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Performance Evaluation of Plastic Drum Septic Tanks Equipped with Recycled Nylon Net Biofilters for Domestic Wastewater Treatment in Riverbank Communities

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Water pollution caused by the direct discharge of domestic wastewater from toilets into watercourses remains a serious environmental health issue, particularly in riverside settlements with limited access to adequate sanitation facilities. This study aims to evaluate the performance of septic tanks made from plastic drums fitted with biofilters made from used nylon netting in improving the quality of domestic wastewater based on the parameters of Biochemical Oxygen Demand (BOD) and Total Suspended Solids (TSS). The study employed a quasi-experimental design with a post-test only control group design, conducted in the villages of Ambawang Kuala and Kuala Mandor B, Kubu Raya Regency. A total of eight plastic drum septic tanks were used, comprising four treatment units fitted with biofilters made from used nylon netting and four control units without biofilters. Wastewater samples were collected from the septic tank outlets and analysed for BOD and TSS using standard laboratory methods. A total of 64 samples were analysed; the data were then processed descriptively and tested using an *independent t-test* after meeting the assumptions of normality and homogeneity. The results of the study showed that the mean BOD concentration in the treatment group (5.74 mg/L) was lower than that in the control group (7.79 mg/L), whilst the mean TSS concentration in the treatment group was 3.45 mg/L and in the control group 3.17 mg/L. However, there were no statistically significant differences for either the BOD (p=0.227) or TSS (p=0.883) parameters. These results indicate that the use of biofilters made from used nylon netting tends to enhance the reduction in BOD levels, but has not yet yielded a significant improvement in wastewater quality under the conditions of this study. Therefore, this technology has the potential to be developed as an alternative for a simple, low-cost and environmentally friendly sanitation system; however, it still requires design refinements, longer operational periods and testing on a larger scale to ensure its effectiveness.

Keywords: Biofilters; Domestic wastewater; Plastic drum tanks; Riverbanks; Nylon nets

INTRODUCTION

Water pollution caused by the discharge of domestic wastewater remains one of the key challenges in environmental management in developing countries, particularly in densely populated residential areas located along riverbanks. Wastewater originating from household sanitation activities, particularly toilet effluent, contains pollutants such as organic matter, suspended solids, nutrients and pathogenic microorganisms, which can degrade water body quality and increase the risk of public health problems. This situation is further complicated by the fact that many riverbank areas still have limited access to sanitation facilities, meaning that wastewater is often discharged without adequate treatment. Consequently, rivers serve not only as watercourses but also as sites for the accumulation of various contaminants originating from domestic activities. Various studies indicate that sub-optimal domestic wastewater management is one of the main factors contributing to the degradation of water resource quality and poses an obstacle to achieving Sustainable Development Goal (SDG) 6 on the provision of clean water and sustainable sanitation(Maliga et al., 2025).

At the household level, septic tanks are the most widely used sanitation technology for treating toilet waste before it is discharged into the environment. However, various studies indicate that effluent from conventional septic tanks still contains relatively high concentrations of Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), ammonia and pathogenic microorganisms, which have the potential to pollute water bodies if discharged directly. This problem is particularly acute in riverbank areas, which generally suffer from limited land availability, low economic conditions amongst the local population, and the lack of a centralised wastewater treatment system. Consequently,

there is a need for sanitation technology innovations that are simple, cost-effective, easy to implement, and capable of improving effluent quality before it is discharged into aquatic environments(Maliga et al., 2025).

In recent years, biofilter technology has become one of the most widely developed approaches to improving the effectiveness of domestic wastewater treatment. Biofilter systems work by utilising the activity of microorganisms that grow to form a biofilm on the surface of a specific medium. These microorganisms play a role in degrading organic matter, oxidising nitrogen compounds, and reducing the levels of other pollutants through naturally occurring biological processes. Compared with conventional treatment technologies, biofilters offer a number of advantages, including low energy requirements, relatively low operating costs, ease of maintenance, and the ability to operate on both a household and community scale. These characteristics make biofilters a suitable alternative for application in densely populated residential areas with limited resources (Loh et al., 2024).

