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Septage Bio – Filter Device

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Abstract
While septage management systems are widely used globally where central sewerage is unavailable, local government units (LGUs) in the Philippines often hesitate to implement them due to budget constraints, technical knowledge gaps, and a lack of urgency regarding water resource protection. To address this, a step-to-date biofilter device was developed to offer an affordable, natural, and localized treatment solution for individual households, making it an excellent alternative for resource-strapped LGUs. Structurally, the device features filtration and media chambers connected via PVC pipes, running directly from a home's septic tank to a sampling faucet. Testing shows that this natural treatment system successfully meets the Total Dissolved Solids (TDS) and Biochemical Oxygen Demand (BOD) standards mandated by the Department of Environment and Natural Resources (DENR via DAO-2016-08), rendering the treated effluent completely safe for ground disposal.

Keywords: Septage, BOD, TDS, Natural treatment

1. Introduction

The Philippine Clean Water Act of 2004 (Republic Act 9275) was enacted to protect the country's water bodies from pollution by mandating proper sewerage and septage management. Despite this legislation, only about 7% of the population currently has access to functional wastewater treatment or sewerage services. Instead, over 80% of Filipinos rely on septic tanks, which are largely poorly maintained. This lack of proper infrastructure causes severe environmental and public health crises; the resulting untreated wastewater spreads diseases, contaminates vital drinking water sources, threatens local biodiversity, and lowers the overall quality of life.

This legislation regulates water quality across all fresh, brackish, and marine environments, focusing on controlling pollution from land-based sources through a national management program. Its core provisions include identifying pollution-heavy "non-attainment" areas, establishing Water Quality Management Areas (WQMAs), and setting up programs for sewerage and septic management. To ensure compliance, the Act also introduces a water pollution permitting system backed by strict legal penalties for violators.

While septic tanks act as an essential primary treatment layer by converting human waste into manageable effluent—a process that can break the cycle of disease, reduce human suffering, and minimize economic losses—they are often insufficient on their own. Standard septic systems frequently fail to adequately lower pollutant levels, which leads to groundwater contamination that directly threatens private wells and poses serious public health risks (Tabassum, 2024).

Natural wastewater treatment systems utilize plants and microorganisms for ecological water purification, though they operate at a slower pace than mechanical options (Wilas et al., 2016). Globally, sanitation remains a critical issue, with a striking 40% of the population either practicing open defecation or lacking basic sanitation facilities. Furthermore, in developing urban centers, more than 2 billion people depend on poorly maintained septic tanks or systems that dump raw sewage directly into the environment, drastically increasing the threat of waterborne diseases (Otunola, 2024).

In the Philippines, poor sanitation and its resulting health crises cost an estimated $1.94 billion annually. To combat this massive financial burden, Republic Act 9275 stresses the urgent need for better sanitation practices, calling for affordable, sustainable innovations and active community involvement to upgrade wastewater treatment. Ultimately, the primary objective of RA 9275 is to shield the country's water bodies from land-based pollution, paving the way for improved public health and long-term environmental sustainability.

2. SYNTHESIS

Globally, septage treatment has been universally adopted, with international laws mandating the construction of wastewater treatment plants. This legal push has driven continuous research and development into new technologies aimed at combating worldwide water pollution. However, building and operating these treatment facilities requires massive financial investment, which stands as a primary reason why many regions across the globe still lack access to them. Ultimately, restoring and protecting our water bodies from pollution remains a highly expensive endeavor.

The septage biofilter device was developed to offer an economical alternative to existing, expensive treatment technologies while still achieving the same high-quality results required for safe final disposal. I am running a few minutes late; my previous meeting is running over.

Prior Art 1. The applicable conditions and scope of the underground sewage treatment plant include a small amount of sewage, less available land on the ground, special requirements for the above-ground landscape, low groundwater level, easy-to-excavate geology, and the buried depth of the sewage return pipe is not very large. It is not under the main road, has a certain distance from residential buildings, is not a depression, does not

accumulate rainwater, and the sewage discharge requirements are not very strict. The underground sewage treatment plants are suitable for construction in areas where thermal insulation needs to be considered, less requisition able land area, and higher environmental requirements. The results of the underground landscape design study showed that the design of principles, features, styles, water ecologies, a combination between community friendly and ecologically friendly, operations and maintenance cost of the underground landscape should be emphasized. The construction of the ecological complex will lead the sewage treatment plant exchange from minus assets to ecological positive assets, which will meet the needs of future urban social economic development and environmental protection. The results of the development direction exploration study showed that innovation in the design concept, breakthroughs of key sewage treatment technology, and variation of investment and operation mode can reduce the land occupation investment and operation cost, and the underground sewage plant with large-scale and semi-underground mode owes broader prospects for development. Giwa, A. S., et. al (2025)

According to Englande Jr, A. J., et. al. (2015) wastewater treatment is how water that has been used and/or contaminated by humans or nature is restored to a desirable quality. Treatment may consist of chemical, biological, or physical processes or a combination thereof. Water may be treated to any level of quality desired; however, as its purity increases, so does the cost of attaining that purity. The required quality of water is dictated by its intended use, for example, aquatic life, drinking water, or irrigation. The purpose of this chapter is to describe wastewater treatment technologies predominantly in use today. Ultimately, the technology selected as appropriate for one application may not be the optimal for another. Selection will be based on site-specific factors, such as resources available, climate, land availability, economics, etc.

Geared toward rural communities, this system offers a high equipment height-to-diameter ratio that minimizes its physical footprint, operates quickly, requires no external electrical power, and is straightforward to manage. However, the device is both highly complex to configure and expensive to implement, requiring consistent, regular maintenance to remain fully operational.

While all existing prior art addresses wastewater treatment for disposal or reuse—aligning with critical environmental laws—these traditional systems remain highly expensive due to their numerous complex attachments and multi-stage components.

