Afropolitan Journals

ISSN: 3027-2114 www.afropolitanjournals.com

Improved Design of Sanitary System at the Nigerian College of Aviation Technology (NCAT), Zaria

A. U. Alka; U. A. Abubakar; and S. B. Igboro

Department of Water Resources and Environmental Engineering, Ahmadu Bello University, Zaria, Kaduna, Nigeria.

Corresponding author: *alkaumaralka@gmail.com*

DOI: *https://doi.org/10.62154/b8pxgv34*

Abstract
Sanitation is a basic human requirement with the primary aim of separating human waste from settlements to prevent the spread of diseases. This study presents a preliminary design of a centralized sewerage collection, transportation, treatment, and final disposal system for the Nigerian College of Aviation Technology (NCAT) Zaria, Kaduna State (Site 1). The results of physico-chemical analysis of samples showed concentrations of Nitrates (2,550mg/l) and total suspended solids T.S.S. (1,778mg/l) were above the acceptable standard limits. The concentrations of Zinc (5.31mg/l) and Lead (2.78mg/l) were also above the acceptable limits. A sewerage system which comprised of 18 manholes, 22 junction chambers and 39 sewers covering a distance of 2,816m was designed for the college. The results of the design showed that, 3 facultative and 3 maturation ponds were required. The capital cost for implementing the proposed sewerage system and WSPs for the college was determined to be ₦14,649,855.75 with an annual cost of operation and maintenance of ₦3,030,000.00. A comparison of the proposed sewerage and WSPs system with the existing septic tank and soak-away system revealed that, the proposed sewerage and WSPs system had a higher cost-benefit ratio (0.94), longer lifespan (30 years), lower cost of annual desludging (₦30,000.00), and lower risks of groundwater contamination.

Keywords: Sanitation, Design, Sewage, Heavy Metals, Sewerage, Sustainability.

Introduction
Unsafe disposal of wastewater remains a serious problem in Nigeria where it has the potential of causing ground and surface water contamination, thereby creating environmental pollution. (Adewumi and Oguntuase, 2016.)

In Nigeria and many developing countries, the bulk of domestic and industrial wastewaters are discharged into receiving water bodies without proper treatment in both rural and urban areas, with more emphasis on improving drinking water quality than on safe and sustainable wastewater treatment and re-use. It is therefore, necessary to develop methods of wastewater treatment that are especially suitable and sustainable for developing countries. (Omenka, 2010). Also, as population grows with rising standard of living, more wastewater is generated and disposed to sensitive environments with negative impacts on humans and the ecosystem. (Adewumi and Oguntuase 2016). Wastewater treatment is the process which converts wastewater into an effluent that can either be returned to the

water-cycle with minimal environmental issues or reused for other purposes (Ibrahim *et al*, 2016). Conventional treatment methods like activated sludge systems and trickling filters have high energy requirements, while methods like constructed wetlands and waste stabilization ponds (WSPs) have no energy requirements and are generally suitable for developing countries. They are sometimes referred to as eco-technologies (Awuah, 2006). Treatment of wastewater before entering the river or other public waters in Kaduna is rarely carried out because of high cost of conventional wastewater treatment facility (Vymazal, 2013; Ugya et al., 2015a; Yu et al., 2016). The indiscriminate discharge of wastewater into the environment in many Nigerian cities has adversely affected sanitation and claimed the lives of many people through diseases like cholera, hepatitis B and typhoid. (Giwa, 2014).
A sewerage system is a network or system of sewers and associated works designed for the collection of foul sewage or wastewater, conveying it through pipes, to a treatment plant or other places of disposal. (Zhang, 2001; Akali, 2013). The design of sanitary systems in institutions is a critical aspect of environmental health and safety. Effective sanitary system design is crucial for preventing environmental pollution and ensuring public health (WHO, 2019). Design of a sewerage system is undertaken to ensure that the entire sewage is effectively and efficiently removed from points of generation to the final point of disposal. (Akali *et al*, 2012). The Simplified Sewerage Software is a design tool used for off-site sanitation technology to remove all wastewater from the household environment. The software is suitable for areas characterized by gently sloping topography, high and low density population with reasonable water supply (Akali, 2013).
Centralized sewerage systems have been recommended as a viable solution for effective wastewater management (Akotey et al., 2020). However, the abandonment of the centralized sewerage system at the Nigerian College of Aviation Technology Zaria highlights the need for a comprehensive design approach that considers technical, financial, and institutional factors (Adeleke et al., 2020).
Environmental sustainability is a critical aspect of sanitary system design and wastewater management (UNEP, 2020). Institutions have a responsibility to ensure that their operations do not harm the environment (ISO, 2015). Recent studies have highlighted the importance of adopting sustainable wastewater management practices in institutional settings (Adebowale et al., 2020).
Egwuonwu *et al.* (2014) carried out a study aimed at the design, construction and performance evaluation of a model Waste Stabilization Pond (WSP). The WSP comprised of one facultative pond and three maturation ponds all in series. The influent of the WSP was filtered through a lined sandy loam media (obtained from the premises of Federal University of Technology, Owerri, Nigeria). The sandy loam soil media was found to be non-promising earlier in the removal process until it was lined with polyethylene material. A clay media was therefore recommended.
Abdullahi *et al.* (2014) undertook the design of a Waste Stabilization Pond for sewage treatment at the Nigerian Defence Academy Staff Quarters, permanent site Mando Kaduna