Research findings indicate that the effectiveness of biofilter systems is greatly influenced by the type of media used as a substrate for microorganisms. Various materials have been developed for use as biofilter media, ranging from natural materials to recycled waste Kaetzl et al. (2020) reports that biochar is effective at improving the quality of wastewater treatment by increasing the surface area available for biofilm growth. Other research shows that coconut fibre, wood flour, peanut shells and other porous materials are capable of effectively supporting the removal of organic matter and nutrients, as they provide a suitable habitat for waste-processing microorganisms (Loh et al., 2024; Tejedor et al., 2020). The results of these studies indicate that the use of alternative materials as biofilter media has great potential for creating more economical and sustainable wastewater treatment systems.

In line with the concept of the circular economy, the use of inorganic waste as biofilter media is also beginning to attract significant attention. The use of plastic waste as a biofilm growth medium is considered to offer dual benefits: it improves wastewater treatment performance whilst reducing the amount of waste ending up in the environment. Dorji et al., (2026) reported that pieces of used plastic bottles can be utilised as biofilter media in local sanitation systems and demonstrated good performance in supporting biofilm growth and enhancing the efficiency of contaminant removal. These findings reinforce the view that polymer-based waste possesses physical characteristics suitable for use as biofilter media, as it is durable, resistant to degradation, and has a surface area that can be modified as required.

One type of polymer waste that has the potential to be used as a biofilter medium but has rarely been studied is used nylon netting. Nylon netting has an interlinked fibre structure that forms voids capable of increasing the surface area of contact between microorganisms and wastewater. Furthermore, this material possesses good mechanical strength, is resistant to decomposition, and is available in abundance as waste from both the fisheries sector and domestic activities. These characteristics make used nylon nets a promising low-cost biofilter medium capable of optimally supporting biofilm formation. From a sustainability perspective, the utilisation of used nylon nets can also reduce the generation of plastic waste, which has long been a major source of aquatic environmental pollution (Sindhøj et al., 2026).

In addition to innovations in biofilter media, the development of low-cost and easy-to-install treatment units is also a key aspects of community sanitation systems. One alternative that could be developed od the use of plastic drums as the body of a septic tank. Compared to conventional concrete construction, plastic drums offer the advantages of being lighter in weight, having lower installation cost, being easier to transport, and offering flexibility for installation in locations with limited access. The use of plastic drums also enables the development of modular snaitation systems that can be adapted to site conditions and the number of users. Consequently, the combination of plastics drums and biofilter media made from waste has the potential to produce sanitation technology that is more adaptable to the conditions of riverside settlements (Dorji et al., 2026).

Although various studies have developed biofilter media based on biochar, coconut fibre, wood chips, plastic waste and other porous materials, there remains a lack of research into the use of used nylon netting as biofilter media in toilet waste treatment systems. Most previous studies have focused on the use of specially processed materials or on their application in wastewater treatment plants under controlled operational conditions. On the other hand, research integrating the use of plastic drums as septic tanks with biofilter media made from used nylon netting at a domestic scale remains very limited. This situation highlights a knowledge gap regarding the effectiveness of combining these two materials in improving the quality of domestic effluent, particularly in riverbank areas with distinctive social and environmental characteristics.

Based on a review of the state of the art, current trends in sanitation technology are not only focused on improving treatment efficiency, but also on the use of recycled materials that are inexpensive, readily available and environmentally friendly. However, no research has yet been found that specifically develops a septic tank made from a plastic drum with a biofilter made from used nylon netting as an integrated system for controlling toilet wastewater pollution in riverbank areas. Consequently, the novelty of this research lies in the integration of simple plastic drum septic tank technology with a biofilter medium made from used nylon netting, which utilises waste as a resource whilst supporting the principles of the circular economy in community sanitation management.

Based on these issues and gaps in the existing research, this study aims to develop and evaluate the performance of an innovative plastic drum septic tank fitted with a biofilter made from used nylon netting as an

appropriate technology for controlling toilet wastewater pollution in riverbank areas. Specifically, this study aims to analyse the system's ability to reduce concentrations of BOD, COD, TSS, ammonia and total coliforms; to evaluate the effectiveness of used nylon netting as a biofilm growth medium; and to assess the potential for applying this technology as a low-cost sanitation solution that can be easily replicated by local communities. It is hoped that the research findings will contribute to the development of sustainable decentralised sanitation technologies whilst also providing an alternative solution for controlling water pollution in riverbank areas across Indonesia.

