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Comparative Analysis on the Use of Septic Tank and Sanitary Sewerage Systems at Malali Housing Estate, Kaduna - Nigeria

*D. M. Akali
Department of Water Resources & Environmental Engineering, Ahmadu Bello University, Zaria - Nigeria.

O. T. Iorhemen
School of Civil Engineering, University of Leeds, United Kingdom.

D. B. Adie
Department of Water Resources & Environmental Engineering, Ahmadu Bello University, Zaria - Nigeria.

Abstract

Sanitation is very important for every community in order to break the faecal-oral route for disease transmission. Inadequate sanitation causes an outbreak of diseases like diarrhoea, cholera, typhoid, malaria, etc. This research evaluated the existing sanitation situation at Malali Housing Estate. The potential of using sanitary sewerage system as a cost-effective alternative system to the septic tanks system was explored. A waste stabilization pond system was designed alongside sanitary sewerage using SIMPLIFIED SEWERAGE software. The capital cost and annual operational cost for the sanitary system were estimated to be ₦44,468,138.00 and ₦1,135,200.00 respectively. Appropriate pricing system was adopted and after conducting cost analysis, ₦63,930,000.00 (143.8% capital cost) would be realised at the end of the design period. This amount gives a benefit-cost ratio of 1.44. Cost comparison between the use of sanitary sewerage and septic tank was also analysed. The use of the existing septic tank system would result to a loss of ₦266,625,000.00 annually on sludge removal for 25 years as against the benefit of ₦63,930,000.00 derived from using the designed sanitary sewerage. The research demonstrates that sanitary sewerage saves about 89.4% cost compared to use of septic tank in a peri-urban area like Malali. It is also more cost effective in securing public health, prevention of diseases and sustenance of the environment.

Keywords: *Sanitary System, Septic Tank, Simplified Sewerage, Waste Stabilization Pond*

1. Introduction

The environment plays a major role in maintaining a healthy life [1]. It needs to be preserved, and sanitation is one of the ways of preserving the environment. Sanitation is a basic human requirement with a primary aim of separating human waste from human settlements so as to prevent disease [2].

A sanitation system refers to a set of technologies which, in combination, treat human excreta from the point of generation to a final point of reuse or disposal, and it comprises components including means of storage, conveyance and treatment [3]. This means it is a multi-step process in which wastes are managed from the point of generation to the point of use or ultimate disposal[4].

Poor sanitation causes an outbreak of diseases like cholera, malaria, diarrhea, typhoid, etc and death [5-7]. Globally, unsafe water, sanitation and hygiene (WSH) have been identified as an important determinant in a number diseases with a high disease burden, such as schistosomiasis, trachoma, ascariasis, trichuriasis and hookworm disease, malaria, yellow fever, filariasis, dengue, hepatitis A and hepatitis E, typhoid, arsenicosis, fluorosis and legionellosis [8]. Diseases related to contamination of drinking-water constitute a major burden on human health [9].

Findings by World Health Organization (WHO) have demonstrated that 85-90% of all diarrhoeal diseases in developing countries are related to unsafe water, sanitation and hygiene (WSH) [8]. Improvement in sanitation relates to good hygiene practices, availability of health facilities, and reliable collection and treatment of wastewater [10]. Lack of

access to improved sanitation and safe water is a global crisis, but nowhere in the world are the effects of inadequate sanitation more visible, more pervasive and more devastating than in Sub-Saharan Africa [11]. Sanitation breaks the feacal-oral pathway of disease transmission [3]. The provision of sanitation facilities in this region is thus, important and urgent, requiring the use of emerging, existing, innovative and low-cost technologies.

The selection of a suitable sanitation is not to be based principally on technical insight, but should also integrate the human and environmental activities that surround it [10].

The Sustainable Sanitation Alliance has identified five broad criteria that should be addressed to make a sanitation system effective and sustainable [12]. These are: health and hygiene, environment and natural resources, technology and operation, financial and economic issues, and socio-cultural and institutional aspects. They further identify the following specific criteria that should be met by a sanitation system are as follows:

1. The ground water is protected from contamination;
2. Health hazards are eliminated from the toilet and from any handling, treatment, transport, and reuse or disposal of excreta;
3. The toilet systems are at an individual household level or small-scale decentralized (collective) level;
4. The toilet system is user friendly (i.e. odourless and no flies);
5. The operation and maintenance requirements are within the technical and economic capacity of the users;
6. Local materials are used and local habits are incorporated to make sanitation socially, economically and practically feasible;
7. Reuse aspects of sanitation (energy, fertilizer, water) are examined since they would be beneficial for the community;
8. Hygiene is integrated with sanitation (i.e. incorporate hand washing as an essential component of visiting the toilet).

