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ON-SITE WASTEWATER TREATMENT SYSTEM DESIGN FOR A MARSHY URBAN AREA IN NIGERIA

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ABSTRACT

This research aims at evaluating the efficiency of soil-based wastewater treatment systems in developing countries and designing an on-site wastewater treatment system for a difficult local site condition. Information on wastewater flow and wastewater quality, transport and fate of typical pollutants, conventional systems and treatment options, and various other design considerations, was reviewed from relevant texts and publications. A site and soil evaluation was carried out in order to locate the area to be used for the absorption field and determine soil characteristics, percolation rate, restriction, and groundwater table. The on-site wastewater treatment and disposal system was sited such that its separation from building structures and boundaries permits repair, maintenance of required separation from wells and reduces undesirable effects of underground wastewater flow and dispersion. The absorption area was sized based on an estimation of the household's wastewater flow and daily loading rate, which corresponds to the percolation rate of the receiving soil surface. The on-site wastewater treatment system designed for Danjuma area, Odi-Olowo Street, Akure, Ondo State, Nigeria, is comprised of a septic tank, dosing chamber and a mound system, which house the absorption area (drain field). The design was based on the minimum standards for design and construction of on-site wastewater systems in the state of Kansas [1]. The septic tank (2 m × 1.5 m × 2 m) was sized based on the estimated wastewater flow of 2160 liters day^{-1} and the dosing chamber (1 m × 0.75 m × 1 m) has half the size of the septic tank. The mound system recommended for this site, which experiences seasonal high water tables and occasional floods, was raised using well-graded sand. The absorption area (10.5 m × 10.5 m) was sized based on an estimated wastewater flow of 2160 liters day^{-1} and a daily loading rate of 20 liters m^{-2} day^{-1}, which corresponds to the obtained percolation rate of 18 mins cm^{-1} (0.056 cm min^{-1}).

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INTRODUCTION

The specific study site is the Danjuma area, Odi-Olowo Street, Isikan, Akure, Ondo State, Nigeria. Wastewater treatment by a conventional, centralized treatment facility for developing countries is in most cases neither practical nor economically feasible. Properly designed, constructed and maintained on-site treatment and disposal are an effective and economically feasible means of managing wastewater in suburban and urban communities in these countries.

The existing oversight of decentralized wastewater treatment systems especially in developing countries like Nigeria is of great concern.

The preponderance of haphazard wastewater management facilities in developing countries like Nigeria necessitates this research approach. The interest in optimizing on-site wastewater systems' performance is increasing due to the recognition of their impacts on groundwater and surface water quality.

According to USEPA [2], public health and environmental protection officials now acknowledge that on-site systems are not temporary installations that will be replaced eventually by centralized sewage treatment services, but permanent approaches to treating wastewater for release and reuse in the environment. On-site systems are recognized as potentially viable, low-cost, long-term, decentralized approaches to wastewater treatment, if they are planned, designed, installed, operated and maintained properly.

GENERAL BACKGROUND

On-Site Wastewater Treatment Systems (OWTS) collect, treat, and release treated effluent from homes, business, and recreational facilities. Household wastewater treatment and disposal, is of particular consideration in this research. OWTS evolved from pit privies used widely throughout history to installations capable of producing a disinfected effluent that is fit for human consumption. On-site systems remove settleable solids, floatable grease and scum, nutrients, and pathogens from wastewater discharges. Typical on-site systems consist primarily of a septic tank and a soil absorption field (see Figure 1). Septic tanks remove most settleable and floatable material and function as an anaerobic bioreactor that promotes partial digestion of retained organic matter. Septic tank effluent, which contains significant concentrations of pathogens and nutrients, has traditionally been discharged to soil, sand, or other media absorption fields for further treatment through biological process, adsorption, filtration, and infiltration into underlying soils.

Only about one-third of the land area in the United States has soils suited for conventional subsurface absorption fields [3]. System densities in some areas exceed the capacity of even suitable soils to assimilate wastewater flows, and retain and transform their contaminants. In addition, many systems are located too

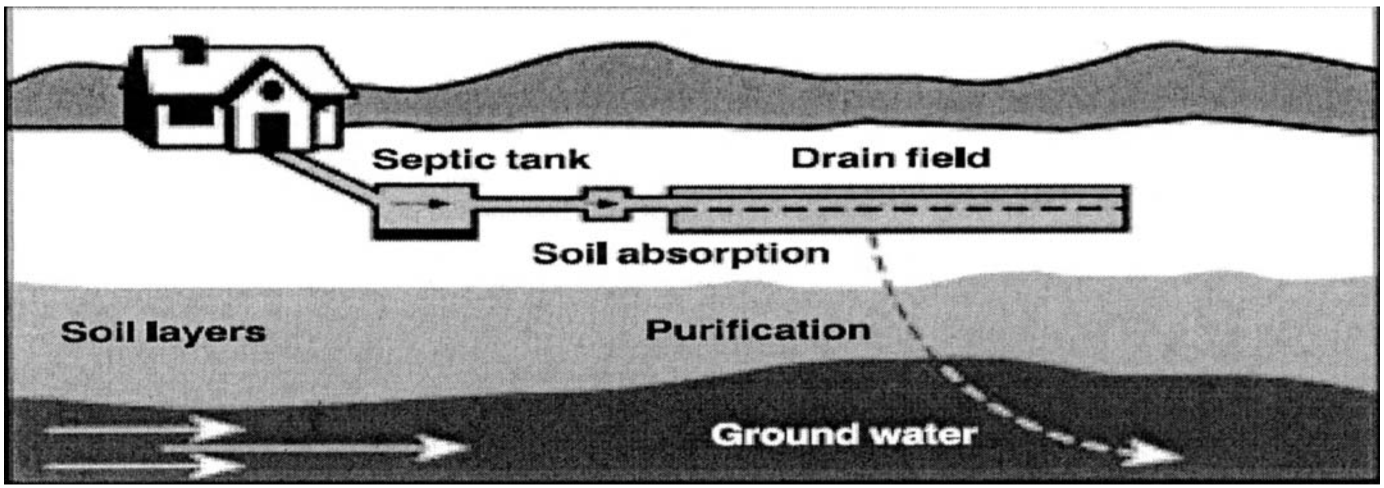

Figure 1. Conventional on-site wastewater treatment system.

close to groundwater or surface waters and others are not designed to handle increasing wastewater flows.

