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Design and Modelling of Urban Stormwater Management and Treatment Infrastructure for Communities in Wuse, Abuja

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ABSTRACT

Effective stormwater management can be used to regulate water quantity and quality for environmental sustainability, flood control, pollution reduction and other advantages of civil engineering infrastructures. Pollution of the environment and contamination of water sources can emanate from improper stormwater management. This study used a small-scale model of rainwater harvesting to analyze the design and model of urban stormwater management and treatment infrastructure for the neighborhoods in Abuja. The water quality of the treated stormwater retrieved has improved as a result of the usage of memory foam, alum, and chlorine to filter out contaminants and pathogens. With the fictitious stormwater treatment model created for this study, average values of the physicochemical parameters were collected from the stormwater discharge after it had been filtered and treated. The use of potash alum has had a variety of effects on the water's quality. From 697 $mg.L^{-1}$ to 635 $mg.L^{-1}$, the total dissolved solids dropped. The DO dropped from 5.87 $mg.L^{-1}$ to 3.92 $mg.L^{-1}$ as well. Additionally, the turbidity rose from 4.42 FNU to 4.58 FNU, and the salinity rose from 0.7 PSU to 1.44 PSU, respectively. pH decreases from 19.78 to 15.17 $mg.L^{-1}$, BOD decreases from 8.35 to 6.51, and COD decreases from 2.55 to 1.9. Calcium hardness has decreased from 287 $mg.L^{-1}$ to 265.83 $mg.L^{-1}$. The conductivity increases marginally from 3.24 $ms.cm^{-1}$ to 3.82 $ms.cm^{-1}$. The Fe^{2+} and Zn^{2+} ions exhibit a little decrease from 0.143 $mg.L^{-1}$ to 0.055 $mg.L^{-1}$ and from 0.092 $mg.L^{-1}$ to 0.045 $mg.L^{-1}$, respectively. Due to inadequate or nonexistent drainage systems in the many states and villages throughout the country, stormwater run-off management and treatment in Nigeria have been a colossal failure. Effective stormwater management can be sustained by using legal and environmental laws.

INTRODUCTION

There are copious challenges facing urban stormwater management in most nations of the world**.** This results in several issues, including floods, which cost lives and destroy property. The vast majority of stormwater that is wasted can be used in the community in several ways, whether at homes, businesses, or industrial facilities. While stormwater serves as a backup water source for irrigation, toilet water tanks, car washing, laundry, fire sprinkler systems, and other uses, it is important to manage and reuse stormwater run-off in a way that conserves potable water. Stormwater is the term for the liquid that is created when it rains. If improperly managed and channeled, stormwater can produce flooding and water contamination, which can be a serious issue for a city. Stormwater can be appropriately harvested and purified to meet the demands of people in the community by a variety of ways of filtration and disinfection due to the substantial rise in the need for clean water for various means of consumption and usage by the people and the community. The primary objective of this research has historically been to recognize the critical relevance of planning and modeling infrastructure for the collection and treatment of urban stormwater that happens during rainfall in a town in Nigeria.

PAST STUDIES

The control of both the quantity and quality of water is known as stormwater management. To manage (and treat) contaminated rainwater, a variety of structural or engineering control devices and procedures (operational and procedural practices) are used. Stormwater. Water quality can be slightly improved, and floods can be decreased with the help of stormwater management. The network of pipelines, impermeable surfaces, storage ponds, and other devices used for stormwater management include several methods of reducing peak discharge (Borgaonkar & Marhaba 2021). For human activity and habitation, water availability is essential. Although there is more than enough water on the planet (1.5 × 10 metric tons) to feed all 5.5 billion people, clean, drinkable water is not commonly accessible. The WHO attributes the great majority of natural disasters that afflict people to water or a lack thereof. Nano-drug delivery, the most recent development in drug delivery technology, provides distinctive physicochemical properties, prolonged physiological retention, and controlled release of medicinal chemicals for increased health benefits (Antoniraj et al. 2022). Many opportunities exist on the job site to evaluate the efficacy of interventions designed to enhance the mental health and quality of life of large populations (Atlantis et al. 2004). Total trihalomethanes in water (TTHMs) are byproducts of municipal water disinfection. Exposure to TTHM has been related to cancer and may harm fertility (Lewis et al. 2021). The main method used nowadays to disinfect domestic drinking water supplies in many places is chlorination. This procedure has been demonstrated to reduce the morbidity and mortality of aquatic infectious illnesses since the early 20th century (Cutler & Miller 2005).

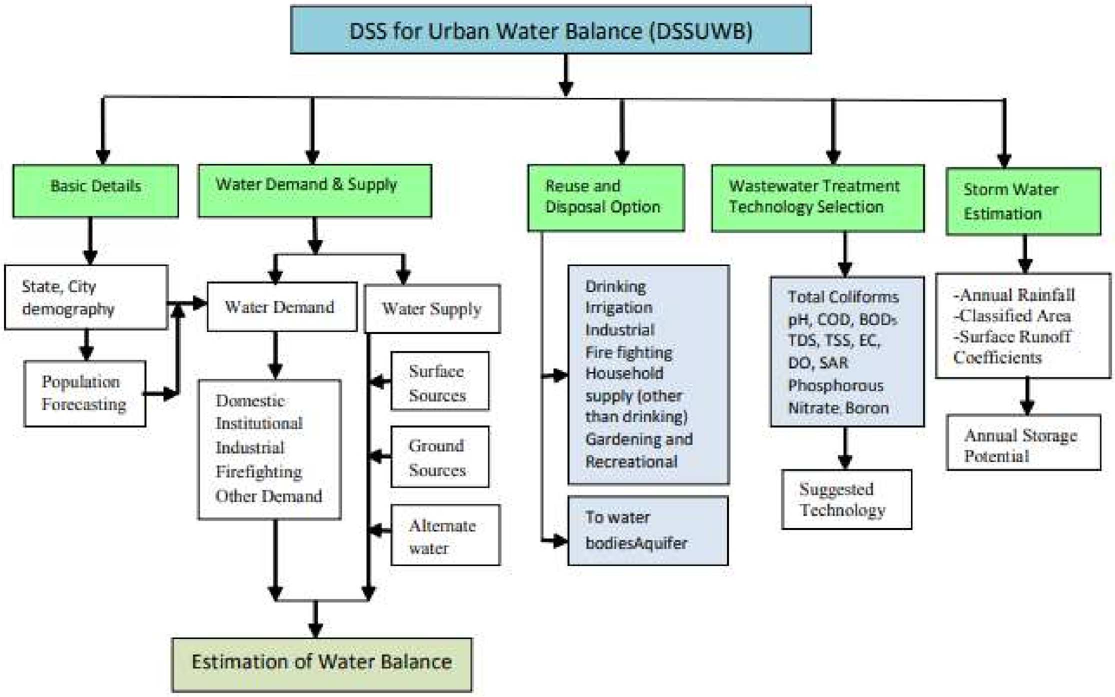
Since there is a great deal of variation in potable water demand across different locations, the potential for potable water savings must be assessed for each area to determine the technical viability of adopting RWHS. While some nations are experiencing a water crisis, rainwater gathering can help these nations manage their sustainable water resources. Using rainwater harvesting systems is advised as a sustainable development approach for managing water resources in light of population increase and fast urbanization (Kolavani 2020). Given how heavily potable water demand is influenced by geography, it is important to assess the potential for potable water savings before determining whether it is technically feasible to adopt RWHS. While some nations are experiencing a water crisis, rainwater gathering can help these nations manage their sustainable water resources. Using rainwater harvesting systems is advised as a sustainable development approach for managing water resources in light of population increase and fast urbanization (Kolavani 2020). Using the application of EPA SWMM5, a mathematical model, engineering, and management alternatives can be used for stormwater management (Harshani & Wijesekera 2010).