Since ownership of the Federal Housing Estate Malali was relegated to individuals occupying them, the sewage treatment plant was abandoned by the Government. Technical and managerial problems started affecting the plant. Some of these problems are lack of finance for the smooth operation and maintenance, and poor staffing of the plant. This abandonment also led to the total collapse of the treatment plant and sewerage system (Figures 1 and 2 below) leading to poor sanitation situation within the estate.

There is therefore the need for the assessment of the wastewater collection and treatment facility with a view to improving it in order to mitigate the associated environmental problems and health risks.

The objective of this research therefore was to explore the potentials of using sanitary sewerage system for the collection, transportation, treatment and disposal of wastewater from the housing estate as against the continuous use of the septic tank system.

Figure 1: Visible shape of old WSP showing abandoned facultative pond

Figure 2: Broken DN200mm AC sewer close to the old waste stabilization pond

2. Materials and methods

The method adopted in this study is based on: system assessment, system improvement and cost analysis for abandoning the existing system.

2.1. Description of the study area

Malali Housing Estate is located in Kaduna North Local Government area of Kaduna State, Nigeria (Figure 3). It is a peri-urban area which lies between longitude 7°27'52"E and 10°33'47"N and latitude 7°28'27"E and 10°33'27"N. It is bounded to the North by Unguwan Dosa; to the West by Badarawa, South; Unguwan Rimi and to the East by River Kaduna (Figure 4). The estate is on a relatively flat terrain. The bulk of it falls between elevation of 591m to 615m above sea level and covers a total area of 61.64 hectares. It was jointly owned by the federal and state government. While the State Government still maintains her own ownership, the Federal Government sold hers to individuals occupying them. The portion belonging to the Federal Government occupies a land area of 37.36 hectares while that of the State Government occupies a land area of 24.28 hectares

Figure 3: Map of Nigeria showing Kaduna

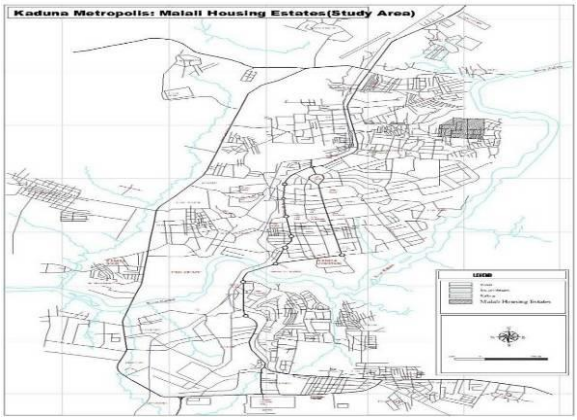

Figure 4: Map of Kaduna Metropolis showing Malali Housing Estate

2.2. Existing system assessment

The overall existing sanitary system (ESS) at Malali Housing Estate was assessed by means of Medical record of households from the Primary Health Care Clinic (PHCC), Malali; on-site physical survey and focused group discussions.

28 weeks record of diarrhoea and emesis cases were obtained from the Primary Health Care Clinic (PHCC) at the housing estate to check linkage between poor sanitation and risk of infection.

The ESS condition survey was conducted in order to know areas that require rehabilitation or further development [13]. Sewer system condition was inspected in terms of manhole cover and wall, and bursts along the sewer line.

Discussions were held with some stakeholders within the community in order to obtain the historical antecedent of the system as well as obtain other factors to be considered during the design of the new improved system.

2.3. Improvement design

A new sanitary sewerage system and new central sewage treatment plant were designed for the collection, transportation, treatment and disposal of wastewater from the estate. The new sanitary sewerage system was designed using the simplified sewerage software [14].

2.4. Cost analysis of abandonment of existing septic tank system

The total capital cost of implementing the improved design scheme was estimated. The analysis of the cost of abandoning the existing septic tank system was also carried out by comparing the cost of the two systems: improved sanitary system and existing septic tank systems.