The overall objective of this work is to design an on-site wastewater treatment and disposal system for a marshy area, such as can produce a relatively disinfected effluent. In the United States, state and tribal agencies report that on-site septic systems currently constitute the third most common source of groundwater contamination and that these systems have failed because of inappropriate siting or design or inadequate long-term maintenance [2]. The United States Environmental Protection Agency (USEPA) estimates that 168,000 viral illnesses and 34,000 bacterial illnesses occur each year as a result of consumption of drinking water from systems that rely on improperly treated groundwater [3].

In Nigeria, the increasing rates of typhoid fever and other water-related health problems can be traceable to improper wastewater management. Shortcomings in the planning, design, construction, and maintenance of on-site wastewater disposal systems have resulted in poor system performance, public health threats, degradation of surface and groundwater, property value declines and negative public perceptions of on-site treatment as an effective wastewater management option.

WASTEWATER CHARACTERISTICS

Wastewater Quality

The physical, chemical, and biological compositions of wastewaters qualitatively characterize it. In the same fashion as the variability of wastewater flows for a typical residential dwelling, so is the variability of pollutants to be removed by an OWTS. OWTS should be designed to accept and process hydraulic flows from a residence while providing the necessary pollutant removal efficiency to achieve performance goals.

Wastewater Pollutants of Concern

Residential water-using activities contribute varying amounts of pollutants to the total wastewater flow. As human activities impact negatively on the environment, so does the environment on humans in turn. Toxic compounds, excessive nutrients, and pathogenic agents are among the potential impacts on the environment from on-site wastewater systems.

According to USEPA [3], a conventional OWTS comprised of a septic tank and Subsurface Wastewater Infiltration System (SWIS), is capable of nearly complete removal of suspended solids, biodegradable organic compounds, and fecal coliforms, if properly designed, sited, installed, operated, and maintained. These wastewater constituents can become pollutants in groundwater or surface waters if treatment is incomplete. Research and monitoring studies have demonstrated removals of these typical constituents to acceptable levels. More recently, however, other pollutants present in wastewater are raising concerns, including nutrients (e.g., nitrogen and phosphorus), pathogenic parasites (e.g., *Cryptosporidium, Parvum, Giardia lamblia*) bacteria and viruses, toxic organic compounds, and metals.

On-Site Wastewater Treatment Systems (OWTS) Design

Most traditional systems rely primarily on physical, biological, and chemical processes in the septic tank and in the biomat and unsaturated soil zone below the SWIS (commonly referred to as a leach field or drain field) to sequester or attenuate pollutants of concern. On-site systems can fail to meet human health and water quality objectives when fate and transport of potential pollutants are not properly addressed. Pollutants migrate into groundwaters used as drinking water and nearby surface waters used for recreation. Such failure can be due to improper siting, inappropriate choice of technology, or faulty design.

For example, in high-density subdivisions conventional septic tank/SWIS systems might be an inappropriate choice of technology because loading of nitrate-nitrogen could result in nitrate concentrations in local aquifers that exceed the drinking water standard. In soils with excessive permeability or shallow water tables, inadequate treatment in the unsaturated soil zone might allow pathogenic bacteria and viruses to enter the groundwater, if no mitigating measures are taken. Poorly drained soils can restrict reoxygenation of the subsoil and result in clogging of the infiltrative surface.

A number of factors influence the shape and movement of contaminant plumes from OWTS. Soils, slopes, geology, regional hydrology, and hydraulic load determine whether the plume will disperse broadly and deeply or, more commonly, migrate in a long and relatively narrow plume along the upper surface of a confining layer or on the surface of the ground water [4].

In general, however, plumes tend to be long, narrow, and definable, exhibiting little dispersion (see Figure 2). Some studies have found SWIS plumes with nitrate levels exceeding drinking water standards (10 mg/l) extending more than 328 feet (100 m) beyond the SWIS [5].

A conventional OWTS (septic tank and SWIS) discharges to groundwater and usually relies on the unsaturated or vadose zone for final polishing of the wastewater before it enters the saturated zone. The septic tank provides primary treatment of the wastewater, removing most of the settleable solids, greases, oils, and other floatable matter and anaerobic liquefaction of the retained organic solids. The biomat that forms at the infiltrative surface and within the first few centimeters of unsaturated soil below the infiltrative field provides physical, chemical, and biological treatment of the SWIS effluent as it migrates toward the groundwater.

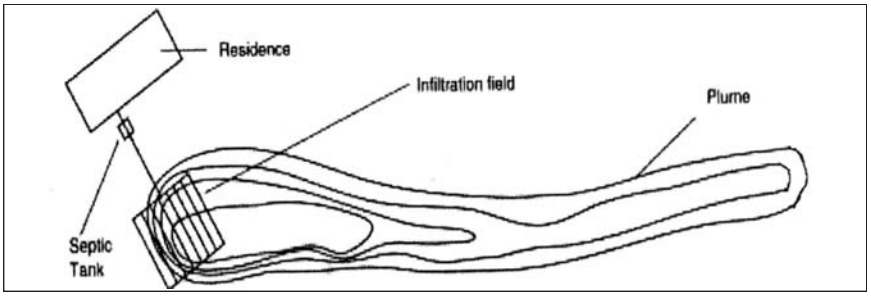

Figure 2. An example of effluent plume movement.

Below the zone of infiltration lies the unsaturated or vadose zone. Here the effluent is under a negative pressure potential (less than atmospheric) resulting from the capillary and adsorptive forces of the soil matrix. Consequently, fluid flow occurs over the surfaces of soil particles and through finer pores of the soil while larger pores usually remain air-filled. This is the most critical fluid transport zone because the unsaturated soil allows air to diffuse into the open soil pores to supply oxygen to the microbes that grow on the surface of the soil particles. The negative soil moisture potential forces the wastewater into the finer pores and over the surfaces of the soil particles, increasing retention time, absorption, filtration, and biological treatment of the wastewater.

From the vadose zone, fluid passes through the capillary fringe immediately above the groundwater and enters the saturated zone, where flow occurs in response to a positive pressure gradient. Treated wastewater is transported from the site by fluid movement in the saturated zone. Mixing of treated water with groundwater is somewhat limited because groundwater flow usually is laminar. As a result, treated laminar water can remain as a distinct plume at the groundwater interface for some distance from its source [6].