To provide an equally effective but more accessible alternative, the innovative septage bio-filter device was designed, built, and evaluated. This device is uniquely innovative because it can be deployed for immediate use, safely treating septage for direct ground disposal without compromising treatment quality. Furthermore, it can be attached directly to residential septic tanks, entirely removing the need for septage collection and transport to a centralized facility. This offers a significant advantage for communities and local government units that lack the financial resources to construct and maintain a traditional wastewater treatment plant.

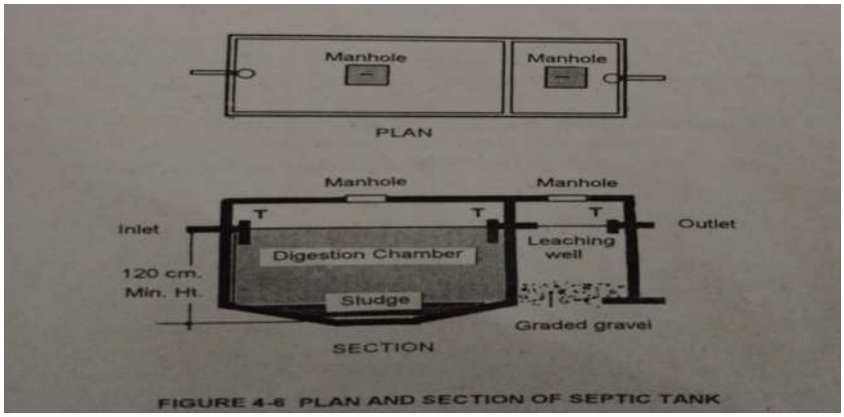
2. LITERATURE REVIEW

2.1. Water and Disposal Management

Water is a fundamental human right, as highlighted by Brown, Collin, et al. (2016), who note that access to safe, clean drinking water and sanitation is crucial for the full enjoyment of life and all other human rights. Beyond individual survival, water is central to sustainable development, driving socioeconomic growth, sustaining healthy ecosystems, and mitigating the global burden of disease to improve public health, societal welfare, and productivity. Recognizing this vital role and the necessity of protecting the nation's aquatic resources, the government enacted the Philippine Clean Water Act of 2004, also known as Republic Act 9275, to guarantee that all Filipinos have access to clean water (Republic Act 9275).

Republic Act 9275, otherwise known as the Philippine Clean Water Act of 2004, is designed to safeguard the nation’s water resources against pollution originating from land-based activities, including industrial, commercial, agricultural, and domestic sources. The legislation mandates a comprehensive, integrated framework to prevent and mitigate pollution, utilizing a collaborative, multi-sectoral approach that engages all relevant stakeholders. Under this act, water quality management is organized regionally by watersheds, river basins, or distinct water resources. Furthermore, the Department of Environment and Natural Resources (DENR), in coordination with the National Water Resources Board (NWRB), is tasked with designating specific water quality management areas based on shared hydrological, hydrogeological, meteorological, or geographic traits that influence pollutants react and disperse within the water bodies.

Figure 1
The Septic Tank



As illustrated in Figure 1 and detailed by Fajardo, Max (2001), a septic tank functions as a collection vault for organic waste received from a residential sewer system. Its primary purpose is to liquefy and precipitate solid waste while treating odorous compounds. This mechanism, known as digestion, alters the characteristics of solid matter by breaking it down into smaller sizes. Consequently, a septic tank operates by integrating two distinct processes: sedimentation within the upper section of the chamber, and anaerobic decomposition of the gathered sludge at the base.
According to Perez, J. (1999), constructing a septic tank is a mandatory requirement under the Revised National Plumbing Code of the Philippines. The code mandates specific minimum design dimensions regarding the tank's width, length, and depth. Consequently, every structure, whether built for residential or industrial use must be equipped with a compliant septic tank system.

This study strictly limits its scope to septage generated by residential households. To determine the necessary dimensions of a septic tank, one can reference Figure 2 from the Plumbing Design and Estimate text, which specifies the required capacity per person. By applying this standard volumetric allocation per occupant, the final size of the tank is calculated by multiplying its depth by the dimensions of its rectangular cross-section (width and length).

Figure 2, Technical Data in Determining Volume of Septic Tank

Figure 3, Capacity of Septic Tank for Residential Homes.

Number of Bedrooms	Home Square Footage	Tank Capacity
1 or 2	Less than 1, 500	750
3	Less than 2,500	1, 000
4	Less than 3, 500	1, 250
5	Less than 4, 500	1,250

Figure 3 stipulates number of bedrooms to home square footage to tank capacity.

For a family of 6 people, the minimum tank capacity should be approximately 1.3 m3 with a minimum size of 90 cm. wide by 150 cm. long and 120 cm. depth.

An oversized tank is counterproductive because it slows down the bacterial processes required for waste treatment. Instead, the tank's dimensions should directly correspond to the number of users. This ensures the volume of the tank remains in perfect balance with the amount of incoming waste, creating an optimal environment for bacterial activity.

For residential installation, the practice is to allow 5 to 6 cubic feet of tank volume per person. Thus, a septic tank that will serve a family of 12 people must have a liquid capacity of (6) *(12) = 72 cubic feet or 538 gallons. (1 ft3 = 748 gallons). Fajardo, Max (2001).

To ensure maximum efficiency and longevity, property owners must commit to regular upkeep of their septic tanks and treatment systems. Consistent maintenance extends the operational life of these systems, allowing them to function properly for decades.

Proper septic system management, as outlined by Guide, M. (2022), relies on regular maintenance and strict preventative measures to maintain optimal treatment efficiency. This includes desludging the tank quadrennially, keeping comprehensive service records, and inspecting the infrastructure for cracks, intact baffles, and localized pooling. Furthermore, system longevity depends on avoiding chemical starters or enzymes, mitigating hydraulic overloads through strict water conservation and rainwater diversion, preventing root intrusion from deep-rooted plants, and restricting heavy vehicle traffic over the system components.