in Kaduna State where 2 facultative and maturation ponds of dimensions 63 x 32 m and 45 x 25 m respectively were provided in the design. A surface BOD loading of 340 kg/ ha.day with an 85% pond removal efficiency was obtained for the facultative ponds. The results were attributed to optimum pond geometry. A total sum of fifteen million, one hundred and five thousand, five hundred and thirty-four naira (₦15,105,534) was estimated for the entire project.

Okparanma *et al*. (2016) investigated the combined effects of municipal and industrial waste discharges on the quality of the new northern Calabar River in the Niger Delta province of Nigeria. Water samples were collected in June, 2015 from five regions along the stretch of the river. The five regions comprised three observed pollution sources (abattoir, open market, and noodle factory) and two non-pollution sources downstream and upstream sections of the river. The results showed that the current pollution loads of the river varied significantly across the three pollution sources. The existing quality of the river was only fair with a Water Quality Index of 64.71. The result suggested that the water quality is usually protected but occasionally impaired by the wastes discharged into the river, leading to conditions that often depart from permissible levels.

Statement of the Problem

The Nigerian College of Aviation Technology (NCAT) Zaria, a premier aviation institution in Nigeria faces significant challenges with its current reliance on septic tanks and soak-away pits systems for its wastewater management. It presently operates an onsite septic tank system with effects such as groundwater contamination, soil pollution and environmental hazards that pose health risks to students, staff and the surrounding community. Septic tanks are underground, and often forgotten and neglected by the people who use them. Improperly sited, designed, installed or operated septic systems can pollute drinking and surface water, and cause many other problems especially environmental. Other sections of the college have sewers that channel the wastewater directly into a receiving stream. The college's uncompleted and abandoned centralized sewerage system which was intended to provide a modern and efficient wastewater management solution has resulted in a reverted reliance on inadequate septic tank and soak-away systems. The results include but not limited to persistent environmental and health hazards such as the spread of water-borne diseases and a lack of compliance with regulatory standards. Lack of proper wastewater treatment facilities have negative public health and environmental impacts including groundwater and drinking water contamination, eutrophication of surface water bodies, and the spread of diseases (Omenka, 2010).

Despite the wealth of research on sanitary system design and wastewater management, several gaps and limitations exist. Firstly, most studies have focused on technical aspects, neglecting institutional and financial factors. (Adeleke et al., 2020). Secondly, few studies have investigated sanitary system design in Nigerian institutions, leaving a knowledge gap. (Akotey et al., 2020). Thirdly, existing studies have primarily focused on wastewater treatment technologies, with limited attention to heavy metal contamination and environmental sustainability (Oluwole et al., 2019). Finally, there is a lack of research on the effectiveness of centralized sewerage systems in Nigerian institutions.

This study addresses these gaps and limitations by investigating the design of a sanitary system for the Nigerian College of Aviation Technology Zaria, considering technical, institutional, and financial factors. By evaluating the effectiveness of a centralized sewerage system in reducing heavy metal contamination and environmental pollution, this study contributes to the existing body of knowledge in several ways. Firstly, it provides insights into the institutional and financial factors influencing sanitary system design in Nigerian institutions. Secondly, it assesses the effectiveness of centralized sewerage systems in reducing heavy metal contamination and environmental pollution. Finally, it provides a comprehensive framework for sustainable wastewater management in institutional settings.

Research Objectives

The objectives of this study are to:

- Design an improved sanitary system for the Nigerian College of Aviation Technology (NCAT) Zaria that addresses the current infrastructure gaps and limitations.
- Develop a sustainable wastewater management plan that prevents environmental pollution and enhances the overall environmental health and safety of the college.