TRANSPORT AND FATE OF POLLUTANTS

Biochemical Oxygen Demand and Total Suspended Solids

Systems that fail to remove BOD and TSS and are located near surface waters or drinking water wells may present additional problems in the form of pathogens, toxic pollutants, and other pollutants. Under proper site and operating conditions, however, OWTSs can achieve significant removal rates (i.e., greater than 95%) for biodegradable organic compounds and suspended solids. According to the University of Wisconsin [7], the risk of groundwater contamination by BOD and TSS below a properly sited, designed, constructed, and maintained SWIS is slight.

Nitrogen

Nitrogen in raw wastewater is primarily in the form of organic matter and ammonia. After the septic tank, it is primarily (more than 85%) ammonia. After discharge of the effluent to the infiltrative surface, aerobic bacteria in the biomat and upper vadose zone convert the ammonia in the effluent almost entirely to nitrite and then to nitrate.

Nitrogen in its nitrate form is a significant groundwater pollutant. The permissible limit of nitrate in the World Health Organization (WHO) drinking water standard is 10 mg/l. High concentrations of nitrate (greater than 10 mg/l) can cause methemoglobinemia or "blue baby syndrome," a disease in infants that reduces the bloods ability to carry oxygen, and problems during pregnancy [3]. Nitrate-nitrogen concentrations in groundwater were usually found to exceed the drinking water standard of 10 mg/l near the infiltrative field [3].

Nitrogen can undergo several transformations in and below a SWIS, including adsorption, volatilization, mineralization, nitrification, and denitification. Factors found to favor denitrification are fine-grained soils (silts and clays) and layered soils (alternating fine-grained and coarser-grained soils with distinct boundaries between the texturally different layers).

Conventional Systems and Treatment Options

The SWIS is the interface between the engineered system components and the receiving groundwater environment. The performance of conventional systems relies primarily on treatment of the wastewater effluent in the soil horizon(s) below the dispersal and infiltration components of the SWIS.

The other major component of a conventional system, the septic tank, is characterized by describing its many functions in an OWTS.

Subsurface Wastewater Infiltration System (SWIS)

There are several designs for SWISs. They include trenches, bed, seepage pits, at-grade systems and mounds. SWIS applications differ in their geometry and location in the soil profile. Trenches have a large length-to-width ratio, while beds have a wide, rectangular or square geometry. Seepage pits are deep, circular excavations that rely almost completely on sidewall infiltration.

Infiltration surfaces may be created in natural soil or imported fill material. Most traditional systems are constructed below ground surface in natural soil. In some instances, a restrictive horizon may be removed and the excavation filled with suitable porous material in which to construct the infiltration surface [4]. Infiltration surfaces may be constructed at the ground surface ("at-grades") or elevated in imported fill material above the natural soil surface ("mounds").

Design Considerations

On-site wastewater treatment system designs vary according to the site and wastewater characteristics encountered. However, minimum requirements (see Table 1) are expected to be met for satisfactory long-term performance.

METHODOLOGY

Site Reconnaissance

A marshy site (at Danjuma area), Odi-Olowo Street, Isinkan, Akure, Ondo State, Nigeria) was selected as a case-study area for this project. Isinkan is a suburban community located along Ondo Road and also accessible from Arakale Road, Akure, Ondo State. Odi-Olowo Street (see Figure 3), having houses on both sides, is crossed by Eru Oba Titun Street and Ala/Elagbin Stream. Old building structures along the stream have settled, such that most of them have been deserted. Observation of some wells around this area shows that the depth to water table is shallow. People living within this area source their drinking water from wells. This area has grass-dominated vegetation which is green during the dry and wet seasons. Interaction with some of the residents shows that this area experiences occasional flooding.

Table 1. Minimum Required and Recommended Separation Distance for On-Site Wastewater Systems

	Minimum distance, ft (m)	
Separations distance	Required	Recommended
Septic tank to foundation of house or other buildings	10 (3.05)	10 (3.05)
Soil absorption system to dwelling foundation	20 (6.10)	50 (15.24)
Any part of a wastewater system to:		
Public potable water line	25 (7.62)	25 (7.62)
Private potable waterline	10 (3.05)	25 (7.62)
Property line	10 (3.05)	50 (15.24)
Public water supply well or suction line	100 (30.48)	200 (60.96)
Private water supply well or suction line	50 (15.24)	100 (30.48)
Surface water course	50 (15.24)	100 (30.48)

Source: [1].

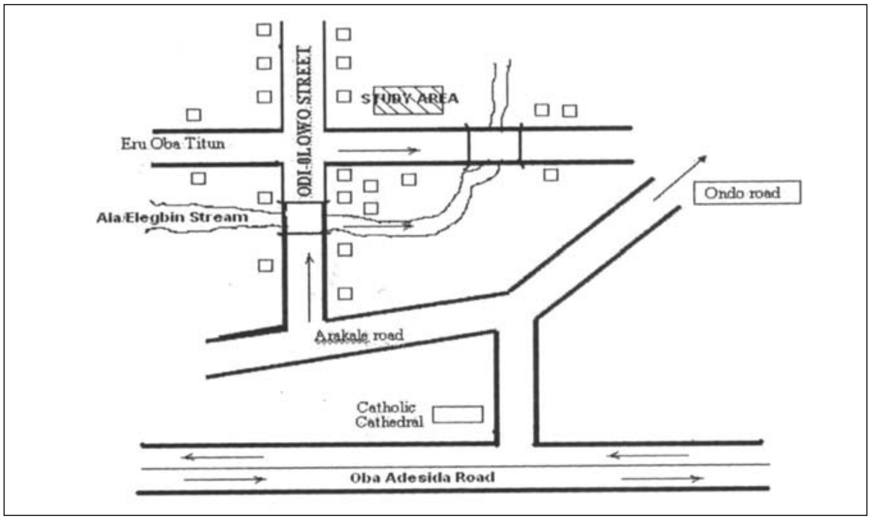

Figure 3. Site layout for the marshy area, Odi-Olowo Street, Isikan, Akure, Ondo State.

Soil Investigation

The depth to water table, soil profile, and the rate at which water percolates into the ground were determined. Two observation (test) pits were dug at the site for which the drain field is to be designed. The digging continued until water was encountered. The depth of water table was measured with reference to the original ground surface 24 hours after the test pits were dug. After the topsoil/vegetative soil was excavated in the process of digging the observation pits, representative soil samples were collected at 0.6-1.0 m, 1.0-1.4m, and 1.4-1.8 m, and stored in watertight containers before being transported to the laboratory.