In Nigeria, there is a severe lack of water, particularly in metropolitan areas, where the water poverty index (WPI) measures the amount of time (in minutes) required to gather a specific amount of water (in liters) for home use each day (Adewumi et al. 2011). Activities aimed at reducing pollution and controlling flooding call for careful management of available water resources, engineering evaluation, cutting-edge technology, and suitable hydraulic structural designs (Oyebode & Paul 2023). For environmental sustainability, pollution reduction, and public health (Oyebode et al. 2023), groundwater monitoring and engineering intervention are required. According to Oyebode & Waterway (2023), the characterization and management of greywater are significant environmental challenges in the majority of countries.

Rapid urbanization is well documented to have several negative consequences on the hydrological cycle due to a decrease in previous land and a decline in stormwater run-off water quality. For managing urban stormwater, there are a variety of software tools available, such as the Storm Water Drainage System Design and Analysis Program (DRAINS), Urban Drainage and Sewer Model (MOUSE), InfoWorks River Simulation (InfoWork RS), Hydrological Simulation Program-Fortran (HSPF), Distributed Routing Rainfall-Runoff Model (DR3M), Storm Water Management Model (SWMM), XP Storm Water Management Model (XPSWMM), MIKE-SWMM, Quality-Quanty Simulators (QQS), Storage, Treatment, Overflow, Run-off Model (STORM), and Hydrologic Engineering Centre-Hydrologic Modelling System (HEC-HMS) (Haris et al. 2016).

Enhancing urban water cycle management can lower greenhouse gas emissions and help cities adapt to climate change. Due to the necessity to control increased surface flow, stormwater in metropolitan areas has traditionally been collected and sent to sewage treatment plants. Over time, Green Infrastructure (GI) methods have been recognized as a viable approach to stormwater management (Jayasooriya & Ng 2014). The chance to achieve environmental sustainability is through stormwater management. To protect the environment and public health, medical waste management strives to enhance health (Oyebode et al. 2023). The weighted average water quality index (WAWQI) method was used to calculate the research area's water quality index, and the USEPA method was used to evaluate any potential health risks (Ogarekpe et al. 2023).

Wet ponds, dry ponds, infiltration trenches, artificial wetlands, permeable pavements, and others are common stormwater treatment techniques. The focus should be placed on evaluating and maintaining stormwater treatment procedures (Erickson et al. 2013). Stormwater control measure inspection and maintenance procedures are frequently unclear and applied inconsistently. Stormwater management methods and green infrastructure are becoming more and more popular for controlling urban hydrology and stormwater as urbanized places throughout the world struggle with growth pains and evolving views on urban development. When calculating life-cycle costs, a stormwater management measure's purpose must be maintained and should not be disregarded (Erickson et al. 2018). Urban areas' continued expansion and the public's growing understanding of stormwater's effects on the environment have stoked interest



Source: (Maurya et al. 2018).

Fig. 1: Proposed framework for urban water balance.

in the receiving water bodies' quality. Several attempts have been made over the past two decades to improve urban drainage systems by using mitigation strategies to reduce the adverse effects of stormwater on the environment (Freni et al. 2010).

Many modules, including Basic Information, Water Demand and Supply, Reuse and Disposal Options, Wastewater Treatment Technology Selection, and Stormwater Management, make up the foundation for the proposed urban water balancing (Fig. 1).

Ecology has suffered as a result of the development brought on by rapid urbanization and industrialization. The quickly expanding industry discharged untreated effluent into the nearby bodies of water (Wanganeo et al. 2009). One of the best instruments for informing concerned consumers and decision-makers about water quality is the Water Quality Index. Water contamination is a significant economic and public health issue in addition to being an aesthetic one. The lake can be kept from degrading further by routinely monitoring the water quality. In many regions of the world, the depletion of freshwater resources has emerged as a significant issue of this century. Wastewater is increasingly posing a major challenge to the sustainability of urban environments in urban settings, in addition to the steadily rising demand for freshwater brought on by population growth and infrastructure development. This problem has an impact on both the environment and human health. Stormwater management is a common activity since it necessitates infrastructure for its execution. Calculating the yearly surface run-off is necessary for both centralized and decentralized collection schemes (Maurya et al. 2018).

According to the organization, natural disasters affected one-third of humanity throughout the twentieth century's last decade, with floods and droughts accounting for 86% of those affected. Drought is the leading cause of death because it frequently results in starvation. Because of the scarcity of drinkable water and the importance of water to human survival, individuals from all walks of life are scrambling to find a way out of this mess. River research has gradually increased in recent years due to the rising social awareness of the need to safeguard the environment of the water. This suggests that measuring water quality has a significant impact on human survival and growth. The potential of water to sequester carbon is directly influenced by its quality. Thus, it is crucial to comprehend the river water quality (Guojiao et al. 2023). Rural communities in developing countries face a slew of issues that wreak havoc on the quality of life there. One of these is the near-complete lack of public infrastructure and services, particularly drinkable water. In the year 2002, there were 1,099 million people without an appropriate water supply, with 84 percent living in rural regions. The misrule and carelessness with which the government responds to emergencies are particularly shocking, given that water is a necessity and a critical life-sustaining element. As a result, the rural poor are at the mercy of the natural water cycle, which includes streams, ponds, rivers, and rain run-off from roofs. The poor's access to water through these sources is dependent on seasonal fluctuations, making it extremely difficult for them to obtain water during the dry season. People experiencing poverty are particularly affected by water-borne infections due to the unsanitary conditions of these sources of water.

Given the circumstances, the purpose of this work is to present a cost-effective and long-term management strategy for rain and run-off in rural areas and, by extension, metropolitan areas of developing Microbial diseases which are rampant in the poorest portions of most developing country cities, costing billions of dollars in wasted lives and sick employees, according to a recent World Bank report. When water sources are contaminated, and sanitation facilities are relatively low or non-existent, when rats, flies, and mosquitoes abound, typhoid, dysentery, and encephalitis are among the plagues of people experiencing poverty.

A stormwater treatment process is the method through which a stormwater treatment practice improves stormwater run-off quality, decreases run-off volume, decreases run-off peak flow, or any combination of the three. A dry pond, for example, collects stormwater and gently releases it to downstream receiving waters (in comparison to uncontrolled conditions). Because most contaminants in stormwater that are retained by a dry pond settle out while the stormwater run-off is held in the pond, sedimentation is the major treatment process of a dry pond. Because the treatment procedure is so crucial, this manual organizes stormwater treatment approaches by their major treatment phase. Table 1 indicates global diarrhoea disease and geo-helminthiases statistics for 1990. However, to comprehend stormwater processes, one must first investigate the composition of stormwater and the effects it has on the ecosystem.