Materials and Methods

Description of Study Area

Nigeria College of Aviation Technology (NCAT) Zaria is located in Sabon Gari Local Government Area of Kaduna State, Nigeria. The college (Site 1) lies on latitude of $11^{o}\ 8^{'}\ 22^{''}$N and $7^{o}\ 40^{'}\ 45^{''}$E with a longitude between of $11^{o}\ 8^{'}\ 8''$N and $7^{o}\ 41^{'}\ 23^{''}$ E. It is situated on an elevation of 669m above mean sea level along Zaria-Sokoto Road. The college sits on a relatively flat terrain of grassland and covers an area of 61.69 hectares. The college comprises of a flying school with an airfield for training students, administrative section and hostels for students' accommodation. It has a flight maintenance department, an aeromedical center, works department and transport section to mention a few.

Plate I: Satellite Image of the Nigerian College of Aviation Technology (NCAT), Zaria Site 1 (Source: Google Earth, 2024).

Data Generation

The method adopted in this study was built on existing system assessment, new system design and cost-benefit analysis. It included information such as the daily water generation data, wastewater sample collection and analysis, and development of layouts and networks.

Assessment of Existing Treatment System.

Physical site inspections of the existing wastewater treatment facilities available for NCAT Zaria Site 1, revealed septic tanks and soak away pits as the mode of collection, treatment and disposal. The systems were inspected for signs of leakages and seepages, broken down or collapsed chambers as an indication of system failure. Performance indices were used to assess the existing system as presented in Table 1.

Table 1: Performance Evaluation for Septic-tank System for NCAT, Zaria.

Key Performance Indicator.	Key Performance Objective.	Score (point)
Rehabilitation	Every 3 years	5
	Every 5 years	4
	Every 7 years	3
	Every 10 years	2
	Every 15 years	1
	None	0
Functionality of system.	Excellent	5
	Very good	4
	Good	3
	Fair	2
	Poor	1
	None	0

Frequency of routine maintenance	Every 2 year Every 3 years Every 4 years Every 5 years Every 10 years None	5 4 3 2 1 0
Frequency of blockages.	None Every year Every 6 months Every month Every week Daily	5 4 3 2 1 0
Frequency of sludge removal	Every 5 years Every 7 years Every 10 years Every 15 years When needed None	5 4 3 2 1 0
Total points Percentage		25 100

Source: (Akali *et al.*, 2013).

Daily water consumption

Data on the daily water consumption was estimated from information obtained from the Works Department of the College during oral interviews. The water supply for the College comes from boreholes which supply overhead tanks connected to all sections, departments and units of the College.

Wastewater generation

The data obtained from the Works Department was used to determine the volume of wastewater generated daily using a return factor of 75% as report by Garg and Garg (2006), Lukman (2009), Akali (2013). These results combined with the results of laboratory analysis of the wastewater samples was used for the design of the different components of the wastewater treatment plant.

Wastewater Samples Collection and Analysis

Grab wastewater samples were collected from two sewer outfalls connected to some sections of the College. The first sewer pipe has GPS coordinates of latitude 11° 8′ 7″ and longitude of 7° 41′1″ and it is located close to the residential houses of the College. The second sewer pipe has latitude of 11° 8′ 13″ and longitude of 7° 40′ 59″ and it is located behind the Flight Maintenance Department and Hangars in the site 1 of the college. The samples were collected in two 4-liter plastic gallons that were previously washed and sterilized using methylated spirit. The samples were immediately taken to the Public Health

Laboratory of the Department of Water Resources and Environmental Engineering of the Ahmadu Bello University, Zaria for analysis. The parameters determined and the methods employed are shown in Table 2.

Table 2: Analysis conducted on Wastewater Samples obtained from NCAT Site 1.

Parameter	Method Used
pH	Electrometric.
Total suspended solids (TSS)	Filtration.
Biochemical oxygen demand (BOD)	Winkler.
Chemical oxygen demand (COD)	Dichromate reflux.
Nitrates	Phenol-disulphonic Acid
Phosphates	Stannous chloride.
Total coliform count	Most probable number (MPN).
Oil and grease	Petroleum Extraction
Digestion of heavy metal sample	Aqua-Regia

The analyses were conducted as specified in the Standard Methods for the Examination of Water and Wastewater, 20^{th} edition, as described by Ibrahim *et al.*, (2016). The analysis for heavy metals was conducted at the multi-user laboratory of the Department of Chemistry, Ahmadu Bello University Zaria. The samples were digested by Aqua-Regia method, then analysed for heavy metals using microwave plasma atomic emission spectrometer MP-AES AGILENT 4200. The heavy metals analysed were cadmium (Cd), chromium (Cr), lead (Pb), copper (Cu), arsenic (As), zinc (Zn), magnesium (Mg) and aluminium (Al).