2.2 Septage Treatment Facilities

1.2.1. Septage Treatment Plant in Baliwag, Bulacan

Baltazar et al. (2021) describe the septage treatment facility in Brgy. San Roque, Baliwag, Bulacan, which provides the region with an economical and ecologically sustainable sanitation system. The treatment workflow begins with a physical screening stage, where a bar screen traps large debris, a macerator shreds remaining solids, and dual rotating mesh screens compact solid waste while an integrated skimmer extracts oil and grease. The liquid then progresses through a holding tank for equalization, while the remaining slurry undergoes polymer-induced sludge thickening to bind solids together. Following a second equalization step, the wastewater undergoes biological treatment via SBR aeration, where diffused oxygen helps bacteria break down organic matter (BOD). Once the aeration stops, the mixture undergoes decantation, allowing solids to settle so the clear supernatant can be drawn off. This water is disinfected with chlorine dioxide—effectively neutralizing pathogens without generating toxic aquatic residues—and is retained in an effluent tank until it is either recycled or released into an irrigation canal.

2.2.2. First Septage Facility in Tacloban, Leyte

Palagi et al. (2016) document the launch of Tacloban City's first septage treatment plant on March 8, 2016, in Brgy. Santo Niño, an initiative funded by international agencies such as USAID, Samaritan's Purse, and UNICEF to elevate local sanitation services. The 21-cubic-meter facility uses lime stabilization to process domestic waste and represents a national milestone as a climate-resilient plant built to fulfill government regulations. According to City Environment and Natural Resources Officer Jonathan Hijada, the project was born out of critical lessons learned after Typhoon Yolanda. Hijada stated that the success of a temporary, emergency septage system during the post-disaster recovery phase ultimately motivated the city to establish this permanent infrastructure to secure long-term, proper sanitation.

2.2.3. Septage Treatment Facility in San Fernando, Pampanga

In June 2008, a collaborative team of engineers and staff from the health, planning, environment, and engineering offices of San Fernando City initiated the first phase of a pilot demonstration project. Their goal was to evaluate the viability of lime stabilization for treating domestic septage within the Philippines. Following these trials, the city officially launched its Septage Treatment Facility (STF) on March 26, 2012, with the overarching goal of enhancing water sanitation, protecting family health, and preserving the environment. According to Baltazar et al. (2021), the facility has two main objectives: its primary mission is to establish an all-inclusive septage collection, treatment, and recycling program for San Fernando and its neighboring areas, while its secondary mission is to serve as an operational blueprint for other Philippine communities striving to elevate public and environmental health nationwide.

2.2.4. Septage Treatment Plant, Dumaguete City, Negros Oriental

Dumaguete City's multimillion-peso septage wastewater treatment plant has become a major highlight of the city's governance, routinely drawing visitors interested in its celebrated best practices. According to Robbins et al. (2019), this septage management system represents the first locally funded project of its kind in the Philippines, serving as a successful template for safeguarding water resources and public health through grassroots efforts. Developed with support from the Local Initiatives for Affordable Wastewater Treatment (LINAW) project, it stands as the nation's premier septage system entirely managed by a Local Government Unit (LGU), showcasing a highly productive model of local government-controlled operations. Mechanically, the system services 22,000 households and 2,500 commercial, institutional, and public market buildings. The waste is processed without electricity or chemicals across a network of eight lagoons and constructed wetlands. To ensure long-term viability, the city established a dedicated septage management ordinance alongside user fees designed to fully fund operations, maintenance, and a portion of the initial capital investment.

2.3. Septage Management in Five Cities in the Philippines

Sanitation infrastructure in the Philippines is severely limited; only 10% of the 98 million population connects to piped sewerage, while 84% utilizes septic tanks. Nationwide treatment rates are critically low, reaching only 30% inside Metro Manila and 5% in outside regions. A 2007 USAID and DILG assessment highlighted the human toll

of this deficit, attributing over 11,338 annual diarrheal deaths and 55% of daily water-borne disease fatalities to poor sanitation. Furthermore, coliform contaminates 58% of groundwater, and 64% of rivers fail Class C quality standards due to elevated coliform and BOD levels. These combined crises prompted the 2013 implementation of a national sewage and septage management strategy requiring Local Government Units (LGUs) to develop septage infrastructure. Successfully guiding LGUs toward the right systems requires a comprehensive assessment of the strengths and weaknesses inherent in current treatment models (Baltazar et al., 2021).

Even though onsite sanitation systems (OSS) have been heavily promoted to meet global sanitation goals, city planners and toilet programs frequently overlook a critical phase: managing the collected septage once these systems fill up. Because public management is severely lacking, private operators have stepped in to empty the systems either manually or mechanically.

The disposal methods of these private providers create distinct environmental and health hazards:
Mechanized Operators: Truck operators typically transport the waste a few kilometers away, dumping it directly into waterways, drainage networks, open land, or farming fields.

Manual Operators: Working primarily in cramped, low-income settlements inaccessible by truck, manual laborers usually dump the waste immediately outside homes, in local pathways, or into nearby drains.

Ultimately, this cycle disproportionately harms impoverished communities. The poorest populations face the highest health risks because they are both the ones performing the hazardous manual emptying work and the ones living closest to these makeshift dumping sites. ASIA, L. W. O. T. (2010)

According to Shukla et al. (2023), 20% of the population in Japan relies on an on-site sanitation (OSS) system known as Johkasou, which is designed to treat both blackwater and graywater combined. Additionally, 14% of the population utilizes vault tanks, which are used exclusively for handling blackwater. These systems function alongside other widespread examples of on-site sanitation utilized globally, such as standard septic tanks, traditional pit latrines, and twin-pit latrines.

Despite a universal objective to elevate water sanitation, safeguard community health, and ensure environmental cleanliness, the deployment of these technologies remains unequal. The presence or absence of dedicated treatment facilities across different localities is dictated by numerous localized obstacles that continue to obstruct the full implementation of the Clean Water Act.

2. RESEARCH SIGNIFICANCE

The results of this study will help everyday citizens by allowing them to use secondary septage treatment technology right at home. This is incredibly convenient for families living in areas without local treatment plants to handle their household waste.

To comply with the Plumbing Code of the Philippines and RA 9275 (the Clean Water Act of 2004), residential households will be motivated to utilize standardized septic tank designs.