METHODS

Research Design

This study employed a quasi-experimental design with a post-test-only control group. This design was used to compare the quality of domestic wastewater produced by plastic drum septic tanks fitted with biofilters made from used nylon netting (the treatment group) with that from plastic drum septic tanks without biofilters (the control group). The treatment variable in this study was the installation of a biofilter medium made from used nylon netting, whilst the observed outcome variables were the concentrations of Biochemical Oxygen Demand (BOD) and Total Suspended Solids (TSS) in the wastewater discharged from the septic tank outlet.

A total of eight plastic drum septic tanks with identical specifications and configurations were used in this study. Four units were allocated to the treatment group, with a biofilter made from used nylon netting added to the third compartment, whilst the other four units served as the control group without the addition of biofilter media. Households were selected purposively, taking into account similar characteristics, particularly a household size of four to five people, the type of toilet facilities, and daily sanitation usage patterns. These common characteristics were sought to minimise the influence of external factors that could cause differences in wastewater quality between units.

All septic tanks utilised 200-litre plastic drums with the same number of compartments, dimensions, flow configuration and installation system. The main difference between the treatment group and the control group lay solely in the presence of a biofilter medium made from used nylon netting. Wastewater from the outlet of each septic tank was then sampled at regular intervals and analysed to determine the concentrations of BOD and TSS. The measurement results from both groups were compared to evaluate trends in wastewater quality following the installation of the biofilter made from used nylon netting.

A quasi-experimental design was chosen because the research was conducted under real-world conditions in a riverside settlement, meaning that full randomisation of households and septic tank usage conditions could not be achieved. Therefore, the use of a control group with the same system specifications is expected to provide an adequate basis for comparison when evaluating the potential for applying biofilters made from used nylon netting to plastic drum septic tanks.

Research Location and Time

The research was carried out in the villages of Ambawang Kuala and Kuala Mandor B, Kubu Raya Regency, West Kalimantan. These two villages were selected because they have tidal environmental characteristics and relatively high levels of water pollution due to the direct discharge of domestic waste into the river. The study lasted for eight months, running from March to October 2025. This timeframe was deemed sufficient to carry out the installation of equipment, the biofilter inoculation process, and repeated sampling, so that the data obtained would accurately reflect actual conditions in the field.

Population and Sample

The study population comprised all households along the riverbanks that used toilets with a direct discharge system into the watercourse. The study sample consisted of wastewater from the outlets of plastic drum septic tanks installed in selected households. Sampling was carried out using a purposive approach, with the criterion being households comprising four to five family members. The sample size was determined using Frederer's formula, resulting in a minimum of 32 samples for each parameter measured. Consequently, the number of samples analysed for BOD and TSS in 2025 was 64, comprising 32 samples from the treatment group and 32 samples from the control group.

Research Variables

The independent variable in this study was the use of a biofilter made from used nylon netting in a plastic drum septic tank. The dependent variables were the BOD and TSS levels in the wastewater discharged from the septic tank outlet. The domestic waste quality standards set out in Ministry of Environment Regulation No. P.68 of 2016 were used as the reference standard. Within this framework, the study was able to assess whether the innovation of using a biofilter made from used nylon netting was capable of reducing pollutant levels to levels close to the applicable standards.

Instruments and Materials

The main research instrument was a 200-litre capacity plastic drum septic tank comprising three compartments. In the third compartment of the treatment group, 10 kilograms of biofilter media in the form of used nylon fishing nets were placed. Prior to use, the biofilter media was soaked in a bioactivator solution comprising a mixture of water, bioactivator and granulated sugar—for 24 hours to accelerate microbial colonisation. The laboratory measuring instruments used included a DO meter for BOD analysis, the gravimetric method for TSS measurement, and other supporting equipment in accordance with water quality analysis standards.