Stormwater Treatment

A stormwater treatment method enhances the quality of stormwater run-off, lowers the volume of run-off, lowers the peak flow of run-off, or any combination of the three. Stormwater treatment techniques include source reduction, sand filters, infiltration basins and trenches, rain gardens, dry ponds, wet ponds, constructed wetlands, filter strips, swales, wet vaults, and subsurface sedimentation techniques. Stormwater treatment is the process of removing contaminants and poisons from surface water run-off before they enter a river, lake, or other body of water. Preventing pollution is usually preferable to treating it since it is challenging to get rid of it after it has gotten into the ecosystem. Even though no two stormwater projects are exactly alike, you must have confidence in your system and the experts that support it. (Erickson et al. 2013).

Since the 1970s, new stormwater development technologies such as detention and retention ponds, permeable surfaces, infiltration trenches, surface and subsurface groundwater recharge, and other source control measures have been created.

Constructed Wetlands

There are designed stormwater wetlands to reduce flood peaks, improve the water quality of surface run-off, and restore part of the city's natural habitat and birdlife, in addition to artificial wetlands (e.g., horizontal flow) for wastewater treatment. They can be used in conjunction with surface and subsurface groundwater recharge systems, as well as the treatment of soil aquifers. An illustration of this strategy is shown in (Fig. 2)

i. **Rainwater Harvesting**: Rainwater collecting is gaining popularity in urban areas because it delivers the dual benefits of preserving potable water and lowering stormwater run-off. When rainwater is collected and used to irrigate landscaped areas, the water is either evapotranspiration by vegetation or infused into the soil, helping to preserve the water balance that existed before development. Rain falling on a catchment surface, such as a roof, is collected and transported to a storage tank. This strategy is illustrated in (Fig. 3). The captured rainwater can be utilized for outside non-potable water purposes like irrigation and pressure washing or within the building to flush toilets and urinals with little pre-treatment (e.g., gravity filtration or first-flush

Table 1: Global diarrhoeal disease and geo-helminthiases statistics for 1990.

Disease	Number	Remarks
Diarrhea	4,073,920,110 cases	56% in children aged 0 to 4, 94% in developing countries
Ascariasis	61,847,000 persons with high-intensity infection	73% of children aged 5 to 14 all in developing countries
Trichuriasis	45,421,000 persons with high-intensity infection	79% of children aged 5 to 14 all in developing countries
Human hookworm infection	152,492,000 persons with high-intensity infection: 36.014,000 persons with anemia	72% of adults aged 15 to 44 all in developing countries

diversion). In rural areas, it is also a commonly utilized and effective strategy.

ii. **Green Roofs:** A thin layer of vegetation and growing medium is planted on top of a typical flat or sloped roof to create green roofs, also known as "living roofs" or "rooftop gardens." Green roofs are hailed as having numerous advantages for cities, including increased energy efficiency, reduced urban heat island effects, and the development of green space for passive recreation or aesthetic delight. For example, treated greywater can be used to irrigate green roofs or vertical gardens. They appeal to a water resources manager because of the benefits they provide in terms of water quality, water balance, and peak flow control. The green roof functions like a lawn or meadow in terms of hydrology, holding rainwater in the growth media and ponding regions.

iii. **Constructed Wetlands:** There are designed stormwater wetlands to reduce flood peaks, improve the water quality of surface run-off, and restore part of the city's natural habitat and birdlife, in addition to artificial wetlands (e.g., horizontal flow) for wastewater treatment (Oyebode et al. 2023). They can be used in conjunction with surface

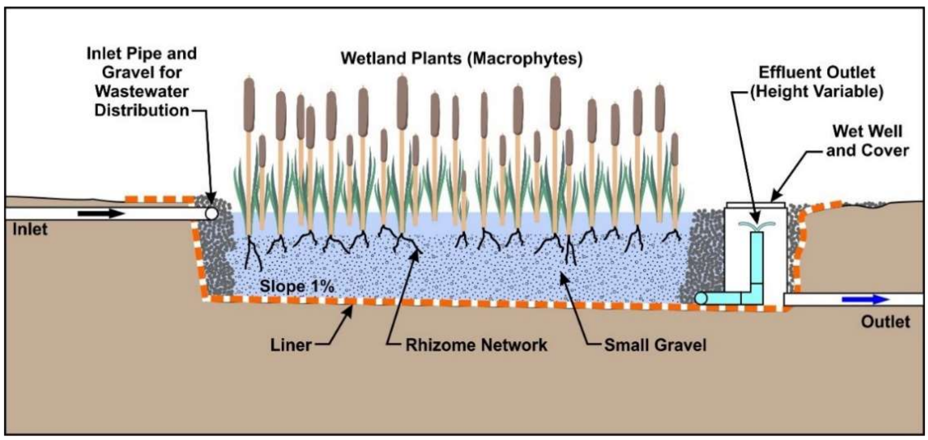


Fig. 2: Constructed wetland.

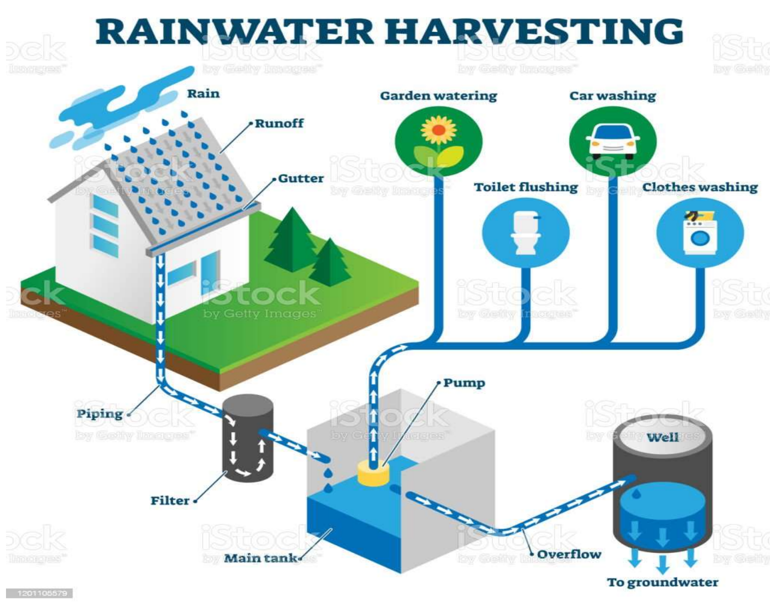


Fig. 3: Rainfall harvesting (William et al. 2023).