3. OBJECTIVES OF THE STUDY

This study aimed to design, fabricate, and evaluate a septage bio-filter device (SBFD). The specific objectives included the construction of the SBFD and the evaluation of its treatment efficiency by analysing the effluent's Total Dissolved Solids (TDS) and Biochemical Oxygen Demand (BOD) levels to verify fitness for safe water disposal.

4. DESCRIPTION OF THE STUDY

5.1. Design Criteria

Products are fundamentally bought to be used, meaning great design must focus entirely on utility. This requires satisfying not just practical needs, but psychological and aesthetic ones as well. Ultimately, excellent design elevates a product's purpose by eliminating any distractions that take away from its functionality. Rams, D., et. al. (2017).
Engineered for convenience, efficiency, and cost-effectiveness, the innovative septage bio-filter device delivers wastewater plant-level treatment performance. Its compact, user-friendly design allows for economical mass production. The primary components of this advanced filtration technology include:

5.1.1. Media Chamber (80–liter Water Drum).

This drum acts as a media chamber as it accommodated the septage from the septic tank to be treated with MBBR (moving bed biofilm reactor).

5.1.2. Filtration Chamber (20 – liter Water Drum).

Serving as a filtration chamber, this unit utilizes activated carbon to provide advanced treatment of the septage prior to its ultimate discharge into the ground or local waterways. The system utilizes the ubiquitous blue plastic drum, a global standard in industrial and warehouse environments. Renowned for its versatility, durability, and

reliability, this specific container is vital for the secure storage and transport of diverse industrial materials. Plastic drums are generally UN certified and of food – grade quality.

Industrial blue plastic drums are composed of high-density polyethylene (HDPE), a material so closely linked to this specific color that the blue hue now serves as an immediate visual identifier for HDPE construction. HDPE is a highly versatile thermoplastic polymer, also referred to as polythene within the piping industry. It is widely utilized across commercial and packaging sectors due to its exceptional tensile strength and superior strength-to-density ratio (Benham et al., 2005).

5.1.3. MBBR (media bed biofilm reactor

Moving bed biofilm reactor (MBBR) technology is increasingly favored in sewage treatment for its high efficiency alongside minimal operation and maintenance expenses. A critical factor in optimizing MBBR systems is determining the appropriate volume of media carriers. These polyethylene carriers provide an extensive surface area that fosters the microbial growth necessary to decompose organic matter (STP Media Calculation Guide, 2024). Specifically, for an 80-liter water drum setup, the required treatment volume equates to approximately 812, or 2 kilograms, of media carriers. Qiqi et al. (2012).

5.1.4. Activated Carbon

Water is indispensable to life, making efficient usage and conservation critical. To reclaim clean water, wastewater treatment facilities frequently utilize activated carbon, a material that functions via adsorption—a process where molecules, atoms, or ions bind directly to the surface of the carbon particles. Prior to treatment, the raw material is processed through either chemical or thermal/steam activation. Suitable base materials include any carbon-rich substance, such as coconut shells, wood, bamboo, peat, coal, lignite, or macadamia nut shells, with certain precursors performing better under specific activation techniques Perrich, (2018).

According to data from Bengtson (2017), a 20-liter drum system utilizing Granulated Activated Carbon (GAC) requires a media filter mass of 30 kilograms. When configured with a 10-inch housing, this setup operates at a flow rate of 0.6 gallons per minute (g/min) with an Empty Bed Contact Time (EBCT) of 25 seconds. Under these specific parameters, the system can eliminate 95% of influent chlorine across a total volume of 2,500 gallons.

A biofilter can be defined as any type of filter media with attached microbial community on surface in the form of biofilm performing at least one essential functions of treatment process. However, some studies referred filter media as biofilter without confirming role of indigenous microorganisms or biofilm in removal of pollutants and pathogens. Biofilter was introduced in wastewater treatment plant as trickling filter where filter media was slag or rock. Nowadays, various kinds of filter media such as rock stones, gravel, sand, GAC, or synthetic plastic media, etc., have been successfully applied for treatment of domestic and industrial wastewater. Maurya, A., et.al. (2020)

5.1.5. Standard Pipes, Connectors, and Control Valves

High-density polyethylene (HDPE) pipes are commonly used for fluid and gas transport, as well as for upgrading deteriorated concrete or steel mainlines due to their flexibility, low permeability, and high-pressure resilience. They are widely implemented in applications such as water, gas, and sewer mains, slurry transport, irrigation, fire suppression lines, drainage, and utility conduits.

While polyethylene (PE) pipe is a broad category encompassing all thermoplastic pipes derived from ethylene gas, HDPE represents a specific subcategory. HDPE pipes offer superior durability compared to alternative PE variations due to their elevated melting points and high impact resistance, alongside being lightweight and resistant to both chemicals and corrosion (Benham et al., 2005)

Computation for the flow/discharge:

Diameter of the housing (activated carbon),
Height = 32 cm; Inner diameter = 11.5 cm; 1m = 100 cm

Figure 8. Shows the different time obtained through the video recorded in 4 trials.

Time, t (sec)	19.38	18.08	18.34	17.98	18.445 (average)

1 cubic meter = 1000 liters

$$Q = \frac{volume}{time} = \frac{0.003324\ m^3}{18.445\ sec} = 0.0001802\ \frac{m^3}{sec} = 0.1802\ \frac{liter}{sec}$$

The computation of flow/discharge was obtained using the formulas of Fluid Mechanics' Measurement of Fluid Flow.

5.1.6. Air Pump and Bubble Stones

To facilitate aerobic activity for the septage and MBBR media, an aerator equipped with bubble stones is positioned at the base of the 80-liter water drum. While the MBBR treatment process typically spans three to four

hours, this specific study extends the treatment duration to a full four hours to ensure optimal outcomes are achieved.

This apparatus connects directly to the septic tank to execute secondary treatment, allowing the processed effluent to be discharged immediately following the treatment cycle.