Design of Sewerage System

Satellite images of the College were obtained using Google Earth Pro software (version 4.3), which enabled a detailed study of layout of buildings. Digital elevation model (DEM) was developed using the ArcGIS software (version 10.5) and used to develop draft sewerage layout along the side of the road network. The ground elevations along the sewer tracks were obtained from the digital elevation model (DEM) to enable siting of junction chambers and manholes. Also, the possible locations for siting of a treatment plant based on the lowest ground elevation and available space was determined. The final sewer network was designed using the simplified sewerage software. This included the hydraulic design of the sewer parameters such as the slope, invert levels, gradient, flow velocity and discharge. A comprehensive drawing showing details of the proposed sewerage system network in relation to buildings, road networks and other features was produced using AutoCAD software (version 2007).

Design Consideration

The following equations were used for the design of individual sewers that form the sewer network:

a). The initial and final daily peak flows were determined from equation (1).

$$q = \frac{k1\ x\ k2\ x\ p\ x\ w}{86{,}400} \quad (1)$$

where ***q*** *is the daily peak flow (ltr/ sec),*

k_1 *is the peak factor,*

k_2 *is the return factor,*

p *is the population served and w is the average water consumption (lcpd).*

b). The minimum gradient was determined using equation (2).

$$I_{min} = 2.33 \times 10^{-4} \times \tau^{16/13} \times q_i^{-16/13} \quad (2)$$

where ***I_{min}*** *is the minimum gradient required by sewer,*

τ *is the minimum tractive tension (Pascal) and??*

q_i *is the initial peak flow (m^3/s).*

c). the diameter of each sewer was calculated using equation (3).

$$D = n^{\frac{3}{8}} \times k_a^{\frac{-3}{8}} \times k_r^{\frac{-1}{4}} \times \left(\frac{q_f}{i_{min}^{\frac{1}{2}}}\right)^{\frac{3}{8}} \quad (3)$$

where ***D*** *is the diameter (mm),*

n *is the roughness coefficient,*

q_f *is the final discharge flow and*

I_{min} *is the minimum gradient required by sewer.*

The diameter of each sewer was determined using the design peak flow.

d). Average per capita wastewater generation.

Also known as the Return factor, it is the percentage of total water consumption that will be discharged to a sewer. It was taken to be 75 % of total water consumption for this research as reported by Akali, 2013.

Design of Wastewater Treatment Plant

The Lab results were combined using the mass balance equation (4) to the obtain the characteristics of the combined wastewater samples.

$$C_d = \frac{Q_a C_a + Q_e C_e}{Q_a + Q_e} \quad (4)$$

where ***C_d*** *is the BOD_{mix},*

Q_a *and* ***Q_e*** *are the discharge (m^3/s) for the two points,*

C_a *and* ***C_e*** *are the BOD concentrations (mg/l) for the two points respectively*.

Design of Facultative Ponds

The area of the facultative pond was obtained using equation (5)

$$A_f = \frac{q_p}{DK_T} \times \frac{L_{i-L_e}}{L_e} \quad (5)$$

where ***A_f*** *is the area of facultative pond (m^2),*

q_p *is the wastewater discharge rate (m^3/ day),*

D is the depth (m),

L_i and Le are the influent and effluent BOD (mg/l) respectively and

K_T is the rate constant.

K_T is given by equation (6).

$$K_T = K_{20^0}(\sigma^{T-20}) \tag{6}$$

where K_{20^0} *for raw wastewater is 0.3/day,*

σ is the Arrhenius constant usually between 1.05-1.09

T is the average temperature of the coldest month (^{oc}).

The facultative pond retention time was obtained from equation (7).

$$q_f = \frac{D\,A_f}{Q_m} \tag{7}$$

Design of Maturation Ponds

The area of the maturation pond was calculated from equation (8).

$$A_m = \frac{Qt}{D} \tag{8}$$

where *A_m is the area of the maturation pond (m^2),*

Q is the discharge (m^3/day),

t is the retention time (days), and

D is the depth (m).

The reduction of faecal bacteria in the maturation pond was calculated using equation (9).

$$N_e = \frac{N_i}{(1+K_b t_a)(1+K_b t_f)(1+K_b t_m)^n} \tag{9}$$

where *N_e is the number of faecal coliform/ 100ml of effluent,*

N_i is the number of faecal coliform/ 100ml of influent,

k_b is the first order rate constant for the removal (/day),

t_f, t_m, and t_a are the detention times in the facultative, maturation and anaerobic ponds in days respectively, and n is the number of maturation ponds.