3. Results and discussion

The results obtained during the assessment of the existing sanitary systems in the study are presented in Tables 1-12 and Figures 5-8 respectively.

3.1. Record of diarrhoea and emesis

Figures 5, 6 and 7 show the findings from medical records of households during the period (28 weeks) of the assessment of the sanitary system at the estate. Figure 5 presents the distribution by age group. Age group 0-5 recorded the highest number as children

under the age of five years are usually more affected by diarrhoeal disease [15].

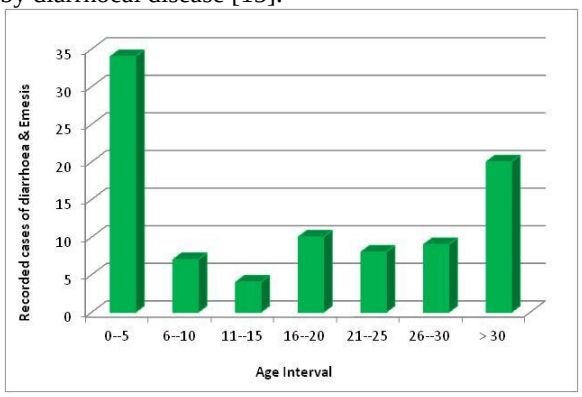

Figure 5: Diarrhoea cases by age group

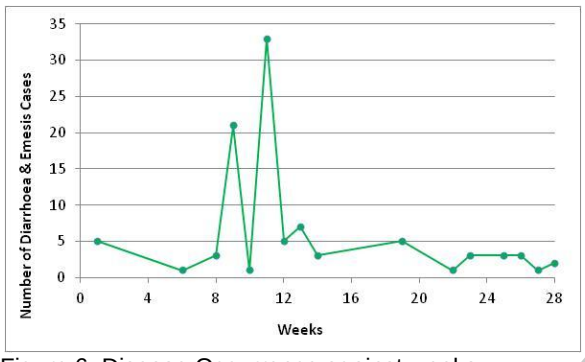

Figure 6: Disease Occurrence against weeks

Figure 6 shows that in weeks 9 and 11, there were outbreaks of diarrhoea and emesis. The highest case occurred in week 11 with a record of 33 cases while week 9 had 21 cases.

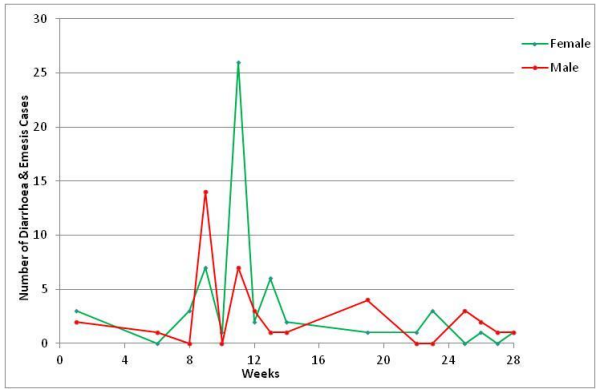

Figure 7: Weeks of disease occurrence against sex

Figure 7 further shows the distribution of the disease frequency based on sex. It indicates that females have the highest record of diarrhoea and emesis cases at week 11 with frequency of 26 while the males only have a frequency of 7. The result above implies that there exist sanitation-related diseases within the estate. This is attributable to the poor state of sanitation within the estate.

3.2. On-site physical survey

From the ESS condition survey conducted, no trace of sewer and manhole was found. The sewage Treatment Plant (STP) was bare. Only some visible shape of the facultative pond with grasses grown on the embankment and bottom were seen (Figure 1). Only one DN200mm AC pipe was seen at the STP (Figure 2). Sewage was seen lying stagnant at Kenya road due to lack of sewer that would convey the wastewater to a treatment plant.

Almost the whole estate is now using Septic tanks for sewage management. However, most of these septic tanks have filled up and usually spill over to flow freely on the ground during or after intense rainfall. The high cases of diarrhea and emesis recorded can be justifiably attributed to this situation.

Potential public health risks were identified during the reconnaissance survey behind Doruwa Street, Sierra Leone, Gambia and Uganda Streets where excreta are thrown indiscriminately inside polythene bags. These excreta-containing polythene bags were seen lying stagnant thereby providing breeding grounds for flies and mosquitoes. Issues of odour and unsightly nature of these bags were identified.