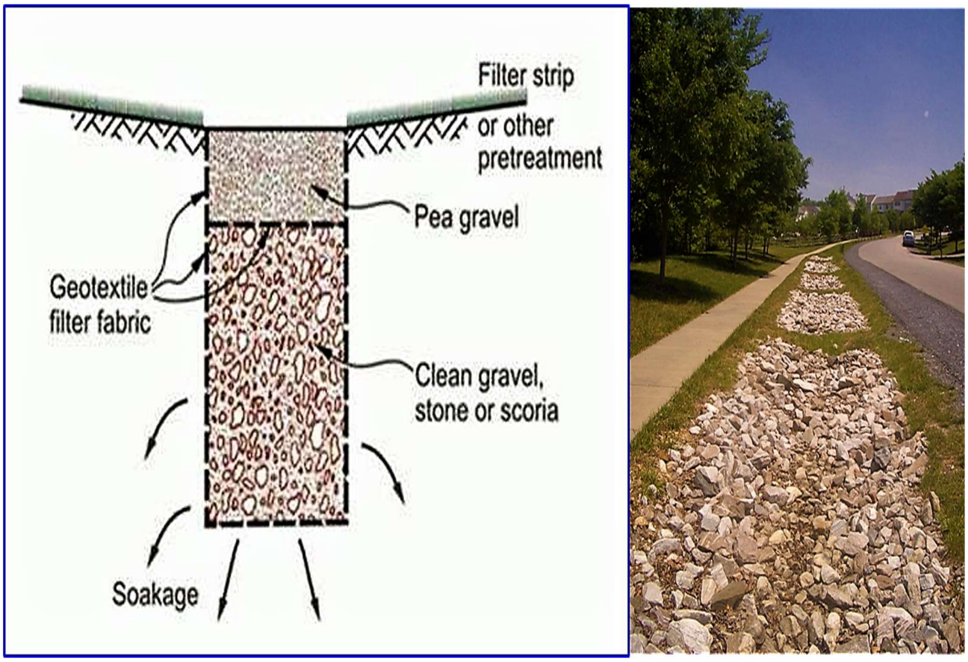


Fig. 4: Design of infiltration trenches.

and subsurface groundwater recharge systems, as well as the treatment of soil aquifers.

Infiltration Type Devices

1. **Infiltration Trenches:** Infiltration trenches (also known as soak pits) are shallow excavations filled with uniformly crushed stone to create underground reservoirs for rainwater run-off. The discharge gradually seeps into the subsoil and eventually into the water table through the trench's bottom. To prevent sediment entry, the walls and top are coated with geotextile. Trench designs can be altered to contain vegetation and other elements, forming a bio-filtration zone. They are frequently built alongside outdoor parking spaces or streets. Infiltration into the soil is used to treat the water. A design of this method is shown in (Fig. 4). However, where sediment concentration in run-off is high, there is a risk of clogging.
2. **Grass Filter Stripes:** Grass filter stripes (also known as grassed filters or filter stripes) are densely vegetated, evenly graded areas that treat surface flow from nearby impermeable areas. Grass filter strips lower run-off speeds, trap silt and other pollutants and provide a small amount of infiltration.
3. **Grassed Swales:** Open grassed channels in which stormwater flow is slowed and partially penetrated are known as grass swales (also known as vegetated swales). Water in the swale is slowed by check dams and vegetation, which allows sedimentation, filtering via the root zone and soil matrix, evapotranspiration, and infiltration into the underlying native soil. An example of this method is shown in (Fig. 5). For stormwater conveyance, simple grass channels or ditches have traditionally been employed, particularly for roadway drainage. Simple grass channel and roadside ditch design that utilize design characteristics such as improved geometry and check dams increase the pollutant removal and run-off reduction functions of enhanced grass swales.
4. **Pervious Pavements:** A permeable pavement surface with a stone reservoir beneath it is known as pervious pavement. The reservoir briefly collects surface run-off before infiltrating it into the subsoil or subsurface drainage, improving water quality in the process. Porous materials, such as ancient lime mortars and pervious pavements, are created from materials that are generally mono-graded. This correlates to a lack of "fine" components in the case of previous pavement. Pervious pavement is also known as "no-fines concrete" in some cases, and it is illustrated in (Fig. 6).
5. **Infiltration basin:** An infiltration basin (also known as an infiltration pond) is a structure built within highly permeable soils to store stormwater run-off temporarily (see also surface groundwater recharge).

Fig. 5: Enhanced grass swales feature check dams that temporarily pond run-off to increase pollutant retention and infiltration and decrease flow velocity.

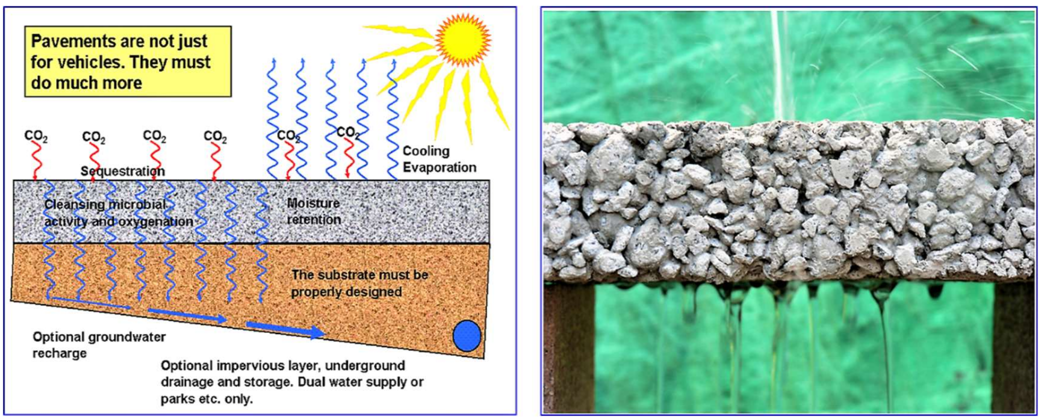


Fig. 6: A theoretical cross-section of porous pavement (left) and porous pavement during a demonstration.

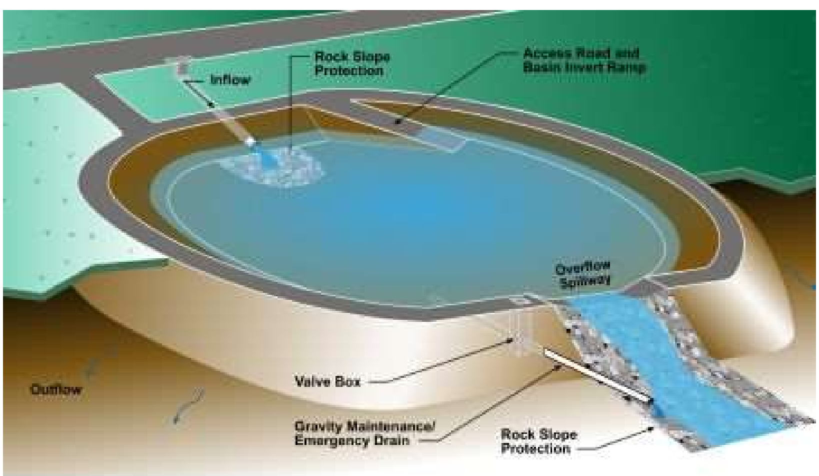


Fig. 7: Infiltration basin.