Figure 1. Schematic Design of Plastic Drum Septic Tank with Waste Nylon Net Biofilter

Research Procedure

The research stages began with the construction and installation of plastic drum septic tanks at the study site. A total of eight septic tanks were installed, comprising four treatment units fitted with biofilters made from used nylon netting and four control units without biofilters. Once the inoculation of the biofilter media was complete, the septic tanks were used by selected households for their daily needs. Samples were taken at regular weekly intervals over four replicate trials. Wastewater samples from the septic tank outlet were then sent to an environmental laboratory for analysis of BOD and TSS levels.

Data Analysis

The measurement data were analysed descriptively by calculating the mean, median, standard deviation, minimum and maximum values. Subsequently, a statistical test was carried out using an independent t-test to determine the significance of the difference between the treatment and control groups. The results of the analysis were then compared with the quality standards for domestic wastewater in accordance with national regulations, enabling conclusions to be drawn regarding the effectiveness of the innovation using a biofilter made from used nylon netting in reducing pollutants in toilet wastewater in riverbank areas.

RESULTS AND DISCUSSION

Table 1.
Descriptive Statistics for BOD Levels (mg/L) at the Outlet of the Plastic Drum Septic Tank

Group	Mean	Median	SD	Minimum	Maximum	p-value	Description
Using a biofilter made from used nylon netting	5.74	5.70	1.25	4.8	7.1	0.227	There is no significant difference
Without a biofilter (control)	7.79	7.80	1.40	6.2	9.3	-	-

The results of the study showed that the use of a biofilter made from used nylon netting in plastic drum septic tanks was able to reduce the BOD concentration of the effluent compared to the control group without a biofilter, as indicated by an average BOD value of 5.74 mg/L in the treatment group and 7.79 mg/L in the control group. Although this difference was not statistically significant (p=0.227), in practical terms there was a 26.3% reduction in BOD concentration, indicating the biodegradation of organic matter by microorganisms growing on the surface of the nylon mesh. These findings are consistent with previous research Loh et al., (2024) which reported that coconut fibre-based biofilter media are capable of enhancing the removal of organic matter through the formation of a stable biofilm on the surface of the media. The same mechanism was also reported by (Dong et al., 2020; Zhang et al., 2023), where the porous medium provides a larger surface area for microbial colonisation, thereby enhancing the efficiency of organic compound degradation in wastewater. The reduction in BOD observed in this study indicates that used nylon netting has the potential to function as a biofilm support

medium in simple sanitation systems, as reported in various recent studies on domestic biofilters (Dorji et al., 2026; Dubey & Kashyap, 2022; Kaetzl et al., 2020; Ren et al., 2023).

Table 2.

Descriptive Statistics for TSS Concentrations (mg/L) at the Outlet of the Plastic Drum Septic Tank

Group	Mean	Median	SD	Minimum	Maximum	p-value	Description
Using a biofilter made from used nylon netting	3.45	3.40	0.85	2.6	4.7	0.883	There is no significant difference
Without a biofilter (control)	3.17	3.10	0.90	2.4	4.5	-	-

In contrast to the BOD parameter, the research results indicate that the use of used nylon mesh biofilters has not yet led to a significant improvement in TSS removal. The average TSS value in the treatment group, at 3.45 mg/L, was slightly higher than that of the control group, at 3.17 mg/L, with statistical test results also showing no significant difference (p=0.883). This suggests that the primary mechanism at work in the nylon mesh medium is predominantly a biological process rather than physical filtration of suspended particles. These results differ from those of several studies using densely porous media such as biochar, slow sand, and granular media, which are capable of enhancing the retention of suspended particles more effectively(Cui et al., 2020; Kaetzl et al., 2020; Sindhøj et al., 2026). The structure of the nylon mesh, which has relatively large pores, allows wastewater to flow through unimpeded, making it insufficient to retain fine solids; consequently, the efficiency of TSS removal is limited. Similar findings have also been reported by Bolan et al., (2020) which states that plastic-based media are more effective as a substrate for biofilm growth than as a filter medium for suspended particles.