This necessitated the need for the development of a new low-cost sanitary sewerage system for the collection and transportation of the generated wastewater from the estate for treatment at a central treatment plant.

3.3. Focused group discussions

Focused discussions with some major stakeholders indicate that the presence of sanitation problems within the estate requires immediate attention. Table 1, in the Appendix, shows the summary of findings from the discussion.

The sanitary system at Phase II is managed by the Kaduna State government, while that at phase I is managed by individual owners.

3.4. System improvement design

Based on the estimated population of the estate (5,650 in 2012, and 15,000 in 2037), a Waste Stabilization Pond (WSP) treatment plant consisting of anaerobic ponds and secondary facultative ponds in series was designed [16]. The dimensions of the designed waste stabilization pond are given in Table 1 below. One additional anaerobic pond and one secondary facultative pond are to be provided as spare. This is to allow for maintenance so that when

one of the two ponds is to be emptied, this spare can be put to use at that time. The theoretical pond sludge removal intervals were also estimated. Table 2 gives the summary of the sludge removal intervals.

Based on the layout map obtained from Google Earth pro and Kaduna State Housing Property and Development Company, sanitary sewerage was designed using simplified sewerage software [14]. The design produced a total sewer length of 12,367m to cover the entire estate. The recommended pipe material is PVC. The summary of results from the sewerage design is shown in Tables 3 and 4 and Figure 8.

Table 1: Pond dimensions

Ponds	A_A	A_B	F_A	F_B
Length(m)	50	50	124	124
Breadth(m)	25	25	62	62
Area (m^2)	1250	1250	7,500	7,500
Retention time (days)	4.9	4.9	14.7	14.7

Table 2: Theoretical estimate of pond sludge removal intervals

Ponds	A_A	A_B	F_A	F_B
n(years)	2.1	2.1	6.25	6.25

Table 3: Summary of proposed sewer diameters with associated length at Malali housing estate Kaduna

type of sewer	*Location*	*sewer diameter (mm)*	*length (m)*	*total length (m)*
Main	Phase II	200	1,939	1,939
Main	Phase I	200	2,099.5	2,765.5
		150	284	
		100	382	
Lateral	Phase II	200	519	2,684
		150	997	
		100	1,168	
Lateral	Phase I (1)	200	428	3,555
		150	1,652	
		100	1,475	
Lateral	Phase I (2)	150	436	1,423
		100	987	
		TOTAL		12,367

Table 4: Summary of proposed sewer length and number of manholes

Total Length of 200mm Sewers (m)	**4,986**
Total Length of 150mm Sewers (m)	3,369
Total Length of 100mm Sewers (m)	4,012
Total No of Sewers	126
Overall Sewer Length (m)	12,367
Total No of Manholes/Junctions	131

3.5. Operation and maintenance of the sanitary sewerage system and treatment plant

The operation and maintenance of both the sewerage and sewage treatment plant includes [17, 18] :

- Clearance of blockages at the inlet and outlets of STP and manholes of sewerage;
- Prompt removal of any accumulation of foreign materials at the junction chambers and manholes of the sewerage system;
- Cutting of grasses on embankments and removing them to prevent them from falling into the pond;
- Removal of floating scum and macrophytes from the surface of facultative ponds;
- Spraying the scum on anaerobic ponds as necessary, with clean water or pond effluent to prevent fly breeding;
- Removal of any accumulated solids in the inlet and outlets;
- Repair of damage to the embankments caused by animals;
- Desludging of the sludge at the ponds when filled.

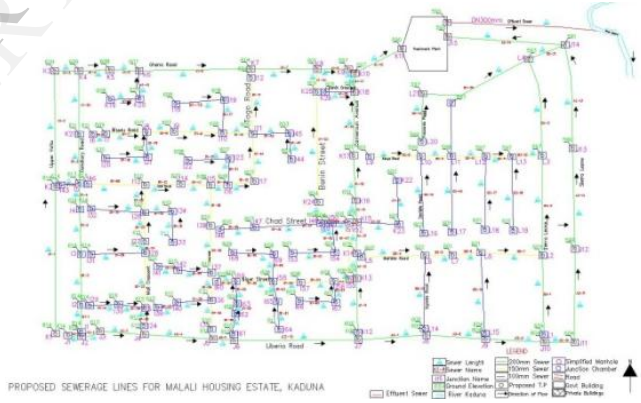

Figure 7: Sanitary sewerage lines and treatment plant for Malali Housing Estate

3.6. Cost analysis for the sanitary sewerage

i. Operation and maintenance cost

The operation and maintenance staff comprise of three operators and two security guards. The operators are to run their operations daily. Table 5 shows the summary of the type of operation and maintenance staff for running the improved system. Table 6 gives the summary of cost for the operation and maintenance of the systems. From Table 6, the operation and maintenance cost shall comprise the staff salary, transportation and other running cost. Table 6 also shows that it would require the sum of

₦1,135,200.00 annually for operation and maintenance.