An example of an infiltration basin is shown in (Fig. 7). Infiltration basins, unlike detention basins, do not often have a structural outlet to release run-off from the stormwater quality design storm. Instead, an infiltration basin's outflow is routed into the surrounding soil. An infiltration basin and an extended detention basin can be coupled to provide additional run-off storage for stormwater quality and quantity management. The TSS clearance rate for infiltration basins has been set at 80%(Oyebode et al. 2023).

Costs to Consider

The costs of various systems are highly dependent on technology, topography, and specialist knowledge. Some are simple to implement, while others are more complicated and cost more. Stormwater management, on the other hand, prevents infrastructure damage and protects the people of urban and rural populations.

Health Aspects

Modern stormwater methods primarily include some ecological treatment effects, with the overall goal of protecting the public's health, welfare, and safety (by preventing water pollution) and property from flood dangers (by securely routing and discharging stormwater from developments)

Urban solid trash can be a hazard to public health as well as the proper operation of stormwater facilities. Domestic sewer connections to stormwater drainage systems, both legal and illegal, result in ancillaries such as retention basins becoming pollutant traps. These are washed out during high floods, resulting in water pollution.

High loads of fine particles can also clog infiltration systems, resulting in permanent ponding. This can lead to mosquito breeding, which is a significant issue in humid locations where malaria and other tropical diseases are prevalent.

Advantages of Stormwater Management

- The surface run-off will be properly drained.
- The ability to recharge groundwater and reuse precipitation and surface run-off for irrigation and household purposes
- Stormwater treatment would begin as soon as possible.
- Damage to infrastructures is avoided; flood prevention is achieved.
- Green and recreational places can be integrated into the urban landscape.

Disadvantages of Stormwater Management

- Expertise is necessary for planning, implementation, operation, and maintenance.
- Depending on the approach, a significant amount of work and effort is necessary.
- High sedimentation rates provide a risk of blocking the infiltration system.

MATERIALS AND METHODS

The method of approach taken for this project is to manage stormwater run-off by harvesting the rainfall using a detention tank (the collection point) to collect stormwater run-off from roofs of various buildings, filtering (using memory foam), and disinfecting the collected stormwater with the use of alum and chlorine as a means to kill all impure particles and bacteria in the water.

Processes

1. **Pre-analysis of influent run-off**: tests are carried out on the stormwater to determine the total suspended solids (TSS), total dissolved solids (TDS), and coliform present before proceeding with the filtration processes.
2. **The collection tank**: based on my analysis, stormwater run-off is channeled with the use of roof gutters from roofs after rainfall into the detention tank. The stormwater passes through a net at the top of the detention tank to remove impurities (like leaves, twigs, sticks, sand, and tree branches) and prevent them from entering the tank.
3. **The polyurethane foam**: the foam is located inside the detention tank, and the stormwater passes through the foam to filter out impurities and suspended solids before transferring to another tank for flocculation.
4. **Flocculation**: adding a certain amount of alum (potassium alum) to the volume of stormwater present for 30 min in the flocculation tank to clarify the water gathers tiny impurities (not visible) and turn them into flocs and make them settle at the bottom of the tank before transferring to another tank for chlorination. Alum dosages range from 5 mg per liter for generally clear water to 85 mg per liter for severely turbid waterways such as industrial effluent (Antoniraj et al. 2022). Potassium alum has a chemical formula of $K_2SO_4.Al_2(SO_4)_3 \cdot 24H_2O$.
5. **Chlorination**: the chlorine solution will be added to this final tank containing the stormwater to disinfect the water volume from various forms of bacteria and

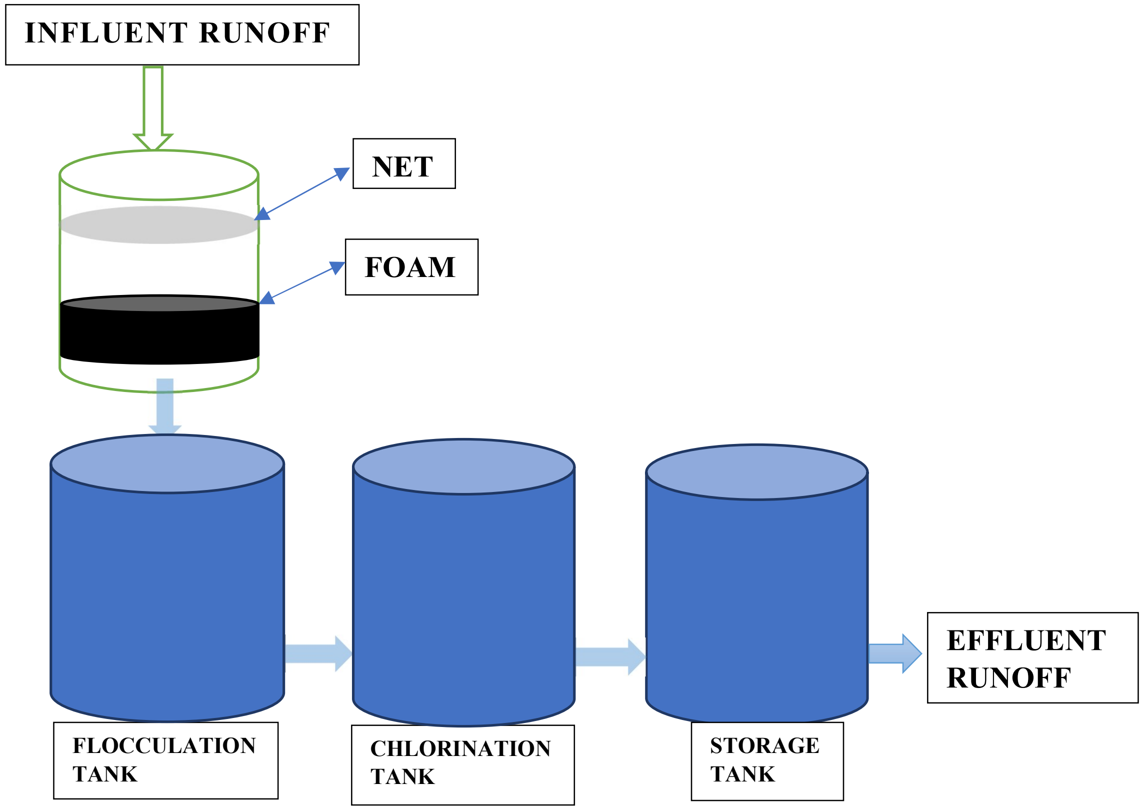


Fig. 8: Diagram of the stormwater treatment process.

germs, rendering it safe for usage. Chlorine levels in drinking water up to 4 milligrams per liter ($mg.L^{-1}$ or 4 parts per million (ppm)) are deemed safe. Harmful health consequences are unlikely to occur at this level. For the chlorination tank, preparation of 0.5% chlorine solution: Grams/liter = [% dilute/% concentrate] × 1000.

6. **Post analysis of effluent run-off**: tests are carried out on the stormwater after the processes to determine the changes and improvement of the TSS and TDS before it can be rendered safe for distribution.
7. **Distribution**: after all the processes, the water is stored in the storage tank and can now be distributed for usage in various forms in the community at large. Fig. 8 presents details of this.