Four 200 mm diameter holes were dug to 0.6 m beneath the ground surface and 5 cm of washed gravel in a mesh bag was placed in the bottom of the hole. Water was poured into the hole and its level maintained for 24 hours. After 24 hours water addition was stopped and a board with a centerline mark was placed across the top of each hole such that this mark was centered over the hole.

A measuring rule was aligned with the mark on the board and used to read the level when it just touched the water surface. The hole was filled with about 150 mm over the gravel and initial measurements of height and time were taken. At 30 minutes intervals, both the water level and time were recorded. The time interval was divided by the drop in water level to find the percolation rate in minutes/mm. These measurements were continued until each of three consecutively calculated rates varied by no more than 10% from the average of the three rates.

Water Usage Determination

In order to estimate the wastewater flow of the household for which the drain field is to be designed, an attempt was made to determine its water usage. Water usage was determined initially by counting the number of times which the residents draw-up water from its well, using a 4-liter container. This procedure was discontinued when it was found that some of the households source their drinking water from other wells, which they consider deeper than theirs.

Laboratory Tests

Natural moisture content determination, sieve analysis, and Atterberg limits test were performed on the soil samples collected from the site according to BS 1377 [8]. Attempts were made to describe the samples that constitute the profile of the soil.

Design Methodology

After assessing the physical characteristics of the proposed site to receive the septic tank effluent, with due consideration to the design boundaries (system/soil interfaces, soil layer, property boundaries, and water table), two options were considered. Either the wastewater generated in this area is disposed-of at a nearby site of suitable hydrologic and geologic characteristics, or a mound system is designed to receive the wastewater on-site. The design was based on the minimum standards for design and construction of on-site wastewater systems by the State of Kansas Department of Health and Environment [1]. After a critical analysis of each of the options, based partly on costs, it was established that the first option is impractical since the nearest suitable land area available is about 2 km away from the point of wastewater generation.

Particle size distribution of a representative sample of sand (fill) to be utilized to raise the infiltration surface was determined. The height of the fill was selected such that the separation distance between the infiltration surface and the design boundary (highest water table) is greater than 1.5 m. A dosing chamber/tank from where the septic tank effluent would be pumped to the infiltration surface was sized. The absorption area was sized using the estimated wastewater flow and loading rate (corresponding to the percolation rate obtained, with reference to Table 2 (adapted from [1])).

RESULTS

Preliminary Results

After digging two observation pits, it was established that the water table was about 1.8 m below the ground surface.

Table 2. Soil Absorption Field Loading Rate and Area Recommendation for Septic Tank Effluent Based on Percolation

Percolation rate mins inch^{-1} (mins cm^{-1})	Recommended absorption area ft^2 bedroom^{-1} (m^2 bedroom^{-1})	Loading rate gpd ft^{-2} (1 m^{-2} day^{-1})
< 5 (1.97)	Not recommended for conventional soil absorption system	
5-10 (1.97-3.94)	165 (15.33)	0.91 (37.07)
11-15 (4.33-5.91)	190 (17.65)	0.79 (32.18)
16-30 (6.30-11.81)	250 (23.23)	0.6 (24.44)
31-45 (12.20-17.72)	300 (27.87)	0.5 (20.37)
46-60 (18.11-23.62)	330 (30.66)	0.45 (18.33)
> 60 (23.62)	Not recommended for conventional soil absorption system	

Source: SKDHE (1997).

Soil samples were taken at depths 0.6-1.0 m, 1.0-1.4 m, and 1.4-1.8 m, and put into appropriately labeled watertight (plastic) containers. Table 4 presents the color of each of the samples.

Percoluation Test Results

The results of the percolation test are summarily presented in Table 3.

Summary of Results

The results obtained for test pits A and B can be summarily presented in Table 4.

Discussion of Results

Preliminary Results

Since it was not established that the water table depth (1.8 m) obtained characterized the heaviest rainfall that this site has ever experienced, it is assumed that the water table is nearer to the ground surface. And this high water table is considered a design restriction. The color of samples taken near the top soil (in the upper horizon) is darker than those in lower horizons due to a higher content of organic matter. The moisture content of soil at 0.6-1.0 m depth is higher than that at depth 1.0-1.4 m for both test pits because the soil at 0.6-1.0 m contains more clay fines and thus retains moisture. On the other hand, the moisture content

Table 3. Result of Percolation Test

	Hole[a]							
	1		2		3		4	
Time readings (mins)	Height (cm)	Percolation rate	Height (cm)	Percolation rate	Height (cm)	Percolation rate	Height (cm)	Percolation rate
0	35	—	38	—	40	—	35	—
30	33.1	0.063	36	0.067	37.5	0.083	33	0.067
60	31.4	0.056	34.2	0.060	35.5	0.067	31.2	0.060
90	29.8	0.053	32.6	0.053	33.7	0.060	29.6	0.053
	Average = 0.058		Average = 0.055		Average = 0.060		Average = 0.055	

[a]Diameter of holes = 200 mm. Percoluation rate = 0.056 cm min^{-1} (0.022 inch min^{-1}).

Table 4. Soil Horizon Features for Test Pits A and B

Horizon	Features	Test pit A	Test pit B
Topsoil	Depth of horizon thickness	0–0.6 m	0–0.6 m
	Thickness	0.6 m	0.6 m
	Color	Dark brown	Dark brown
A1	Depth of horizon	0.6–1.0 m	0.6–1.0 m
	Thickness	0.4 m	0.4 m
	Moisture content	56.80%	46.20%
	Color	Dark gray	Dark gray
	Root distribution	Scanty	Scanty
	Texture	Coarse	Coarse
	Structure	Single grain	Single grain
	Soil consistence	Friable	Loose
A2	Depth of horizon	1.0–1.4 m	1.0–1.4 m
	Thickness	0.4 m	0.4 m
	Moisture content	41.70%	32.10%
	Color	Light brown	Light brown
	Root distribution	Scanty	—
	Texture	Medium coarse	Medium coarse
	Structure	Single grain	Single grain
	Soil consistence	Loose	Loose
A3	Depth of horizon	1.4–1.8 m	1.4–1.8 m
	Thickness	0.4 m	0.4 m
	Moisture content	54.60%	93.00%
	Color	Ash	Ash
	Root distribution	—	—
	Texture	Medium coarse	Medium coarse
	Structure	Single grain	Single grain
	Soil consistence	Loose	Loose

of the soil at depth 10-1.4 m is lower than that at depth 1.4-1.8 m for both test pits because the soil at 1.4-1.8 m is nearer to complete saturation.

