein (2011), who reported a total coliform count of $9.0\text{x}10^2$ CFU/mL in treated effluent in Israel. The high total coliform count in the effluents could be attributed to incomplete treatment of the released effluent from the wastewater treatment plant. This could be of health risk to humans who come into contact with this effluent.

The wastewater treatment plant receives a continuous discharge of waste of faecal origin. The presence of faecal coliforms usually indicates faecal contamination from human or animal sources (Díaz-Gavidia *et al*., 2022). A decline in the faecal coliform count in released effluent (4.1×10^5 CFU/ml) was observed compared to the influent (1.6×10^6 CFU/ml). The ANOVA showed significant differences ($P \leq 0.05$) in the faecal coliform counts of influent and effluents. However, the faecal coliform count of the effluent was beyond the acceptable limit of 1.0×10^3 CFU/ml recommended by NESREA (2009). High levels of faecal coliforms in effluent indicate that the discharged effluent still contains faecal matter and also an indication of the presence of potentially pathogenic bacteria and pathogenic strains of coliform (Adefisoye and Okoh, 2016); this is of environmental and public health concern. The faecal coliform count showed that the treatment process was not effective in reducing the faecal coliform of the effluent to the acceptable faecal coliform count of <1000 CFU/ml of treated effluent to be used in agriculture. This finding is in contrast to the findings of Cui and Liang (2019) who did not detect faecal coliform in an anaerobic biofilm bioreactor treated effluent in China and that of Sacks and Bernsteinb (2011) who reported a faecal coliform count of 1.0×10^2 CFU/mlin treated wastewater and similar to the findings of Mojid and Wyseure (2013) who reported a faecal coliform count of 1.6×10^4 CFU/mlin treated municipal wastewater.

The high total coliform count (4.9×10^6 CFU/g) in lettuce on plot 3 could be attributed to the fact that this plot was irrigated with effluent collected from a puddle used for effluent storage. The high total coliform count observed in this study is similar to the findings of Cui and Liang (2019) who reported a total coliform count of 3.1×10^6 CFU/g in lettuce irrigated soil in China and in contrast to the findings of Aguas *et al.* (2019) who reported a total coliform count of 9.0×10^2 CFU/g in lettuce irrigated soil in Spain. The high total coliform count in the soil could be due to the abundance of coliforms in the effluent or soil. A high total coliform count in effluent irrigated soil observed in this study can adversely affect public health and the environment. Excessive total coliform counts in soil can disrupt the ecological balance of the soil, deplete oxygen levels in the soil and negatively impact soil microbes (Sinegani and Maghsoudi, 2011). If the soil comes in direct contact with farmers, there is a risk of disease transmission (Navab-Daneshmand *et al.*, 2018). Also, the vegetables planted on these plots could become contaminated with coliforms trapped in the soil.

The faecal coliform count of the lettuce plot, tomato plot and onion plot recorded from the study site was high. This could be a result of the incomplete treatment of the released effluent from the wastewater treatment plant used in irrigation. The faecal coliform count in this study is similar to the findings of Ja'afar *et al.* (2020), who reported a high faecal coliform count of 1.22×10^6 CFU/g in wastewater irrigated soil. High faecal coliform count observed in effluent irrigated soil in this study is of public health and environmental concern because their presence in soil indicates possible contamination with faecal matter and the potential of faecal contamination to crops. The total coliform count of vegetables obtained from the study site was high. This could be due to contamination by coliforms present in the effluent or soil. The results obtained in this study are similar to the findings of Farhad *et al.* (2018), who recorded a high total coliform count of 4.0×10^3 CFU/g on lettuce leaves. The finding in this study contrasts with the report of Aguas *et al.* (2019), who reported a total coliform count of 2.0×10^2 CFU/g on lettuce leaves in Spain. The vegetable samples obtained in this study are often eaten raw, and the presence of coliforms in these vegetables has significant implications on public health and is also of food safety concern, as their presence may indicate the presence of other harmful pathogens. When effluent is used to irrigate vegetables, the presence of faecal coliforms in the vegetables could be an indication of contamination from the improperly treated effluent used for irrigation of vegetables. The faecal coliforms were detected on the surfaces of lettuce leaves, tomato fruits and onion bulbs from the study site. This is similar to the findings of Ja'afar *et al.* (2020), who reported a faecal coliform count of 3.5×10^4 CFU/g in wastewater irrigated lettuce. Consumption of vegetables contaminated with faecal coliforms can cause foodborne illnesses in humans, especially in vulnerable people who are more susceptible to infection (Luna-Guevara *et al.*, 2019).

CONCLUSION

The wastewater treatment process did not adequately reduce organic loads and coliforms to acceptable limits set by WHO and NESREA. This rendered the effluent non-compliant for safe discharge or for use in irrigation of food crops consumed by humans.

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