Engineered with specialized pressure-control mechanisms, standard water compressors achieve elevated pressure levels by significantly reducing fluid volume. To endure these severe pressure demands, most units are constructed from highly durable materials. While a diverse market offers specialized compressors tailored to distinct applications, these devices differ only slightly from pumps, as both perform similar functions. Ultimately, fluid compressors operate efficiently to boost and regulate water flow through piping networks for various applications (Bloch, 2006).

5. THE TECHNOLOGY

The Septage Biofilter Device (SBFD) was developed in direct alignment with the mandates of Republic Act 9275, also known as the Clean Water Act of 2004, which seeks to safeguard aquatic environments against pollution**.**

As established in the preceding chapters, various septage treatment technologies and processes share a singular objective: ensuring that discharged effluent complies with the regulatory standards of the Clean Water Act of 2004 (RA 9275) prior to environmental release into the ground or local waterways. To achieve this, the Septage Biofilter Device (SBFD) was conceptualized as an innovative, more streamlined alternative for managing septage directly at the outlet of domestic septic tanks.

Pursuant to Section 4.0 (aa) of DAO-2016-08, "Treatment" is defined as any method, technique, or process engineered to modify the physical, chemical, biological, or radiological properties of waste or wastewater with the goal of mitigating or preventing pollution. Operating under this framework, the SBFD system utilizes an 80-liter and a 20-liter HDPE water drum to serve as the media and filtration chambers, respectively. These primary components are linked via interconnected HDPE piping, valves, and fittings to systematically transport the septage between chambers.

To facilitate processing within the media chamber, a bottom-mounted aerator supplies continuous oxygenation. The system utilizes Moving Bed Biofilm Reactor (MBBR) PE 75S media chips, measuring 25 mm in diameter and 4 mm in thickness, which provide an extensive surface area of greater than 1,600 m^3 ideal for wastewater treatment. Perforations are integrated along the internal piping of the chamber to deliver supplemental aeration. Operationally, the treatment cycle begins when the chamber is filled with septage from the domestic septic tank, at which point the MBBR carriers are introduced, and the aerator is engaged for a three-to-four-hour period. To eliminate the risk of backflow during treatment, a control valve is positioned between the septic tank and the media chamber, with an optional siphon tube available to streamline septage conveyance.

Following the MBBR treatment phase within the media chamber, the septage is transferred to the secondary water drum, which functions as the filtration chamber. Inside this unit, the septage undergoes rapid filtration through granular activated carbon, completing the process within minutes. An inline control valve is positioned between the filtration chamber and the discharge faucet to prevent premature or unregulated fluid flow. Once the brief filtration cycle is complete, the control valve is opened, allowing the treated septage to flow to the faucet where it is collected in sample bottles.

To determine the total dissolved solids (TDS), an initial sample is immediately transferred into a 200 ml beaker, and the measurement is recorded using a TDS meter. Following this, a set of three samples—labeled A, B, and C—is collected in plastic reagent bottles to determine the initial dissolved oxygen DO levels via a Dissolved Oxygen Analyzer. A final set of three replicate samples (also labeled A, B, and C) is gathered to evaluate the 5-day biochemical oxygen demand or BOD_5. To suppress solar penetration and prevent photosynthetic activity, these final samples are incubated in total darkness at 20°C for five days prior to recording their final DO readings.

Upon completing the five-day incubation period, the samples are analyzed to obtain their final dissolved oxygen DO levels. The biochemical oxygen demand, BOD, value for each individual sample (A, B, and C) is determined by calculating the difference between its initial and final DO measurements.

Subsequently, the resulting BOD and total dissolved solids TDS data are compared against the regulatory thresholds established in DAO-2016-08, as detailed in Table 1 (Comparison of Values achieved and DAO–2016–08).

As presented in Table 1, the septage treated by the SBFD achieved a total dissolved solids (TDS) level of 383 ppm, which comfortably satisfies the 500-ppm maximum threshold mandated by Section 4.0 (f) of DAO-2016-08. Additionally, the table demonstrates that the post-treatment biochemical oxygen demand BOD concentrations fell below the limits outlined in Table 10 of DAO-2016-08 for Class C, D, SC, and SD water bodies under the high-strength influent BOD ≥ 3,000 mg/L classification.

Due to a research constraint where raw influent from the septic tank was not quantified prior to using the SBFD, Table 10 of DAO-2016-08 was adopted as the baseline for performance evaluation. Under standard conditions outside of this data gap, Table 9 of DAO-2016-08 serves as the conventional benchmark for evaluating mandatory BOD parameters.

Ultimately, based on the final comparative analysis of both TDS and BOD levels, the treated effluent safely complies with the requirements for environmental discharge into the ground or local waterways.

7. GATHERING OF DATA

7.1. Device Technical Evaluation

The technical evaluation of the Septage Biofilter Device (SBFD) was executed at two locations: the Iloilo Science and Technology University (ISAT U) in Iloilo City on April 19, 2024, and the Environmental Management Bureau (EMB) in Bacolod City on April 25, 2024. The evaluating panel comprised three experts from ISAT U and two from the EMB, all possessing specialized expertise in plumbing systems and the regulatory standards of DAO 2016-08. As a bureau operating under the Department of Environment and Natural Resources (DENR), the EMB is legally mandated by Executive Order (EO) 192 to deliver research and laboratory services, alongside serving as the secretariat for adjudicating pollution cases. Ultimately, the SBFD successfully passed this rigorous evaluation, meeting all criteria regarding industry standards, safety mechanisms, environmental sustainability, and its objective-based engineering design.

7.2. Device Performance Evaluation

The primary objective of this study is centered on evaluating the water quality of the treated septage, focusing specifically on achieving compliant total dissolved solids (TDS) and biochemical oxygen demand (BOD) levels to verify its suitability for environmental discharge. To accomplish these parameters, the treatment methodology employed a dual-stage process consisting of media-based biofilm treatment and activated carbon filtration.