Classification Test Results

The soil on this site, from the result of sieve analysis, is gravelly sand with clay fines at the upper horizon and silt fines at the lower horizon. Combining the results of sieve analysis and Atterberg limits test, the soil within the upper horizon (0.6-1.0 m below the ground surface) is A-2-7 (silty or clayey gravel and sand) according to American Association of State Highway and Transportation Official (AASHTO) classification system.

The results are respectively plotted in Figures 4 and 5. The sieve analysis results for samples A1, A2, A3, and the filter sand has been plotted side by side on the same particle size distribution chart. The same has been done for samples B1, B2, B3, and the filter sand.

From Figures 4 and 5, the soil samples from pits A and B can be described as gravelly sand. The filter sand is a light brown well graded sand.

The liquid limit of this soil sample is 53.8% while the plastic limit is 33.3%. The plasticity index is therefore (53.8 – 33.3) = 20.5. It is observable that no more than 35% of soil sample within depth 0.6-1.0 m passes through the No. 200 sieve (0.075 mm). Therefore by the AASHTO classification system, the soil within the depth 0.6-1.0 m is A-2-7 (silty or clayey gravel and sand).

Percolation Test Result

The percolation rate 18 mins cm^{-1} (0.056 cm min^{-1}) of the in situ soil falls within the recommended 1.97-23.62 mins cm^{-1}, given by [1] as seen in Table 2.

Design

The relevant results obtained from the previous sections and other information that would be utilized for sizing the infiltration surface are stated below:

- The receiving soil of the septic tank effluent is gravelly sand with single grain structure
- Highest groundwater table is about 1.8 m below the ground surface
- Percolation rate is 0.056 cm min^{-1}
- Twelve persons occupy the house

World Health Organization (WHO) estimates the per capita water demand of developing nations as 180 liters per capita demand (180 lpcd).

Assuming the wastewater flow per day is equal to the water demand per day of the household,

$$\text{Wastewater flow per day} = 180 \text{ lpcd} \times 12 \text{ persons} = 2160 \text{ l day}^{-1}$$

Using Table 2, the loading rate corresponding to a percolation rate of 18 mins cm^{-1} (45.7 mins $inch^{-1}$) is approximately 20 l m^{-2} day^{-1}.

The required absorption area is computed by dividing wastewater flow per day by the daily loading rate.

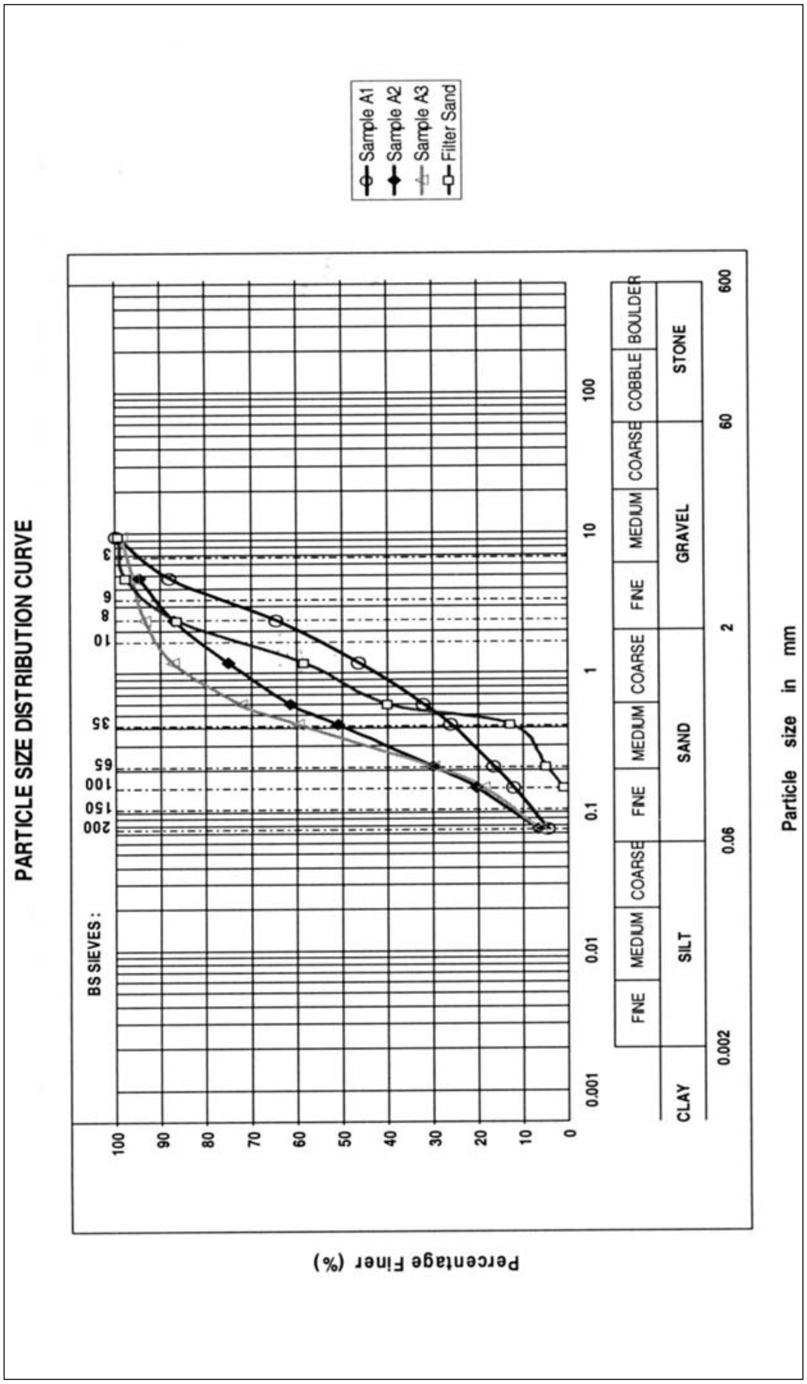

Figure 4. Particle size distribution of samples A1, A2, A3, and filter sand.