Table 5: Operation and maintenance workers for STP sewerage

S/ No	Location	Position	Working Shift	Working hours	Workers/ Shift
	Sewage Treatment Plant				
1	STP	Operator	1	8	1
2	STP	Security	2	12	1
	Pipelines				
3	Pipeline	Operators	1	8	1

Table 6: Summary of operation and maintenance cost

S/ No	**Category of Personnel**	**Per Month (₦)**	**Per Year (₦)**
1	Operator Salary	18, 000 x 3 (54,000)	648,000
2	Security	16, 000 x 2 (32,000)	384,000
	Total	86,000.00	1, 032, 000
3	Transportation, Communication and other running cost	14,000	168, 000
	Grand Total	100,000.00	1,200, 000

ii. Capital cost

The capital cost for implementing the scheme was also estimated using Bill of Engineering Measurement and Evaluation (BEME). The total capital cost for the scheme was estimated to be ₦39,617,138.00.

This capital cost was distributed to the household based on the number of persons living in the house. Table 7 gives the summary of capital cost distribution per person. From Table 7, the cost per capita at phase I is ₦ 4,952.14k while that at phase II is ₦ 1,886.53k.

Table 7: Distribution of capital cost for the improved sanitary systems

Category	Phase I	Phase II
Total Capital Cost	₦19, 808, 569.00	₦19,808,569.00
Population Served	4000	10,500
Average Cost Per Person	₦4, 952.14k	₦ 1, 886.53k

iii. Price charges

Appropriate price charges were apportioned to the household (based on the economic situation of the day) so as to involve the community in the scheme. Table 8 shows the summary of price charges. From Table 8, if ₦700.00 is charged per house at phase I and ₦200.00 per room phase II, the total sum of ₦3,692,400.00 would be realized on annually.

Table 8: Summary of price charges at the estate for the operation and maintenance of the improved systems

S/No	No of Houses	Monthly Charges per House (₦)	Total Charges /Month (₦)	Total Charges /Year(₦)
Phase I	131	700	91, 700	1, 100, 400
Phase II	1080	200	216, 000	2, 592, 000
		Total	307, 700	3, 692, 400

iv. Benefit-cost analysis of sanitary sewerage system

The total accrued revenue from the operation and maintenance charges was estimated for 25 years and the analyses were carried out. Table 9 shows the summary of income-expenditure for operation and maintenance.

Table 9: Summary of income and expenditures for operation and maintenance

Year Intervals	**Generated Revenue (₦)**	**Expenditure (₦)**	**Net Income (₦)**
10	36,924,000	11,352,000	25,572,000
20	73,828,000	22,704,000	51,146,000
25	92,310,000	28,380,000	63,930,000

From Table 9, the net balance after 25 years of implementation of the scheme would be of ₦63,930,000.00. This is the net profit that would be generated.

Table 10 below shows the cost-benefit analysis of embanking on the scheme. From the analysis, a benefit-cost ratio of 1.43 was obtained. This implies that the scheme is economically viable and the capital cost would be realized with even a profit of ₦19,461,862.00.

Table 10: Cost-benefit analysis for the sanitary sewerage system at Malali

Year Intervals	Phase I Gross Income (₦39,617,138)	Phase II Gross Income (₦44, 468, 138.)	Net Income (Benefit) (₦)	% Capital Recovery	Benefit -Cost Ratio
10 Years	₦25, 572, 000	-	-14,045,138	64.55%	0.65
20 Years	-	₦51, 146, 000	+6,675,862	115%	1.15
25 Years	-	₦63, 930, 000	+19,461,862	143.8%	1.43

v. Cost analysis of existing septic tank system

As stated in section 3.2 above, the whole estate is swampy and intense precipitation fill up the tanks, causing the sewage to flow freely on the surface. The households employ the services of desludging tankers in emptying the septic tanks. The average cost of desludging one septic tank is ₦9000. Assuming that, on the average, septic tanks are emptied five times annually, the cost of sludge removal within the estate is as shown in Table 11. The cost for the entire estate amounts to ₦10, 665,000.00 annually.