The formula used to determine k_b is shown in equation (10).

$$K_b = 2.6\ (1.19)^{T-20} \tag{10}$$

where *T is the average temperature of the coldest month in degrees.*

Pond Desludging

The pond desludging rate for both facultative and maturation ponds was calculated using equation (11)

$$n = \frac{V}{3Ps} \tag{11}$$

where *n is the desludging interval (years),*

V is the volume of pond (m^3),

s is the sludge accumulation rate (m^3/capita-year), and

P is the population served.

The sewerage system and waste stabilization ponds were designed for a useful life of 30 years.

Economic Analysis

Economic analysis was carried out to determine the viability of designing a sewerage system and wastewater treatment plant for the (NCAT), Zaria. Using the cost - benefit analysis, a comparison was made with the existing on-site treatment system in terms of costs and technical requirements.

Cost- Benefit Ratio

The ratio of the discounted annual costs to discounted annual benefits is the cost-benefit ratio as shown in equation (12).

$$\frac{cost}{benefit}=\frac{discounted\ annual\ cost}{discounted\ annual\ benefit} \quad (12)$$

A project which gives a cost benefit ratio (C/B) less than one is economically feasible. (Egharevba, 2009).

Results and Discussion

The results obtained during the assessment of the existing wastewater treatment system and proposed sewerage and WSPs system in the study are presented in Tables 3-6 and Figures 2-3 respectively.

Assessment of Existing Treatment System

Assessment of the septic-tank system based on performance indices are presented in Table 3.

Table 3: Performance evaluation of Septic tank and Soak-away system for the College.

Performance Indicator.	Performance Objective.	Score for the College	Top Score.
Rehabilitation	Where needed	1	5
Functionality of system and record keeping.	Good	3	5
Frequency of routine maintenance	When needed	1	5
Frequency of blockages and system failure.	Monthly	3	5
Frequency of sludge removal	When needed	1	5
Total points		9	25
Percentage		36 %	100%

Wastewater Generation

The total volume of water consumed for the college was determined to be 103,000 liters/ day and using a return factor of 75% the daily wastewater generation was calculated as 77,250 liters/day equivalent to 0.89 X 10^{-3} m^3/s.

Physicochemical Analysis

The results of physicochemical analysis for the wastewater collected from the college are presented in Table 4.

Table 4: Physico-Chemical Analysis for combined wastewater concentration.

Parameter	Concentration
1. pH	5.9
2. BOD_5	166.67mg/l
3. COD	84.44mg/l
4. Nitrates	2,340mg/l
5. Phosphates	51.14mg/l
6. Oil and grease	7.00mg/l
7. T. S. S.	2,427mg/l
8. Coliform count	cfu/100ml

Heavy Metals Analysis

The result of heavy metal analysis of the samples were: copper Cu(0.86mg/l), cadmium Cd(0.07mg/l), chromium Cr(0.22mg/l), zinc Zn (5.31mg/l), magnesium Mg(48mg/l), arsenic As(0mg/l), lead Pb(2.78mg/l) and nickel Ni(0mg/l), which indicated that the heavy metal concentrations are within the safe limits set by the National Environmental Standards and Regulations Enforcement Agency (NESREA,2005), except zinc and lead.

Final Design of Sewerage System

The sewers were designed to follow the contours of the area and flow by gravity from higher to lower elevation. A draft layout plan was developed using the Simplified sewerage software (version 1.25) showing the proposed connections and relative positions of junctions and manhole chambers as shown in Figures 1 and 2.

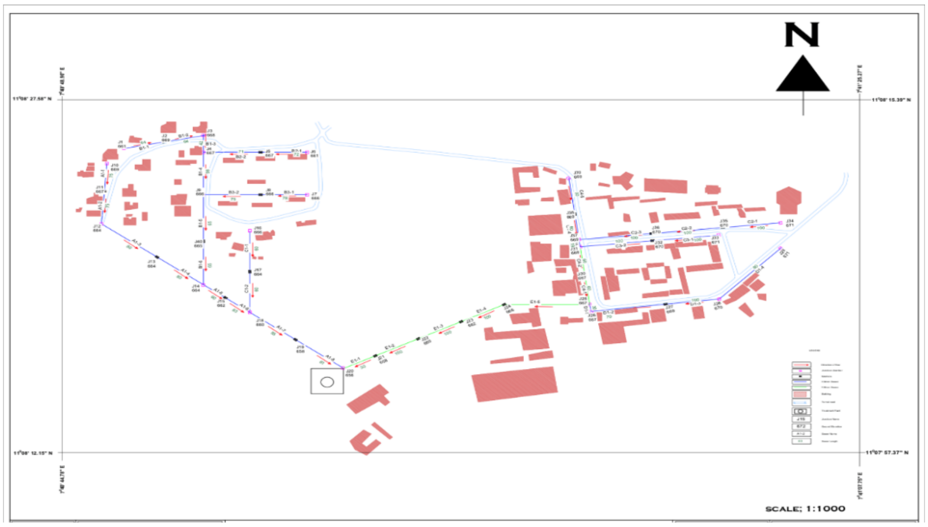

Figure 1: Draft Design of Sewerage Layout for NCAT Zaria. (Mains and laterals).