Apparatus

i. **Stormwater collection tank**: the volume of the tank used for the collection of influent stormwater run-off for this experiment is 18.9 liters.

ii. **Net**: a net with a mesh size of 1.2 mm (0.047 in) is used as the first stage of filtration to remove debris from the stormwater run-off.

iii. **Foam**: a polyurethane foam sheet is used as the second stage of filtration to remove smaller debris that may have escaped the net from the stormwater run-off.

Fig. 9, Fig. 10, and Fig. 11 present polyurethane foam, potash alum, and sodium hypochlorite, while Fig. 12 presents the model of the stormwater treatment system.

iv. **Flocculation tank**: after the run-off passes through the filters to the flocculation tank, alum is added to bring the colloidal particles out of suspension to sediment under the form of floc or flake.

v. **Chlorination tank**: after flocculation, the run-off is then released into the chlorination tank, where chlorine is added to disinfect the stormwater run-off and render it safe for usage in various forms.

vi. **Storage tank**: after all the processes have taken place, the water is stored in this tank to manage the distribution.

Relevance of the Method

After the process of filtration and treatment of stormwater run-off using this method, the effluent water can be used for:

i. Watering your garden.

Fig. 9: Polyurethane foam.

Fig. 10: Potash alum.

Fig. 11: Sodium hypochlorite.

Fig. 12: Model of the stormwater treatment system.

ii. Toilet flushing.
iii. Adding water to your swimming pool without using the mains water.
iv. Car and driveway cleaning.
v. Clothes cleaning.

Catchment Capacity

After calculating the catchment area of the roof and the annual rainfall, the estimated catchment capacity of that specific roof can be calculated using the following formulas:

Monthly Roof Catchment Capacity = Monthly rainfall (in millimeters) × Roof surface area (in square meters).

Annual Roof Catchment Capacity = Annual rainfall (in millimeters) × Roof surface area (in square meters).

RESULTS AND DISCUSSION

The average values of the physicochemical parameters obtained from the stormwater run-off after passing through the filtration and treatment process of the fabricated model of stormwater treatment used for this project. The use of potash alum has caused several modifications in the water quality. TDS is lowered to 635 mg.L^{-1} from 697 mg.L^{-1}. Since then, the DO has dropped from 5.87 mg.L^{-1} to 3.92 mg.L^{-1}. Additionally, the turbidity and salinity both increased from 4.42 FNU to 4.58 FNU and from 0.7 PSU to 1.44 PSU, respectively. From 8.35 to 6.51, 2.55 to 1.9 mg.L^{-1}, and 19.78 mg.L^{-1} to 15.17 mg.L^{-1}, respectively, the pH, BOD, and COD were all reduced. It was discovered that the calcium hardness has decreased from 287 mg.L^{-1} to 265.83 mg.L^{-1}. As the conductivity rises from 3.24 ms.cm^{-1} to 3.82 ms.cm^{-1}, it does so slightly. From 0.143 mg.L^{-1} to 0.055 mg.L^{-1} and from 0.092 mg.L^{-1} to 0.045 mg.L^{-1}, respectively, the Fe^{2+} and Zn^{2+} ions show a small drop.

The usage of potash alum and chlorine might have several negative health consequences, such as:

i. Digestive issues because the acidity increase can cause several digestion difficulties.
ii. Inhalation: If fine particles are breathed in while it is dissolved in water, it may irritate the respiratory system.
iii. Contact with the skin and eyes might irritate, including redness, itching, and discomfort.

The correct use of alum, according to the WHO and the Water Sanitation and Health (WSH), needs competence. As a result, a standard value for the application of potash alum for ordinary people is required, particularly in Nigeria, where there is a problem with inadequate stormwater management.

Pre-Analysis of Stormwater Run-Off

Table 2 presents various tests that were carried out on stormwater samples (Before treatment), while Table 3 presents the monthly average rainfall in Abuja. Fig. 13 presents information on annual rainfall.

Table 2: Combined Results compared to recommended standards.

TEST	Unit	Value 1	Value 2	Value 3	Average value
Total Dissolved Solids (TDS)	$mg.L^{-1}$	697	701	693	697
Dissolved Oxygen (DO)	$mg.L^{-1}$	5.76	5.84	6.02	5.873333333
Salinity	PSU	0.7	0.7	0.7	0.7
Turbidity	FNU	4.95	4.24	4.08	4.423333333
pH	-	8.3	8.36	8.4	8.353333333
Biochemical Oxygen Demand (BOD)	$mg.L^{-1}$	2.7	2.35	2.6	2.55
Chemical Oxygen Demand (COD)	$mg.L^{-1}$	20.35	20.5	18.5	19.78333333
Calcium Hardness	$mg.L^{-1}$	288	280	293	287
Conductivity	$ms.cm^{-1}$	3.12	3.31	3.29	3.24
Fe^{2+}	$mg.L^{-1}$	0.145	0.1	0.185	0.143333333
Zn^{2+}	$mg.L^{-1}$	0.065	0.105	0.105	0.091666667

Calculations and Estimates

Table 3: Monthly average rainfall in Abuja.

Months	Rainfall 1 (mm) source:(Climate-data.org, 2020)	Rainfall 2 (mm)source:(Spark, 2019)	Average Monthly Rainfall(mm)
January	2	0	1
February	6	2.5	4.25
March	20	17.5	18.75
April	57	75	66
May	138	132.5	135.25
June	205	160	182.5
July	269	207.5	238.25
August	326	245	285.5
September	290	225	257.5
October	144	105	124.5
November	11	10	10.5
December	1	0	0.5

Total Annual Rainfall = $\sum$(Average monthly rainfall) = 1,324.5mm.

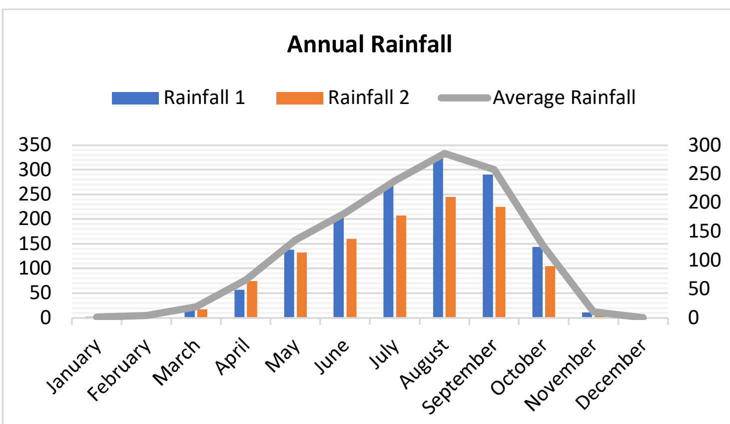


Fig. 13: Annual rainfall.