Table 11: Cost analysis of septic tank

Location	No of Houses	No of Septic Tank	Ave. No of De-sludging / Year	Total Cost (₦9000/Septic Tank)
Phase I	131	131	5	₦5,895,000
Phase II	53	106	5	₦4,770,000
			Total Cost/ Year	₦10,665,000
Total Cost After 25 Years				₦266,625,000

vi. Comparison of cost between sanitary sewerage system and existing septic tank at Malali.

As shown in Table 9, the cost of operation and maintenance of the sanitary sewerage system for 25 years is ₦28,380,000. This amount, when compared with the cost of de-sludging septic tanks within the entire estate for 25 years (₦266, 625,000), would yield about 89.4% savings when sanitary sewerage system is used. Table 12 below shows some advantages of adopting the use of sanitary sewerage system at the estate as against the use of septic tank system.

Table 12: Comparison of soak away and proposed sanitary system (WSP & sewerage)

S/No	Description of Item	Soak Away/Septic Tank	WSP and Sewerage
1	Risk of Disease	High	Low
2	Frequency of Desludging	5 times/Year	Once/2.5 year
3	Environmental Factor	Not friendly (Not aesthetically friendly)	Friendly (aesthetically okay)
4	Economic Factor	Not beneficial(Not economically viable)	Beneficial (Viable)

4. Conclusion

The existing sanitation situation at Malali Housing Estate was evaluated. It was found that the sanitation system has totally collapsed. This necessitated the design of an improved system.

Simplified sewerage system was designed alongside a Waste Stabilization Pond (WSP) for the estate. The capital and operating cost of implementing this proposed improved scheme was estimated and the cost compared with that of using septic tanks systems as it is the case now. The benefit-cost ratio of implementing the new scheme was found to be 1.43. A cost savings of about 89.4% will be achieved when compared with the existing septic tank system.

This research has shown that sanitary sewerage (Simplified Sewerage) with a Waste Stabilization Pond (WSP) could be more cost effective than the use of septic tanks systems most especially in swampy areas in urban and peri-urban settings. The total net profit of ₦63,930,000.00 from the use of the sanitary systems as observed in this research is comparable with that of septic tank which yields a loss of ₦266,625,000.00 among others.

The community involvement aspect of the improved system would also give them a mindset of guiding and maintaining their system jealously which is contrary to their initial mindset of not owning the septic tanks, hence, not catering for it.

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Appendix

Table 1: Summary of Results from Group Discussions among the Major Stakeholders

Streets	No. of Plumbers	Water Availability	Common Problems	Proposed Remedial Action
Kenya & Tanzania Streets	Nil	Water is available only in 1st block houses. The remaining 6 blocks have no water because they are not connected to the world bank line.	No trace of sewer line was seen. Some private houses have been constructed directly on top of the lines. Sewage is seen lying stagnant with flies and mosquitoes breeding and hanging around. The estate is a swampy area thereby making shorter the tanks desludging period.	Government should sell ownership to individuals occupying the houses. Households should connect their water lines to the new world bank line so as to have water. New sewers should be introduced so as to cater for the collection and transportation of the sewages to STP.
Gambia Street		No water. The majority houses are relying on water from hand dug wells. The people are waiting on government to cater for their need.	Sewage are seen lying stagnant in some places thereby causing breeding grounds for mosquitoes. The condition of the sanitation systems is capable of causing ground water pollution.	There should be community effort in tackling the sanitation problems. Construct a new WSP and sewerage network for the collection and transfer of the wastewater. Households should be encouraged to keep their environment tidy.
Uganda Street	Nil	All the houses have no water. They are currently relying on hand dug wells. Water is only available to few houses connected to the world bank line.	No trace of sewer lines. Some chambers were seen and are in total state of collapse. The market has no public toilets. Houses within the market do not also have toilets. Poly bags (containing faeces) and other materials are thrown recklessly within the market as a result.	Government should sell the houses to occupants. The occupants should contribute and connect to the existing world bank line. Community efforts should be put in place so as to built public toilets at the market places. The environs should be enlightened on the need to keep their environment tidy.
Zambia Street	Nil	No water is available	No trace of sewer line seen. There are spillage of sewages seen which are causing discomfort and aesthetic problems.	Households should contribute and connect to the existing world bank line.
Sierra Leone Street	Nil	Water is only available to few houses connected to the world bank lines.	No any sewer seen. No access road for vehicle meant for desludging of septic tanks due to illegal construction of private houses. Nonchalant attitude on the part of the people towards maintenance of their system.	The people should be enlightened on the danger of poor sanitation. Government should sell ownership to individuals occupying the houses. Central sewage treatment should be constructed in order to channel the collected wastewater through sewers for onward treatment.
Doruwa & Dabino Streets		No water because all the houses are not connected to the world bank line. All the houses are currently relying on hand dug well.	No sewer line seen. Private houses are seen constructed on top of existing septic tanks. Sewage are seen lying stagnant due spillage. No access road for desludging of sewers.	Sewer lines should supply and installed. Plumbers and sanitation engineers should be employed for the operation and maintenance of their systems at the community level.
Phase I Houses	Nil	Water is available to about 90% of the houses. The remaining 10% are not having water because they are not connected to the world bank line.	No trace of sewer line seen. The only manhole seen is around Ghana road and has already collapsed.	Houses without water should connect to the existing world bank line.