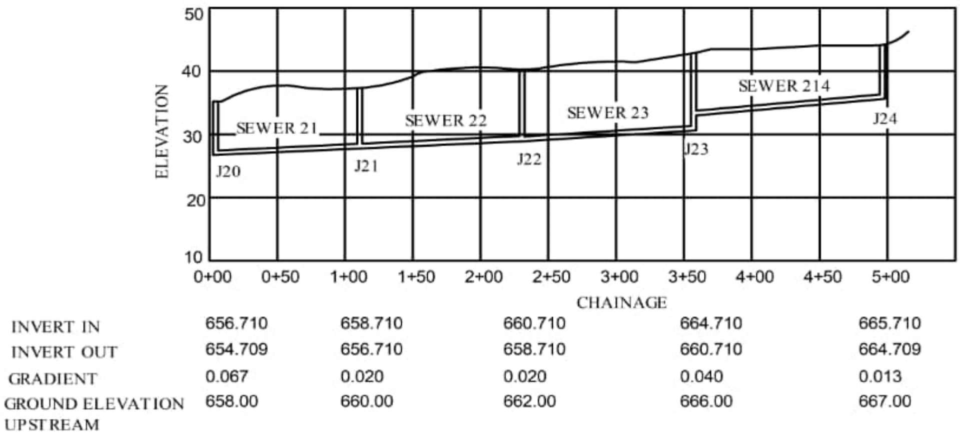

Figure 2: Cross-section of Draft Design of Depth Profile.

Design of the draft sewerage system was planned to minimize the depth and cost of excavation, provide easy access for operation and maintenance, and eliminate the need for pumping the sewage.

Table 5 shows the summary of sewerage design for NCAT Zaria with a total of 39 sewers covering a total length of 2,816m. The design has 40 junctions with 18 manhole chambers and 22 junction chambers with its design criteria for dimensions shown in Table 6. The minimum self-cleansing velocity of 0.50 m/s was achieved in the design.

Table 5: Summary of proposed sewerage design for NCAT.

Location	Type of Sewer	Sewer Diameter(mm)	Length (m)
Site 1	Main	150	530
	Lateral	100	2,286
Total Length(m)			2,816
Total No of sewers		39	
Total No of Junctions		40	

Table 6: Summary of Design Criteria for Junction/ Manhole Chamber

Diameter (mm)	A(m)	B(m)	C(m)	D(m)
100	0.45	0.23	0.53	0.18
150				

Summary of Designed components

Table 7 gives an overview of all the designed components for the wastewater treatment system for NCAT site 1.

Table 7: Summary of design WSPs for the college.

Ponds	Facultative	Maturation
Number of ponds	3	3
Length (m)	51	51
Breadth (m)	17	17
Depth (m)	1.2	1.2
Area (m^2)	840	843
Volume(m^3)	1,008	1,011.6
Retention time (days)	5.98	3
Desludging Rate (years)	9.79	9.83

Cost Estimate for Sewerage System and WSPs

The Bill of Engineering Measurement for the cost (capital only) of sewerage system and wastewater treatment plant for NCAT Zaria shows that a total sum of ₦14,649,855.75 is required to complete the project.

Operation and Maintenance Cost

The cost of operation and maintenance for the designed sewerage system and wastewater treatment plant was determined to be ₦3,030,000.00. The cost of operation and maintenance for the designed sewerage system and wastewater treatment plant includes payment of staff emoluments, repairs to damaged parts and any blockages, routine maintenance in form of desludging, provision for replacing used parts and spare parts in case of emergency breakdowns and transportation and communication.

Cost-Benefit Analysis

- Annual cost of proposed sewerage and WSPs = ₦5,550,475.00
- Annual benefit (cost saved from septic tank and soak-away system) = ₦5,935,600.00
- Cost-Benefit Ratio of Proposed Sewerage and WSPs = 0.94

A cost-benefit ratio of less than one implies that the project is viable, and hence it is recommended for execution and implementation.

Comparison of Soak-Away and Proposed Sewerage System.

Table 8 shows that the useful lifespan of the sewerage system and wastewater treatment plant coupled with its lower costs of desludging annually makes it more effective than the existing septic tank and soak-away system. A comparison of the annual cost of operation and maintenance, cost-benefit ratio also shows that the sewerage system is more viable compared to the existing system. Lastly, the high risks of groundwater pollution as widely reported in reviewed literature, risk of environmental pollution from the septic tanks which increases the risk of exposure/ spread of diseases, makes the septic tank and soak-away system less desirable and less safe for implementation as a means of wastewater collection, treatment and disposal.