Following a four-hour treatment cycle with a Moving Bed Biofilm Reactor (MBBR) in the primary chamber, the septage was transferred to the filtration chamber. This stage utilized activated carbon as a filter medium, processing the fluid within minutes, after which sample collection was immediately initiated. A single sample analyzed via a TDS meter yielded a total dissolved solids level of 383 ppm. Concurrently, a DO analyzer was used to record initial dissolved oxygen levels from three distinct samples (labeled A, B, and C), resulting in baseline readings of 4.3 mg/L, 2.8 mg/L, and 3.4 mg/L, respectively. To determine biochemical oxygen demand, a final set of three identically labeled samples was collected in amber or dark-colored bottles and incubated at 20°C in total darkness. As noted by Blankenship, R. E. (2021) this light deprivation is essential to suppress photosynthetic activity, a process in which light energy is captured to synthesize oxygen and organic compounds from water, carbon dioxide, and minerals.

Oxygen is measured in water as dissolved oxygen DO. Natural processes like animal breathing, the decaying of organic matter, and various chemical reactions constantly consume this oxygen. According to Mocuba (2010), if oxygen consumption exceeds the amount being produced, DO levels will fall. As a result, sensitive aquatic organisms may abandon the habitat, become physically weakened, or die.
The five-day storage of three samples in total darkness or incubated at 20°C defines the BOD protocol, a method used to quantify biochemical oxygen demand BOD. This metric reflects the volume of organic material biodegradable by aquatic organisms, thereby serving as an indirect indicator of organic water pollution. Mocuba (2010).

Following the five-day incubation window, final dissolved oxygen DO levels were recorded at 1.2 mg/L, 0.1 mg/L, and 2.0 mg/L for Samples A, B, and C, respectively. By calculating the difference between the baseline and final DO measurements, individual BOD values were determined: Sample A yielded 3.1 mg/L, Sample B yielded 2.7 mg/L, and Sample C yielded 1.4 mg/L. Given a total dissolved solid, TDS concentration of 383 ppm alongside these compliant BOD outcomes, the treated septage effluent is verified as fit for final environmental disposal.

7.3. Instrumentation and Data Gathering

The target respondents selected for this study comprise household owners, as the system treats their domestic septage immediately at the outlet of their residential septic tanks.

Septage from residential homes is the description of the sample to be treated using the septage biofilter device.

This study utilizes the regulatory framework of DAO-2016-08 as the baseline to evaluate the post-treatment condition of the septage processed by the biofilter device. Specifically, total dissolved solids (TDS) and biochemical oxygen demand (BOD) metrics serve as the primary criteria to determine whether the treated effluent qualifies for safe environmental disposal into the ground or local waterways.

Figure 10. Section 4.0 (f) of DAO – 2016 – 08.

or predominantly one kind of economic activity at a single physical location. This includes industrial, commercial, and institutional establishments.

f) **"Freshwater"** means water containing less than 500 parts per million dissolved common salt, sodium chloride, such as that in groundwater, rivers, ponds and lakes.

In Figure 7 espoused Section 4.0 (f) Definition of Terms of DAO – 2016 – 08 states that Freshwater means water containing less than 500 parts per million (ppm) dissolved common salt, sodium chloride, such as ground water, rivers, ponds, and lakes.

Measuring total dissolved solids TDS is a standard method used to evaluate water quality, as it quantifies the concentration of impurities and dictates the level of purification required to remove them. Consequently, elevated TDS concentrations reflect greater water contamination, whereas perfectly pure water contains zero dissolved solids. These dissolved components originate from a variety of sources, including industrial wastewater, natural formations, urban runoff, domestic sewage, and the chemical agents used during extensive water treatment processes. Without proper filtration prior to residential distribution, consuming water with high TDS levels poses significant risks to human health. Pushpalatha, N., Sreeja, et.al. (2022).

The septage treated with the SBFD achieved a TDS value of 383 ppm, which easily satisfies the 500-ppm regulatory limit mandated by Section 4.0 (f) of DAO-2016-08. Consequently, the water quality of this processed effluent meets all requirements for final disposal.

Figure 8 . Table 1 of DAO – 2016 – 08.

SECTION 5.0 Classification of Water Bodies. For purposes of maintaining water quality according to its intended beneficial usage, the following classification of water bodies shall be adopted (see Tables 1-2).

Table 1. Water Body Classification and Usage of Freshwater

Classification	Intended Beneficial Use
Class AA	Public Water Supply Class I – Intended primarily for waters having watersheds, which are uninhabited and/or otherwise declared as protected areas, and which require only approved disinfection to meet the latest PNSDW
Class A	Public Water Supply Class II – Intended as sources of water supply requiring conventional treatment (coagulation, sedimentation, filtration and disinfection) to meet the latest PNSDW
Class B	Recreational Water Class I – Intended for primary contact recreation (bathing, swimming, etc.)
Class C	1. Fishery Water for the propagation and growth of fish and other aquatic resources 2. Recreational Water Class II – For boating, fishing, or similar activities 3. For agriculture, irrigation, and livestock watering
Class D	Navigable waters

Note: For unclassified water bodies, classification shall be based on the beneficial use as determined by the Environmental Management Bureau (EMB).

In Figure 8 shown the classification of water bodies concerning different classes of bodies of water and its usefulness under the freshwater category.

Figure 9, Table 2 of DAO – 2016 – 08.

Table 2. Water Body Classification and Usage of Marine Waters

Classification	Intended Beneficial Use
Class SA	1. Protected Waters – Waters designated as national or local marine parks, reserves, sanctuaries, and other areas established by law (Presidential Proclamation 1801 and other existing laws), and/or declared as such by appropriate government agency, LGUs, etc. 2. Fishery Water Class I – Suitable for shellfish harvesting for direct human consumption
Class SB	1. Fishery Water Class II – Waters suitable for commercial propagation of shellfish and intended as spawning areas for milkfish (*Chanos chanos*) and similar species 2. Tourist Zones – For ecotourism and recreational activities 3. Recreational Water Class I – Intended for primary contact recreation (bathing, swimming, skin diving, etc.)

In Figure 9, referring to Table 2, water body classification and usage of marine waters also described the different classes of bodies of water and its usefulness under the marine water category.

Figure 10. Continuation of Table 2 on Classification.