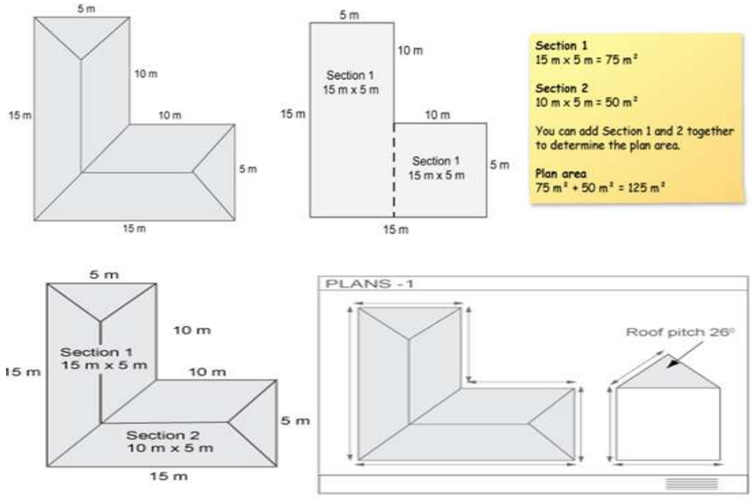


Fig. 14: The pitch roof details.

Table 4: Catchment area slope factor (F).

Roof slope degrees	Factor for the increased surface area of the roof (F)	Roof slope degrees	Factor for the increased surface area of the roof (F)	Roof slope degrees	Factor for the increased surface area of the roof (F)
0	1.00	22	1.20	44	1.48
1	1.01	23	1.21	45	1.50
2	1.02	24	1.22	46	1.52
3	1.03	25	1.23	47	1.54
4	1.03	26	1.24	48	1.56
5	1.04	27	1.25	49	1.58
6	1.05	28	1.27	50	1.60
7	1.06	29	1.28	51	1.62
8	1.07	30	1.29	52	1.64
9	1.08	31	1.30	53	1.66
10	1.09	32	1.31	54	1.69
11	1.10	33	1.32	55	1.71
12	1.11	34	1.34	56	1.74
13	1.12	35	1.35	57	1.77
14	1.12	36	1.36	58	1.80
15	1.13	37	1.38	59	1.83
16	1.14	38	1.39	60	1.87
17	1.15	39	1.40	61	1.90
18	1.16	40	1.42	62	1.94
19	1.17	41	1.43	63	1.98
20	1.18	42	1.45	64	2.03
21	1.19	43	1.47	65	2.07

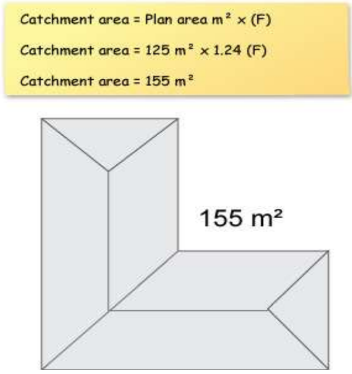


Fig. 15: Catchment area (Plumb 2010).

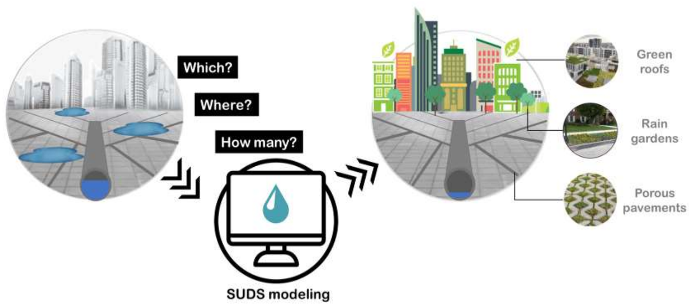
Catchment Area

For example, to determine the catchment area of stormwater for a roof drainage system of a house with an eaves gutter (Fig. 14):

We first divide the roof into simple shapes and determine its area by multiplying the length of the roof by the breadth of the roof will give you the catchment area of a building with a flat roof. When calculating the catchment area of a roof with a pitched roof, remember to factor in the pitch of the roof. The roof pitch is usually indicated on the plan by the architect. The pitch of this building's roof is 26°. The 'Catchment area – Slope factor (For eaves gutter alone) table (Table. 4) from AS/NZS 3500.3.2003 will be needed to determine the slope factor (F).

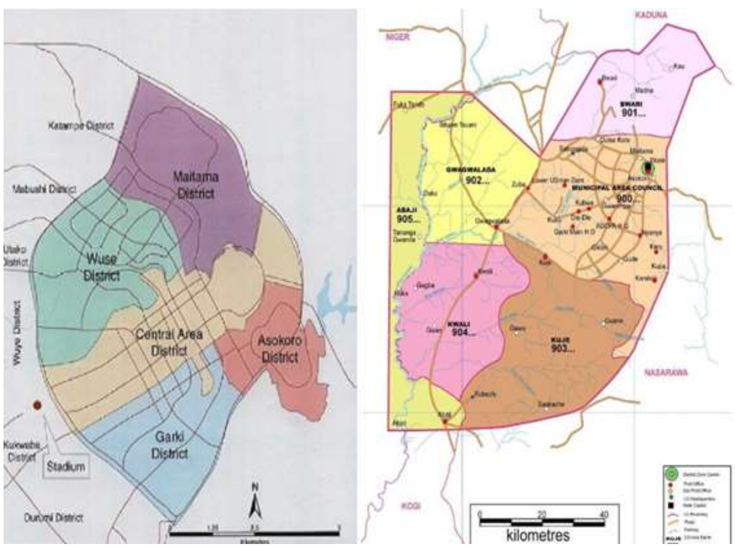
The roof, in this case, has a pitch of 26°. Therefore, the slope factor (F) is 1.24. By multiplying the plan area by the slope factor (F), you can now calculate the catchment area (Fig. 15).

Fig. 16 presents a typical Sustainable Urban Drainage Systems (SUDS) Decision Making. Also, Fig. 17 presented a map of Abuja Central Area and six area councils in Abuja.



Source: (Ferrans et al. 2022).

Fig. 16: Sustainable Urban Drainage Systems (SUDS) decision making.



Source: (Afolabi & Raimi 2021).

Fig. 17: Map of Abuja Central Area and area Councils in Abuja, Nigeria.

Table 5: Monthly roof catchment capacity.

Months	Rainfall	Catchment	Monthly Roof Catchment Capacity (Liters)
January	1	155	155
February	4.25	155	658.75
March	18.75	155	2906.25
April	66	155	10230
May	135.25	155	20963.75
June	182.5	155	28287.5
July	238.25	155	36928.75
August	285.5	155	44252.5
September	257.5	155	39912.5
October	124.5	155	19297.5
November	10.5	155	1627.5
December	0.5	155	77.5

Table 6: Various Tests were carried out on Stormwater samples (After treatment).

Test	Unit	Value 1	Value 2	Value 3	Average Value
Total Dissolved solids (TDS)	$mg.L^{-1}$	654	620	632	635.3333333
Dissolved Oxygen (DO)	$mg.L^{-1}$	3.67	4.12	3.96	3.916666667
Salinity	PSU	1.26	1.56	1.51	1.443333333
Turbidity	FNU	4.51	4.57	4.66	4.58
pH	-	6.43	6.31	6.79	6.51
Biochemical Oxygen Demand (BOD)	$mg.L^{-1}$	1.9	1.75	2.05	1.9
Chemical Oxygen Demand (COD)	$mg.L^{-1}$	20.5	12	13	15.16666667
Calcium Hardness	$mg.L^{-1}$	268	263	266.5	265.8333333
Conductivity	$ms.cm^{-1}$	3.2	4.06	4.21	3.823333333
Fe^{2+}	$mg.L^{-1}$	0.055	0.065	0.045	0.055
Zn^{2+}	$mg.L^{-1}$	0.045	0.045	0.046	0.045333333

Table 7: Results compared to recommended standards.