Table 8: Comparison of Septic System and Sewerage System.

S/No.	Description of Category.	Septic System.	Sewerage and WSPs System.
		Site 1	Site 1
1.	Useful Design Life of Project	15 years.	30 years.
2.	Frequency of Desludging	2 years.	9 years.
3.	Cost of Desludging per year	₦980,000	₦30,000.00
4.	Annual Cost of O&M	₦1,604,000	₦3,030,000
5.	Cost-Benefit Ratio	1.06	0.94
6.	Risk of Groundwater Pollution	High	Low
7.	Environmental Pollution	High	Low
8.	Spread of Disease/Pathogens.	High	Low
		High	Low

The findings of this study demonstrate the significance of considering technical, institutional, and financial factors in the design of sanitary systems in Nigerian institutions. The results show that the current soak-away pits and septic tank systems are inadequate and contribute to environmental pollution. The study's findings also highlight the importance of centralized sewerage systems in reducing heavy metal contamination and environmental pollution.

This study contributes significantly to the existing body of knowledge on sanitary system design and wastewater management in institutional settings. Firstly, it provides insights into the institutional and financial factors influencing sanitary system design in Nigerian institutions. Secondly, it assesses the effectiveness of centralized sewerage systems in reducing heavy metal contamination and environmental pollution. Finally, it provides a comprehensive framework for sustainable wastewater management in institutional settings.

This study has some limitations that should be acknowledged. The study's design and methods were limited to a single case study, which may not be generalizable to all Nigerian institutions. Additionally, the study focused on technical, institutional, and financial factors, but did not consider other factors like social and cultural influences.

Future studies could investigate the social and cultural factors influencing sanitary system design in Nigerian institutions. Additionally, research could focus on developing innovative and sustainable wastewater management technologies for institutional settings.

Conclusion

The working conditions of the existing septic system was assessed based on performance indices having a score of 36%.

The results of physico-chemical analysis revealed extremely high concentrations of nitrates (2,550mg/l) and total suspended solids T.S.S. (1,778mg/l) while the concentrations of zinc (5.31mg/l) and lead (2.78mg/l) were above the acceptable limits for discharging to a receiving water body.

The results of the design showed that, a total of 39 sewers covering a distance of 2,816m having 18 manholes and 22 junction chambers, 3 facultative and 3 maturation ponds were required to adequately treat the wastewater generated. This consisted of DN150mm pipes covering a distance of 530m and DN100mm pipes with a ground distance of 2,286m.

The total capital cost for implementing the proposed sewerage system and WSPs for the college was determined to be ₦14,649,855.75.

A comparison of the proposed sewerage and WSPs system with the existing septic tank and soak-away system revealed that, the proposed sewerage and WSPs system had a higher cost-benefit ratio (0.94), longer lifespan (30 years), lower cost of annual desludging (₦30,000.00), and lower risks of groundwater and environmental pollution.

Recommendations

i. Research on artificial wetlands to treat the heavy metals present in the treated wastewater should be undertaken.
ii. Research on the effects of septic-tank system to groundwater contamination should also be undertaken.

References

Abdullahi, I., Nasiru, I., Saminu, A., Sagir, L., and Charity, E., (2014). Design of Waste Stabilization Pond for Sewage Treatment at Nigerian Defence Academy Staff Quarters, Permanent Site Mando Kaduna. International Journal of Engineering and Applied Sciences (IJEAS) ISSN: 2394-3661, Volume-1, Issue-2, November 2014.

Adewumi, J. R. and Oguntuase, A. M. (2016). Planning of Wastewater Reuse Programme in Nigeria. *Consilience: The Journal of Sustainable Development* Vol. 15, Iss. 1 (2016), Pp. 1-33

Adebowale, K. O., & Adewumi, J. R. (2020). Sustainable wastewater management practices in institutional settings: A review. Journal of Environmental Management, 248, 109-118.

Adeleke, A. O., Adewumi, J. R., & Ademola, K. B. (2020). Evaluation of wastewater management systems in Nigerian institutions: A case study of the University of Ibadan. Journal of Environmental Science and Health, Part C, 34, 53-63.

Akotey, J. N., Addo, M. A., & Nyarko, K. B. (2020). Factors influencing the adoption of centralized sewerage systems in Ghanaian institutions. Journal of Water, Sanitation and Hygiene for Development, 10(2), 247-257.