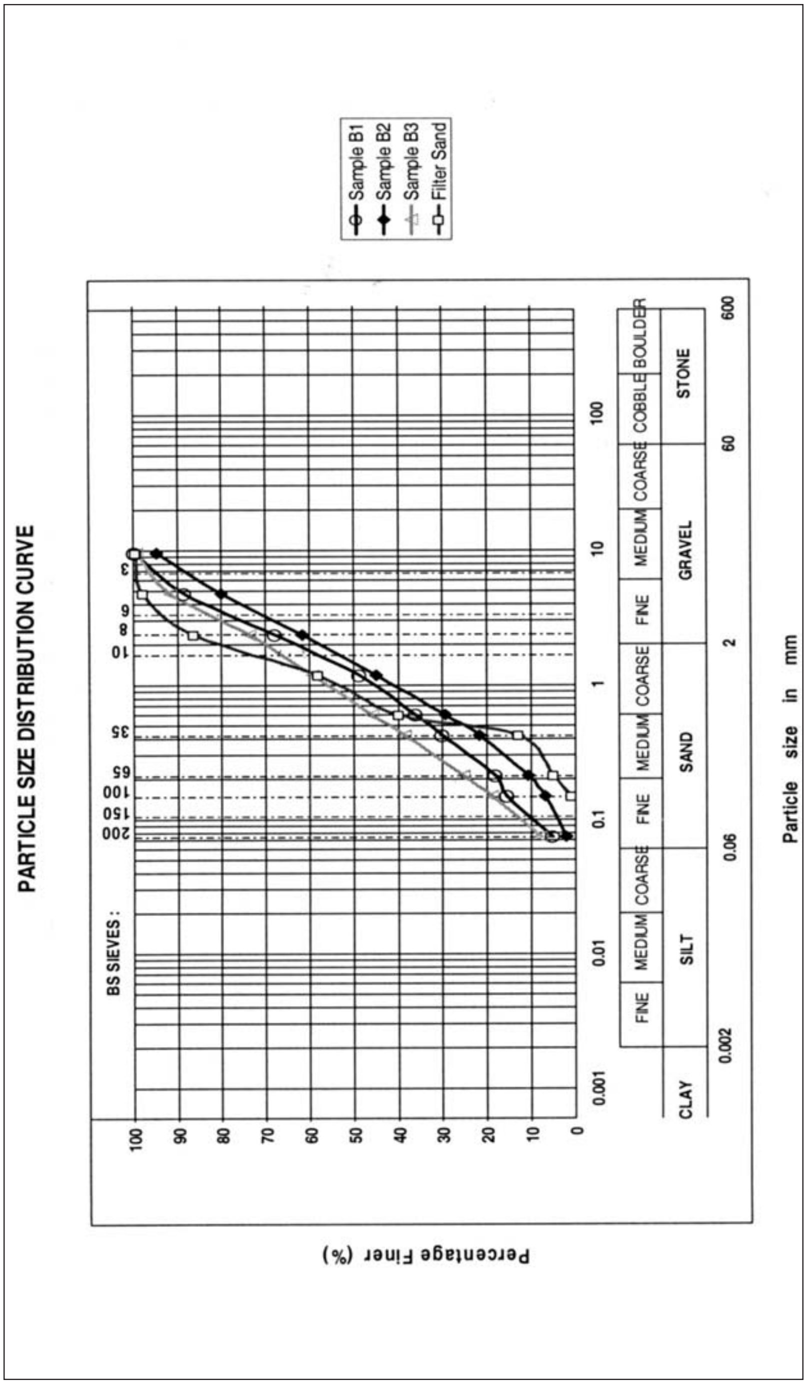

Figure 5. Particle size distribution of samples B1, B2, B3, and filter sand.

$$\text{Absorption area required} = \frac{\text{Wastewater flow per day}}{\text{Daily loading rate}} = \frac{2160}{20} = 108 \text{ cm}^2$$

$$\text{Absorption area provided} = 10.5 \text{ m} \times 10.5 \text{ m} (= 110 \text{ m}^2)$$

The topsoil would be replaced by the filter sand and filled to a height of 0.6 m above the ground surface. A section of the OWTS is as shown in Figure 6 which shows that wastewater from the house flows into the septic tank where anaerobic bacteria digest organic materials, while allowing scum and sludge materials to separate from the wastewater.

The effluent from the septic tank flows into a dosing chamber (see Figure 7), where it will be pumped to the mound system via pipes which are perforated at the discharging points. Figure 7 shows that as the wastewater level in the dosing chamber just reaches the level of the float (ON), the pumping machine becomes "ON," pumping the wastewater until the wastewater level just reaches the float (OFF). The process is repeated once the wastewater level rises again to the level of the float (ON). In a case where the wastewater level reaches the alarm float, due to a fault in the pumping process, an alarm is triggered which draws the attention of residents.

A reference sketch of the septic system is shown in Figure 8.

The system is sited such that the minimum separation distances between natural and man-made features requirements (specified in most design codes) are met.

The functions and specifications of each of the components of this system are given in the following subsections.

Septic Tank

The septic tank is sized so that wastewater flow through the tank takes at least 24 hours even with sludge and scum accumulation. This detention time permits the settling of solids heavier than water and allows scum, grease, and other materials lighter than water to float to the surface before the water is discharged to the dosing chamber.

The internal volume of the septic tank is specified as 2 m × 1.5 × 2 m, which accommodates more than twice the wastewater flow of 2160 l day^{-1}.

Dosing Chamber

Dosing of wastewater flow to the mound (which occurs in the dosing chamber) achieves better distribution of the wastewater effluent over the infiltration surface and provides intervals between doses, when no wastewater is applied. This dosing reduces the rate of soil clogging, more effectively maintains unsaturated conditions in the subsoil (to effect good treatment through extended residence times