Test	Units	Before Treatment Value	After Treatment Value	Recommended raw water criteria set by WHO
TDS	$mg.L^{-1}$	697	635.3	600 - 900
DO	$mg.L^{-1}$	5.87	3.92	6.5 - 8.0
Salinity	PSU	0.7	1.44	30 - 37
Turbidity	FNU	4.42	4.58	1.0 - 5.0
pH	~	8.35	6.51	6.5 - 8.5
BOD	$mg.L^{-1}$	2.55	1.9	<5.0
COD	$mg.L^{-1}$	19.78	15.17	<120
Calcium Hardness	$mg.L^{-1}$	287	265.83	0 - 150
Conductivity	$ms.cm^{-1}$	3.24	3.82	<0.4
Fe^{2+}	$mg.L^{-1}$	0.143	0.055	<0.3
Zn^{2+}	$mg.L^{-1}$	0.092	0.045	<5.0

Catchment Capacity

After calculating the catchment area of the roof and the annual rainfall, the estimated catchment capacity of that specific roof can be calculated using the following formulas:

Monthly Roof Catchment Capacity = Monthly rainfall (in millimeters) × Roof surface area (in square meters).

Annual Roof Catchment Capacity = Annual rainfall (in millimeters) × Roof surface area (in square meters).

Note: Roughly speaking, 1 millimeter of rain over 1 square meter of roof equals 1 liter of water. If the catchment area is 155 m^2, the monthly roof catchment capacity is as indicated in Table 5.

This is the amount of water that can be saved and reused by stormwater harvesting for every month of the year.

Therefore, if the Total Annual Rainfall = 1,324.5 mm while the catchment area is 155 m^2.

The Annual Roof Catchment Capacity = 1,324.5mm × 155m^2 = 205,297.5 liters. This is the amount of water that can be saved and reused over a year by stormwater harvesting.

Post-Analysis of Stormwater Run-Off

Table 6 presents various tests that were carried out on Stormwater samples (After treatment), while Table 7. Results compared to recommended standards.

Combined Results

The correct use of alum, according to the WHO and the Water Sanitation and Hygiene (WASH), needs competence. As a result, a standard value for the application of potash alum for ordinary people is required, particularly in Nigeria, where there is a problem with inadequate stormwater management.

CONCLUSIONS

For a clean environment and to reduce pollution, communities' urban stormwater management and treatment infrastructure must be designed and modeled. The typical values of the physicochemical parameters obtained from the stormwater run-off after it has been filtered and treated by the constructed stormwater treatment model utilized for this study. The water quality has changed in several ways as a result of the usage of potash alum. TDS is now 635 $mg.L^{-1}$ instead of 697 $mg.L^{-1}$. The DO was 5.87 $mg.L^{-1}$ and is now 3.92 $mg.L^{-1}$.

Moreover, the turbidity and salinity both increased from 4.42 FNU to 4.58 FNU and from 0.7 PSU to 1.44 PSU, respectively. BOD, COD, and pH all decrease from 8.35 to 6.51, 2.55 to 1.9, and 19.78 to 15.17 $mg.L^{-1}$, respectively. There is a decrease in calcium hardness, from 287 $mg.L^{-1}$ to 265.83 $mg.L^{-1}$.

As the conductivity rises from 3.24 $ms.cm^{-1}$ to 3.82 $ms.cm^{-1}$, it does so slightly. From 0.143 $mg.L^{-1}$ to 0.055 $mg.L^{-1}$ and from 0.092 $mg.L^{-1}$ to 0.045 $mg.L^{-1}$, respectively, the Fe2+ and Zn2+ ions show a small drop. Ecosystems become unstable as a result of nutrients and organic materials, and this can lead to biological disasters like algal blooms. To make sure that the stormwater treatment methods are running flawlessly and fulfilling their intended purposes, they should be frequently inspected and maintained. Inadequate equipment maintenance could lead to a decrease in the effectiveness of pollution removal or even an increase in pollutant loadings, worsening the effects down the line. According to the results of the above small-scale constructed model's effective treatment of the stormwater sample, the sample satisfies the WHO's suggested standards for raw water in terms of TDS, pH, turbidity, BOD, and COD. Since effluent water is primarily used for non-potable applications like car washing, gardening, toilet flushing, and laundry, these uses are considered safe. Stormwater management provides a means for achieving environmental sustainability. The use of green infrastructure techniques is now acknowledged as a successful stormwater management strategy. The Storm Water Drainage System Design and Analysis Program (DRAINS), the Urban Drainage and Sewer Model (MOUSE), InfoWorks River Simulation (InfoWork RS), the Hydrological Simulation Program-Fortran (HSPF), and many other software tools can be used to manage urban stormwater. It is legitimate to state that after treatment, rainwater can be used as raw water. One of the most difficult things is to get a reliable figure on water needs because it depends the availability, cost and the location. Rainwater harvesting is a decentralized and environmentally solution that can avert many environmental problems associated with centralized, conventional and large project approaches. To reach the highest level of sustainability, all stakeholders should be involved in the planning and implementation rainwater harvesting systems. The effectiveness of this method and data on water quality must be periodically monitored and updated for adequate pollution abatement and environmental sustainability.

RECOMMENDATIONS

Recommendations are the following:

More research and Water quality management are essential for ensuring that water resources and stormwater are safe and healthy for human consumption and other uses.

i. More research and water quality management are essential for ensuring that water resources and stormwater are safe and healthy for human consumption and other uses.

ii. To ensure that the stormwater treatment methods are working properly and are in excellent operating condition, they should be frequently inspected and maintained. Inadequate equipment maintenance could lead to a decrease in the effectiveness of pollution removal or even an increase in pollutant loadings, worsening the effects down the line.

iii. Capacity building and community participation are essential for ensuring that stakeholders have the knowledge, skills, and tools necessary to manage water resources sustainably.

iv. The need for operating and maintaining the tanks should be made clearer to house owners. There is a need to verify that PVC or another corrosion-resistant material, such as the gutter, downpipe, and tank, are used. Add a gutter trap or a net to prevent leaves and branches from falling into the tank.

v. The rainwater tank should be tightly covered for safety reasons as well as to keep dust, run-off, and insects out of the tank.

vi. Since the initial cost of building a tank is the main barrier to adoption, a loan program or subsidy for homeowners to meet this cost should be implemented.

vii. In dry zone districts where the groundwater is both mineralized and polluted, drinking rainwater after proper treatment should be encouraged. It is believed that the high calcium and mineral content in the dry zone regions is to blame for the rising occurrence of renal illnesses.

viii. The generally great quality of rainwater should be made known to enable more people to consume it and use it for other varied communal reasons.

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