Akali, D. M. (2013). Assessment and Improvement Design of the Sanitary System at Malali Housing Estate Kaduna, Kaduna State Nigeria. An Unpublished M.Sc. thesis, Department of Water Resources and Environmental Engineering, Ahmadu Bello University, Zaria Kaduna State Nigeria.

Akali, D. M., Iorhemen, O. T., and Adie, D. B. (2012). Comparative Analysis on the Use of Septic Tank and Sanitary Sewerage Systems at Malali Housing Estate, Kaduna – Nigeria. International Journal of Engineering Research & Technology (IJERT) Vol. 1 Issue 09, November- 2012 ISSN: 2278-0181

Awuah, E., 2006, "Pathogen Removal Mechanisms in Macrophyte and Algal Waste Stabilization Ponds", Academic Board of Wageningen University and the Academic Board of the UNESCO-IHE Institute for Water Education, Netherlands.

Egharevba, N. A (2009). Irrigation and Drainage Engineering. Principles, Design and Practice. 2nd ed. Jos University Press, Nigeria.

Egwuonwu, C.C., Okafor, V.C., Ezeanya, N.C., Nzediegwu, C., Suleiman, A. and Uzoigwe, O., (2014). Design, Construction and Performance Evaluation of a Model Waste Stabilization Pond. Department of Agricultural Engineering, Federal University of Technology, Owerri, Imo State, Nigeria. Research Journal of Applied Sciences, Engineering and Technology 7(9): 1710-1714, 2014 ISSN: 2040-7459; e-ISSN: 2040-7467

Garg, S.K. and Garg, R. (2006). Sewage Disposal and Air Pollution Engineering. 18th ed khanna Publishers, Nai Sarak, Delhi-India.

Giwa, A., (2014). Sustainable Wastewater Treatment- The way to go. The Nigerian Voice Newspaper June 23, 2014. http://www.thenigerianvoice.com/news/150573/1/sustainable-wastewater-treatment-the-way-to-go.html

Ibrahim F. B., Bayero, M. T., Courageous, T., Ismail, A. (2016). Characterization of Laboratory Wastewater: A Case Study of Faculty of Sciences, Ahmadu Bello University, Zaria. Book of proceedings of the 15th annual international conference, Nigerian Materials Congress (NIMACON 2016).

ISO (2015). Environmental management systems - Requirements with guidance for use. International Organization for Standardization.

Lukman, S. (2009). Improvement Design of Ahmadu Bello University Sanitary Sewerage System. An Unpublished M.Sc. thesis, Department of Water Resources and Environmental Engineering, Ahmadu Bello University, Zaria Kaduna State Nigeria.

National Environmental Standards and Regulations Enforcement Agency (NESREA) (2005) Guidelines to Standards for Environmental Pollution Control in Nigeria, Federal Government Press Lagos, Nigeria.

Okparanma, R. N., Jumbo, R. B., and Chukwu, F. N. (2016) Combined Effects of Municipal and Industrial Wastes on the Quality of the New Northern Calabar River, Nigeria. Department of Agricultural and Environmental Engineering, Rivers State University of Science and Technology, Rivers State. International Journal of Water Resources and Environmental Engineering. Vol. 8(8), pp. 103-112, DOI: 10.5897/IJWREE2016.0656 Article Number: 489D8F459899 ISSN 2141-6613.

Oluwole, A. O., Oladunjoye, I. K., & Adebowale, K. O. (2019). Heavy metal contamination in wastewater: A review of treatment technologies. Journal of Environmental Management, 248, 109-118.

Omenka, E., (2010). Improvement of Decentralised Wastewater Treatment in Asaba, Nigeria. Department of Chemical Engineering, Water and Environmental Engineering. Lund University, Sweden.

UNEP (2020). Environmental sustainability in institutional settings: A guide. United Nations Environment Programme.

Ugya, A.Y., & Imam, T.S. (2015a). The efficiency of *Eicchornia crassipes* in the phytoremediation of waste water from Kaduna Refinery and petrochemical company. IOSR *J. Environ. Sci. Toxicol*. Food Technol., 9: 43-47.

Vymazal, J. (2013). The use of hybrid constructed wetlands for wastewater treatment with special attention to nitrogen removal: A review of a recent development. J Water Res 47:4795–4811.

WHO (2019). Guidelines for wastewater management in institutions. World Health Organization.

Yu, X., Wang, Z., Lynn, A., Cai, J., & Huangfu, Y. (2016). Heavy Metals in Wheat Grown in Sewage Irrigation: A Distribution and Prediction Model. Polish Journal of Environmental Studies 25: 413-419.

Zhang, J. (2001). Modern Concept of City Sewerage System. China Eng. Sci., 3(10): 33 – 35.