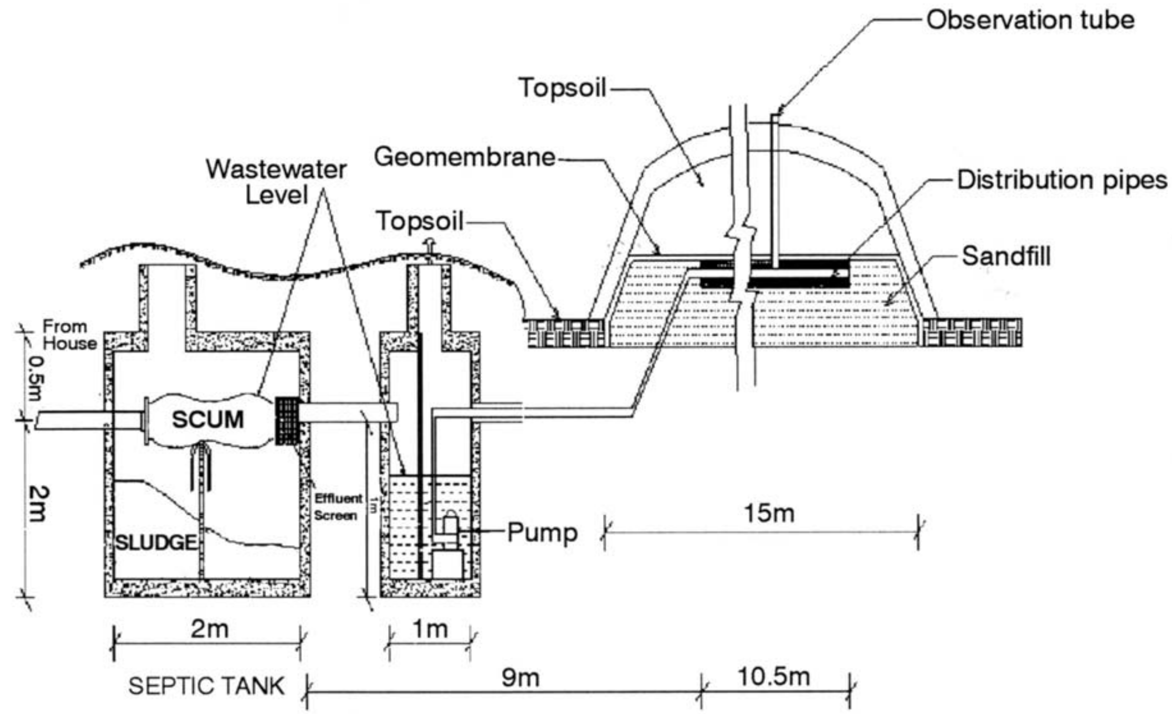

Figure 6. Section through on-site wastewater treatment system.

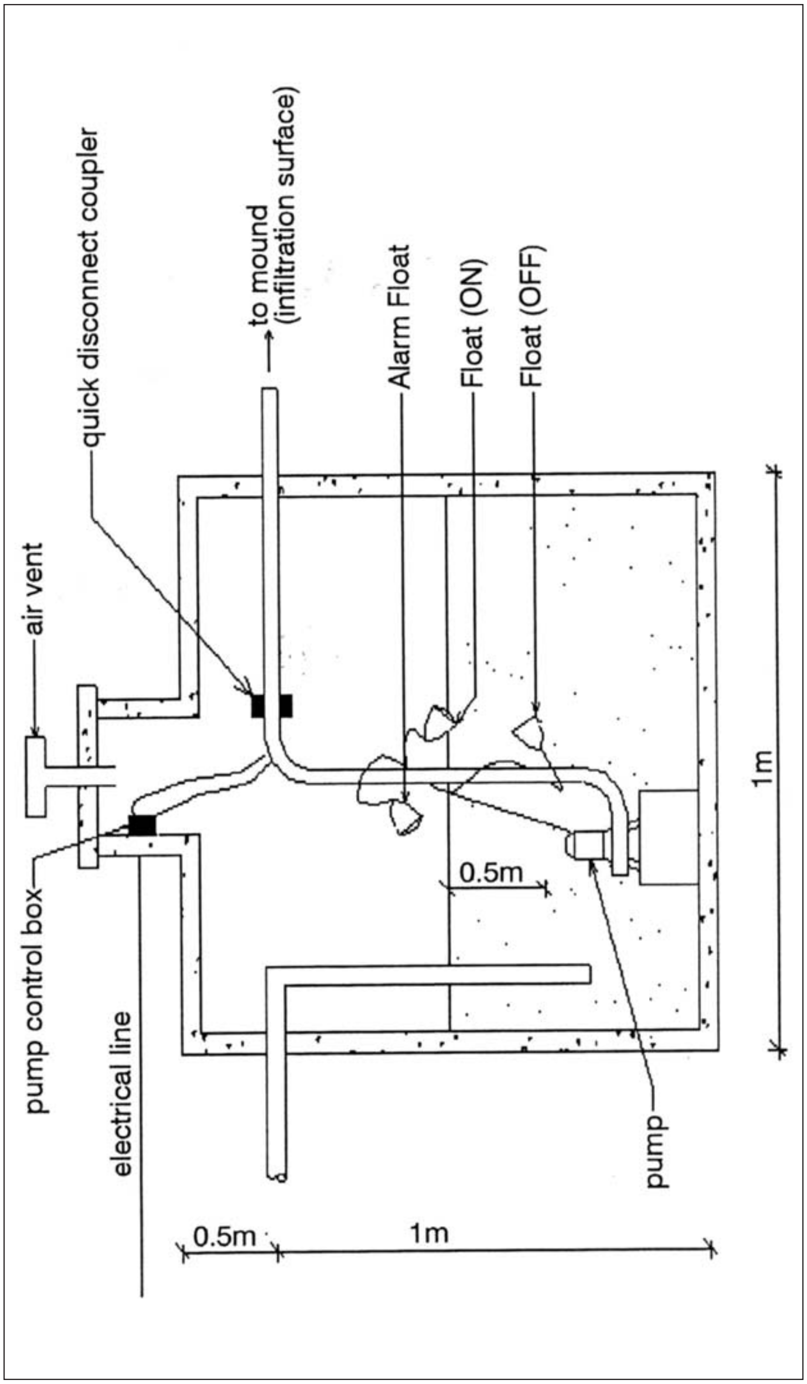

Figure 7. Dosing chamber.