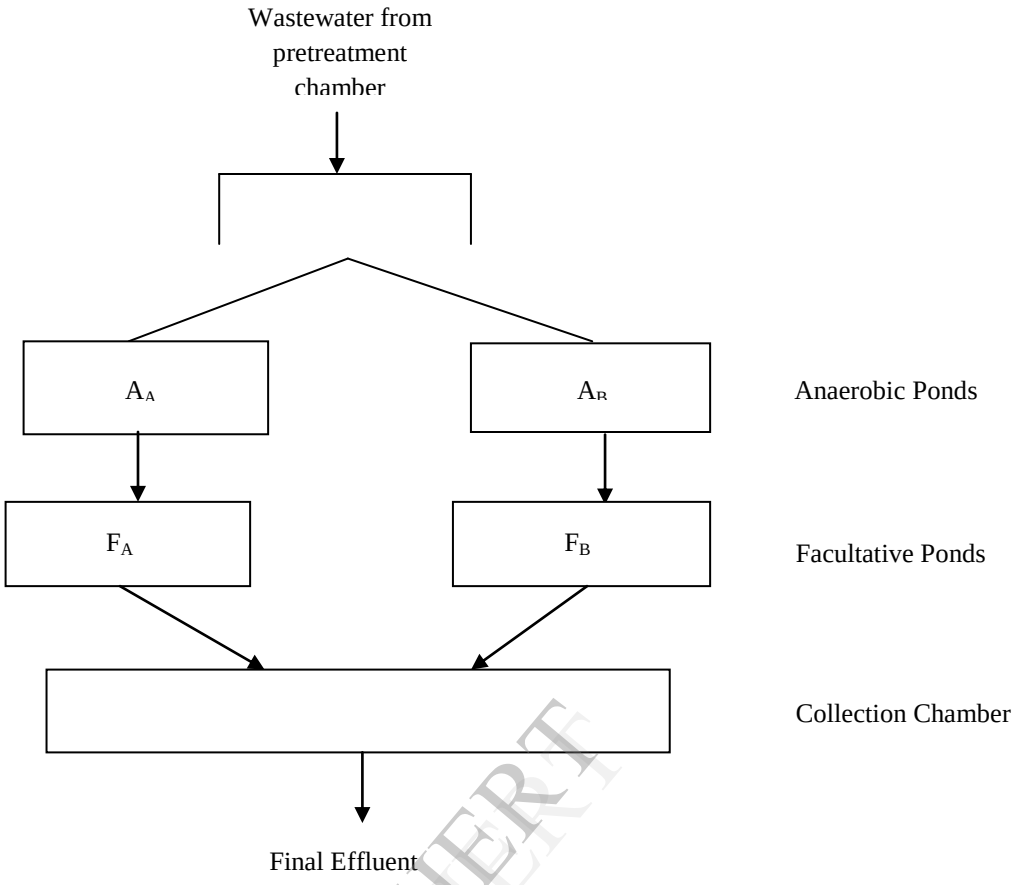

Figure 1: Process Flow Diagram for WSP