Classification	Intended Beneficial Use
Class SC	1. Fishery Water Class III – For the propagation and growth of fish and other aquatic resources and intended for commercial and sustenance fishing 2. Recreational Water Class II – For boating, fishing, or similar activities 3. Marshy and/or mangrove areas declared as fish and wildlife sanctuaries
Class SD	Navigable waters

Note: For unclassified water bodies, classification shall be based on the beneficial use as determined by EMB.

In Figure 10 shown the water body classification and usage of marine waters on Table 2 the description of the class of body of water and its usefulness under the marine water category.

Figure 11. Table 3 of Dao – 2016 – 08.

Table 3. Water Quality Guidelines for Primary Parameters

Parameter	Unit	Water Body Classification								
		AA	A	B	C	D	SA	SB	SC	SD
BOD	mg/L	1	3	5	7	15	n/a	n/a	n/a	n/a
Chloride	mg/L	250	250	250	350	400	n/a	n/a	n/a	n/a
Color	TCU	5	50	50	75	150	5	50	75	150
Dissolved Oxygen[a] (Minimum)	mg/L	5	5	5	5	2	6	6	5	2
Fecal Coliform	MPN/100mL	<1.1	<1.1	100	200	400	<1.1	100	200	400
Nitrate as NO_3-N	mg/L	7	7	7	7	15	10	10	10	15
pH (Range)		6.5-8.5	6.5-8.5	6.5-8.5	6.5-9.0	6.0-9.0	7.0-8.5	7.0-8.5	6.5-8.5	6.0-9.0
Phosphate	mg/L	<0.003	0.5	0.5	0.5	5	0.1	0.5	0.5	5
Temperature[b]	°C	26-30	26-30	26-30	25-31	25-32	26-30	26-30	25-31	25-32
Total Suspended Solids	mg/L	25	50	65	80	110	25	50	80	110

Notes:
MPN/100mL – Most Probable Number per 100 milliliter
n/a – Not Applicable
TCU – True Color Unit
(a) Samples shall be taken from 9:00 AM to 4:00 PM.
(b) The natural background temperature as determined by EMB shall prevail if the temperature is lower or higher than the WQG; provided that the maximum increase is only up to 10 percent and that it will not cause any risk to human health and the environment.

As illustrated in Figure 11, the primary parameters outlined in Table 2 represent the mandatory baseline water quality metrics that must be monitored for all fresh and marine water bodies, pursuant to Section 6.1 of the DAO-2016-08 Guidelines for Water Quality.

Evaluated against these definitive Table 2 standards, the post-treatment biochemical oxygen demand BOD values of 3.1 mg/L, 2.7 mg/L, and 1.4 mg/L comfortably comply with the requirements designated for Class B through Class D water bodies. Consequently, the treated effluent is officially certified as fit for environmental disposal.

Figure 12. Effluent Standards for BOD for Strong Wastewater.

7.2 Effluent Standards. Consistent with the goal of maintaining the quality of water bodies based on their intended beneficial usages, Table 9 shall be enforced and complied with at all times.

7.3 Effluent Standards for BOD for Strong Wastewater. For establishments with influent BOD equal to or greater than 3,000 mg/L and the receiving water body is Class C, D, SC, or SD, the applicable effluent standards in Table 10 shall at all times be enforced and complied with.

For parameters other than BOD, Table 9 shall apply.

Figure 12 details the legal effluent benchmarks and BOD rules reserved for strong wastewater. Since the actual values of the incoming septic waste were not recorded before treatment, the researcher relied on Section 7.3 of DAO-2016-08 to treat the influent as strong wastewater. Because the waste comes directly from home septic tanks, the researcher assumed its baseline concentration fits the high-strength tier of BOD ≥ 3,000 mg/L, making the strong wastewater table of DAO-2016-08 the correct standard to adopt for this study.

Figure 13. **Table 10 of DAO – 2016 – 08**

Table 10. Effluent Standards for BOD Applicable to Establishments with Influent BOD of ≥ 3,000 mg/L

Influent BOD (mg/L)	Units	Class C	Class D	Class SC	Class SD
3,000 to <6,500	mg/L	100	150	100	150
6,500 to <10,000	mg/L	200	300	200	300
10,000 to 30,000	mg/L	600	1,000	600	1,000
>30,000	mg/L	900	1,500	900	1,500

As illustrated in Figure 13, the post-treatment biochemical oxygen demand BOD concentrations reached 3.1 mg/L, 2.7 mg/L, and 1.4 mg/L. These resulting values confirm that the processed effluent successfully complies with safety standards, rendering it fully fit for environmental disposal.

7.4. Parameters for Analysis

To ensure the safe and legally compliant discharge of treated effluent, the device underwent a comprehensive assessment by specialists in professional plumbing and environmental jurisprudence. This evaluation verified that the system satisfies the rigorous regulatory benchmarks established under Republic Act (RA) 9275, otherwise known as the Philippine Clean Water Act of 2004.

The evaluation conducted on the study of the Septage Biofilter Device prototype utilized the following parameters:

This treatment process aimed to transform heavily contaminated septage into clean water that is safe for final environmental discharge. According to the regulatory definitions in Section 4.0 (f) of DAO-2016-08, water is officially classified as freshwater if it contains less than 500 parts per million of dissolved sodium chloride (common salt). Achieving a TDS reading under this 500-ppm threshold ensures that the processed effluent mirrors the water quality typically seen in natural lakes, rivers, ponds, and groundwater.

Table 10 outlines the specific General Effluent Standards used to determine if treated wastewater is safe for environmental release. The regulations mandate that when the incoming waste is strong, it has an initial BOD value of 3,000 mg/L or higher—the treated effluent must not exceed the maximum allowable thresholds listed in Table 10 before it can be legally discharged into a creek or the ground.

In this context, "water condition" denotes the immediate physical and chemical state of wastewater. Specifically, this study evaluates the quality of domestic septage following its processing through the Septage Biofilter Device (SBFD). Before this treated effluent can be lawfully and safely discharged into the ground or local creeks, it must satisfy a defined set of environmental quality criteria.