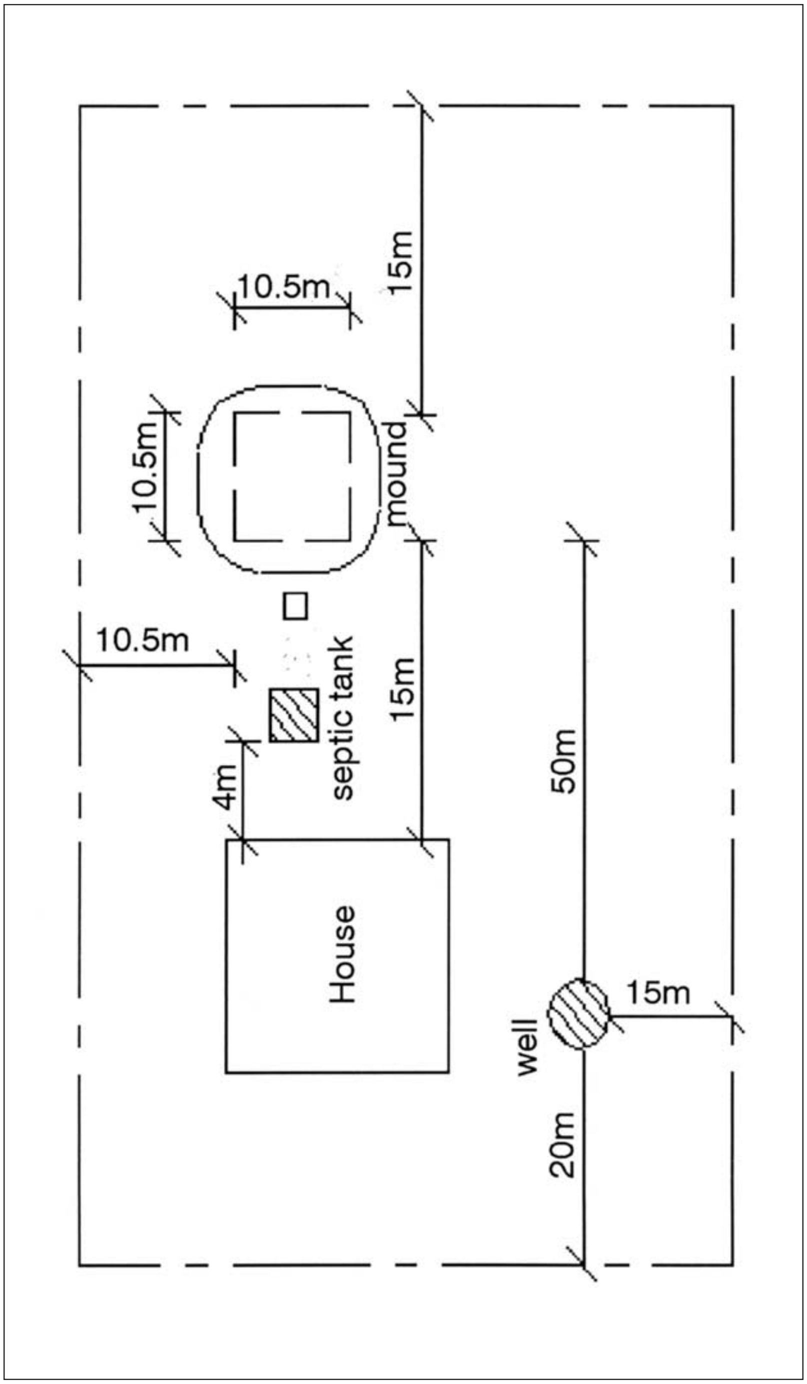

Figure 8. Plan layout of on-site wastewater treatment system.

and increased reaeration potential), and provides a means to manage wastewater effluent applications to the infiltration system.

Dosing frequency = six times daily

Dosing frequency = half the volume of septic tank
= 1.0 m × 0.75 m × 1.0 m

$$\text{Dosing volume} = \frac{\text{daily wastewater flow}}{\text{Dosing frequency}}$$

$$= \frac{2160 \text{ l day}^{-1}}{6 \text{ does day}^{-1}}$$

$$= 360 \text{ l dose}^{-1} \ (0.36 \text{ m}^3 \text{ dose}^{-1})$$

Let separation distance between float (ON) and float (OFF) = d

Therefore 1 × 0.75 × d = 0.36
d = 0.36/(1 × 0.75)
d = 0.48 = 0.5 m

Distribution Box and Pipes

The distribution box is used to divide the wastewater effluent flow among the five distribution lines. It is a watertight structure with a single inlet and five outlets. Fifty millimeters (50 mm) diameter distribution pipes, having 12.5 mm diameter perforations is provided. A 100 mm observation tube (Rigid PVC) is also provided.

Geomembrane

The geomembrane is used primarily as a liquid barrier. The geomembrane may be made by impregnating geotextiles with asphalt.

CONCLUSIONS

The design of the on-site wastewater system has been done in accordance with the procedures stipulated in some of the relevant literatures reviewed. Appropriate factors of safety have been incorporated in the design with adequate considerations given to the environmental conditions of the site and imperfections of construction. From the results of the site evaluation and laboratory tests carried out on soil samples from the site, it was found that the subsoil layers/horizons are predominantly gravelly sand of different colors. The color variation is due to the varying content of organic matter in each of horizons.

The mound system designed for this site, which experiences occasional flooding, is more environment-friendly than an at-grade or in-ground wastewater disposal system. The separation distance between the infiltration surface within the mound and the highest water table is sufficient to appreciably remove nitrates, phosphorus, and pathogens that may be present in the septic tank effluent.

The mound system designed is adequate and requires maintenance. It has the advantage that the system is not completely out of sight and thus, not out of mind. Although this system requires a consistent power supply, the alarm system warns the residents of any impending danger and prompts them to action.

The soil absorption field (drain field) was sited such that its separation from building structures and boundaries permits repair, maintenance of required separation from wells and reduces undesirable effects of underground wastewater flow and dispersion. The septic tank designed has a size of 2 m × 1.5 m × 2 m, while the dosing chamber has half of this volumetric capacity. The absorption area (10.5 m × 10.5 m) was sized based on an estimated wastewater flow of 2160 liters day^{-1} and a daily loading rate of 20 liters m^{-2} day^{-1}, which corresponds to the obtained percolation rate of 18 mins cm^{-1} (0.056 cm $mins^{-1}$), using correlations presented in Table 2 [1].

This system can be adapted to other sites with similar characteristics (high water table and occasional floods). Residents should employ water conservation to reduce hydraulic flows and pollutant reduction to minimize contaminant loading, in order to increase the efficiency of the system.

Presently, there are many buildings with no on-site wastewater treatment system, toilet, or proper plumbing fixtures. Relevant governmental authorities saddled with approving the construction of building structures should endeavor not to do so unless a septic system design (prepared by a civil and environmental engineer) is submitted along with the architectural and structural designs. Approvals for change in the use of buildings should be subject to plans made to replace facilities such as the on-site wastewater treatment systems.

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