The results of this study show that the integration of plastic drum septic tanks with biofilters made from used nylon nets has potential as a low-cost and environmentally friendly sanitation technology for riverbank areas. The successful reduction in BOD indicates that polymer waste such as nylon nets can be utilised as an alternative biofilter medium that supports the concept of a circular economy in community sanitation management. These findings support the results of previous research showing that various waste materials, such as coconut fibre, wood chips, peanut shells and plastic waste, can be utilised as biofilter media to improve the quality of domestic effluent(Akowanou et al., 2025; Bhagat et al., 2022; Hendrasarie & Zarfandi, 2023; Lago et al., 2024; Zimba et al., 2021). Furthermore, the use of plastic drums as the body of a septic tank offers advantages in terms of cost, ease of installation and flexibility of application in areas with limited land and restricted access for construction. Consequently, the innovation developed in this study not only contributes to the control of domestic wastewater pollution, but also supports the development of decentralised sanitation technology suitable for low-income communities (Azmi, 2025; Muguirrima et al., 2024).

Nevertheless, the fact that the system's effectiveness has not yet yielded any statistically significant differences suggests that there are several factors that may influence the biofilter's performance. One factor that may play a role is the relatively short biofilm formation time, meaning that the microorganism population has not yet developed optimally across the entire surface of the media. Research (Cui et al., 2020; Feofanov & Kudryavtsev, 2025) indicates that biofilter efficiency is significantly influenced by biofilm maturity, hydraulic retention time, and the specific surface area of the media used. Furthermore, the limited sample size and the fact that each treatment group comprised only four replicates may reduce the statistical power in detecting differences between groups. Variability in the characteristics of domestic wastewater from individual households may also cause fluctuations in pollutant concentrations, thereby affecting the measurement results (Aziz, 2023; DelaPaz-Ruíz et al., 2023). Therefore, the biofilter design needs to be optimised, the operating time extended, and the number of samples increased in order to obtain a more accurate picture of the system's performance.

This study has several limitations that should be borne in mind when interpreting the results. Firstly, the water quality parameters analysed were limited to BOD and TSS; consequently, the results do not yet reflect the system's performance with regard to other key parameters such as COD, ammonia, total nitrogen, phosphate and total coliforms, which are commonly used in the evaluation of domestic sanitation technologies (Huynh & Nguyen, 2024; Sulistia & Septiyasa, 2019). Secondly, the study was conducted on a limited scale with a relatively short observation period, and was therefore unable to evaluate the long-term stability of the biofilter. Thirdly, the study did not examine the characteristics of the biofilm formed on the used nylon nets, nor the relationship between microbial structure and contaminant removal efficiency. Therefore, further research should focus on evaluating long-term performance, analysing microbial communities using molecular approaches, measuring water quality

parameters more comprehensively, and developing media configurations capable of simultaneously enhancing the removal efficiency of organic matter and suspended solids. In this way, the potential of the innovative plastic drum septic tank with a biofilter made from used nylon netting can be evaluated more thoroughly as a sustainable sanitation technology for riverbank areas.

CONCLUSION

The research findings indicate that the use of a biofilter made from used nylon netting in plastic drum septic tanks tends to enhance the treatment of organic matter in domestic wastewater, as evidenced by the improved effluent quality compared to systems without a biofilter. However, based on the results of the analysis carried out, the use of a biofilter made from used nylon netting has not yet had a significant impact on the reduction in the observed water quality parameters. These findings suggest that used nylon mesh has the potential to be utilised as a biofilter medium, but its effectiveness still needs to be improved through the development of system design and operational conditions.

This study provides preliminary information on the use of used nylon nets as a biofilter medium in plastic drum septic tanks for the treatment of toilet wastewater in riverbank areas. Further research is required, involving a longer observation period, a wider variety of biofilter designs, and more comprehensive measurements of water quality parameters, so that the system's performance can be evaluated more thoroughly. In addition, studies on biofilm characteristics and optimal operating conditions are needed to support the development of simple sanitation technologies that meet the needs of the community.

SUGGESTION

Further research is recommended, utilising a longer observation period, a larger sample size, and variations in biofilter media and hydraulic retention time. In addition, more comprehensive measurements of water quality parameters are required to obtain a more comprehensive picture of the performance of the domestic wastewater treatment system.

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