Biochemical Oxygen Demand BOD serves as an indicator of organic water pollution, where higher readings directly correlate with increased contamination. Conversely, dissolved oxygen DO levels reflect water health and cleanliness; elevated DO concentrations signify that water is safe for human uses, such as drinking, bathing, or recreational activities. In short, DO and BOD share an inverse relationship: high DO indicates clean water with low BOD demands, whereas high BOD indicates heavily polluted water where the available DO has been severely depleted.

6. Results And Discussion

After the design and fabrication were done, determination of TDS, BOD, performance of the SBFD and maintenance of the device were evaluated. The results. A total of 7 samples were taken during the treatment of the domestic waste from the septic tank.

Table 1. Comparison of the Values Achieved using the SBFD and DAO – 2016 – 08

Samples	DO Initial, mg/L	DO Final, mg/L	BOD, mg/L	BOD, mg/L ≥ 3000 mg/L (Table 10, DAO – 2016 – 08)			
				Class C	Class D	Class SC	Class SD
A	4.3	1.2	3.1	100	150	100	150
B	2.8	0.1	2.7	100	150	100	150
C	3.4	2.0	1.4	100	150	100	150
Total Dissolved Solids, ppm	383			DAO – 2016 – 08 Section 4.0 (f) ≤ 500 ppm			

Table 1 indicated the comparison of the results gathered after the septage went through the treatment using the septage biofilter device and the values found in Section 4.0 (f) and Table 10 of DAO – 2016 – 08.

The domestic waste that went through the treatment process using the septage biofilter device was no recorded, hence the researcher utilized DAO 2016 – 08 Section 7.3 Effluent Standards for Influent BOD for Strong Wastewater under the category of BOD ≤ 3, 000 mg/L.

The BOD results after the treatment showed that these met the criteria set forth in Table 10 of DAO – 2016 – 08 and is fit for disposal to the ground or creek.

Table 2. Overall Observations of Parameters.

Parameters	Samples	Remarks
Total Dissolved Solids, ppm	1 beaker at 200 ml	The water sample became slightly cleared. Value was a little lower compared to the standard value.
Bio – Oxygen Demand, mg/L	6 bottles at 250 ml each	Values achieved were lower than standard values for the category applied.

Seven samples of the treated septage were taken for TDS and BOD parameters. One sample was taken immediately for the TDS reading by using the TDS meter and the result was 383 ppm. This value was slightly lower than the standard value of 500 ppm.

Three samples labeled as A, B, and C were taken for the DO initial readings. The results were 4.3 mg/L, 2.8 mg/L, and 3.4 mg/L for A, B, and C, respectively. The tool used in getting the readings was the Dissolved Oxygen Analyzer.

Another three samples labeled A, B, and C were kept for five days. These were stored in a dark place or incubated at 20°C. This is to limit the sunlight penetration to avoid photosynthesis. This is because photosynthesis captures light and uses it to convert water, carbon dioxide, and minerals into oxygen and other minerals. Britannica (2024).

The three samples of the treated septage were placed inside in reagent white bottles while the other three samples were placed in dark bottles or amber bottles.

After five days the samples that were labeled A, B, and C and using the Dissolved Oxygen Analyzer, the final readings were 1.2 mg/L, 0.1 mg/L, and 2.0 mg/L, respectively. The difference between the initial and final readings became the value of the BOD. BOD values were 3.1 mg/L, 2.7 mg/L, and 1.4 mg/L for samples A, B, and C, respectively.

The findings indicate that the Septage Biofilter Device (SBFD) is highly capable of reducing both total dissolved solids TDS and biochemical oxygen demand BOD concentrations during treatment. Furthermore, the resulting effluent quality successfully complies with the environmental regulatory standards established under DAO-2016-08.

6. SUMMARY OF FINDINGS

The operational performance metrics of the septage biofilter device were quantified utilizing a total dissolved solids TDS meter and a dissolved oxygen DO analyzer. The post-treatment TDS concentration reached 383 ppm, comfortably complying with the 500-ppm maximum disposal threshold mandated by Section 4.0 (f) of DAO-2016-08. Concurrently, the biochemical oxygen demand BOD values for Samples A, B, and C were recorded at 3.1 mg/L, 2.7 mg/L, and 1.4 mg/L, respectively. When evaluated under the high-strength influent tier BOD $\geq$ 3,000 mg/L, these levels sit significantly below the maximum allowable Table 10 limits of 100 mg/L for Class C, 150 mg/L for Class D, 100 mg/L for Class SC, and 150 mg/L for Class SD. Consequently, both parameters confirm that the effluent is fully fit for environmental disposal.

7. Conclusions

The newly developed and fabricated Septage Biofilter Device (SBFD) successfully transforms raw septage from a highly contaminated state into compliant effluent based on the regulatory metrics of DAO-2016-08. Specifically, the system reduces total dissolved solids TDS and biochemical oxygen demand BOD values to levels that safely qualify the treated wastewater for legal disposal into the ground or local creeks.

8. RECOMMENDATIONS

This device offers a viable interim solution for Local Government Units LGUs lacking the financial resources to construct municipal wastewater treatment facilities, enabling them to mandate that residential households adopt this decentralized technology to uphold the Clean Water Act. However, further research is required to optimize the system, as additional minerals and ions must be targeted and reduced before the treated wastewater can safely meet the standards required for human consumption.

12. CONFLICT OF INTEREST

The authors state that the sponsor played no role in designing the study, developing the system, interpreting the results, writing the paper, or choosing to submit it for publication. They also declare that this institutional funding does not create any conflict of interest.

13. DECLARATION OF AI USE

The authors declare that AI tools—including ChatGPT, Grammarly Plagiarism Pro, and QuillBot Premium—were used solely to improve language, check grammar, paraphrase text, and organize the document. These technologies were never used to create, change, or falsify any research data, findings, analyses, or conclusions. The authors personally examined, verified, and authorized all interpretations and final content, taking full responsibility for the study's overall integrity, accuracy, and originality.

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