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Fiberglass Reinforced Plastic (FRP) Septic Tank as a Modern Alternative: A Comparative Study with Conventional Septic Tank

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Abstract *~ Domestic wastewater management in densely populated areas remains challenging because conventional concrete/steel septic tanks can crack or corrode, increasing leakage risk and potentially degrading groundwater quality. This study aims to compare conventional septic tanks with Fiberglass Reinforced Plastic (FRP) septic tanks and to develop an FRP septic tank concept that improves durability, installation practicality, and treatment performance for residential use. A qualitative comparative approach was applied through purposive selection of households/public facilities, in-depth interviews (users, technicians, manufacturers), direct observations of tank conditions and maintenance, and documentation; findings were reduced, categorized (material, efficiency, cost, environmental impact), and thematically interpreted. The study produced an FRP septic tank design concept developed using an Objective Tree, Function Structure, and Morphology Chart, resulting in planning criteria and conceptual drawings. The FRP concept emphasizes lightweight strength, corrosion/chemical resistance, and shape stability under soil loads, while incorporating multi-partition internal processing and media (bioballs) to support staged treatment using gravity flow. The proposed design can reduce leakage risk, simplify installation and maintenance, extend service life, and support more sustainable domestic waste management in space-limited urban neighborhoods. The novelty lies in a residential FRP septic tank concept that integrates three partitions, bioballs, and gravity-based flow without relying on pumps/motors, supported by a structured product-engineering design framework.*

Keywords *~ Septic Tank, Fiberglass Reinforced Plastic, Waste, Environment*

INTRODUCTION

Domestic waste management is a critical issue in many regions, particularly with rapid population growth and urbanization. In Indonesia, efficient and environmentally friendly waste disposal systems are essential to protect public health and environmental sustainability. However, conventional septic tanks made from iron and concrete often experience cracking and corrosion, which can lead to leakage and environmental pollution, particularly groundwater quality degradation (Yanggen & Born, 1990). Consequently, Fiberglass Reinforced Plastic (FRP) septic tanks have emerged as a promising alternative because FRP is generally characterized by high durability, lower weight, and corrosion resistance, which may reduce structural damage risk and extend service life (Maiti et al., 2022; Rafie et al., 2024; Sun et al., 2020).

From a product-engineering perspective, FRP septic tank development also allows more efficient and modular design approaches that can facilitate installation and

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maintenance processes (Kumari, 2018; NSF International, 2018). Nevertheless, the practical understanding of benefits, challenges, and best practices for FRP septic tanks in residential settings remains limited, indicating the need for deeper evaluation and clearer design justification (Kar & Gupta, 2023; Pryce et al., 2021).

A review of relevant patents such as Indonesia Patent No. IDP000095218 on bonding methods for attaching FRP materials to structures (Matsui et al., 2020) and China Patent No. CN 220926528U describing a fiberglass septic tank design that uses a motor-assisted mechanism to remove separated waste (Liu et al., 2024) suggests that prior designs do not explicitly propose a residential FRP septic tank using three partitions, incorporating bioballs, and relying on gravity-driven flow (without pumps or motors) through an inclined final partition prior to discharge. This gap supports the rationale for developing an FRP septic tank design that is structurally durable and operationally simple while strengthening treatment staging within the tank.

This article aims to provide deeper insight into the implementation and benefits of FRP septic tanks as an innovative solution for sustainable domestic waste management in residential environments. Specifically, the study aims to:

1. Compare conventional septic tanks and FRP septic tanks in terms of material-related performance, operational efficiency, maintenance implications, and environmental considerations (Kar & Gupta, 2023; Pryce et al., 2021); and
2. Propose an FRP septic tank concept that integrates three partitions and bioballs while utilizing gravity-driven flow (without pumps or motors), thereby addressing the design gap indicated by the patent review (Liu et al., 2024; Matsui et al., 2020).

Despite the growing adoption of Fiberglass Reinforced Plastic (FRP) in sanitation infrastructure, evidence-based guidance that translates FRP's material advantages into clear residential septic-tank design requirements and performance trade-offs (e.g., durability under soil loading, staged treatment efficiency, maintenance practicality, and groundwater-protection implications) remains limited in the Indonesian urban context (Kar & Gupta, 2023; Pryce et al., 2021; Sun et al., 2020). Moreover, a review of relevant patents indicates that existing FRP-related solutions either focus on structural bonding methods or employ motor/pump-assisted mechanisms and do not explicitly propose a residential FRP septic tank architecture that combines three partitions, bioballs, and

gravity-driven operation through an inclined final partition without pumps or motors (Liu et al., 2024; Matsui et al., 2020). To address this gap, this study contributes a qualitative comparative analysis of conventional versus FRP septic tanks and proposes a structured product-engineering design concept for a gravity-driven, three-partition FRP septic tank integrated with bioballs for improved residential wastewater management.

METHODS

This study uses a qualitative method with the aim of understanding in depth the differences in the use of conventional septic tanks (concrete/brick) and septic tanks made of Fiberglass Reinforced Plastic (FRP).

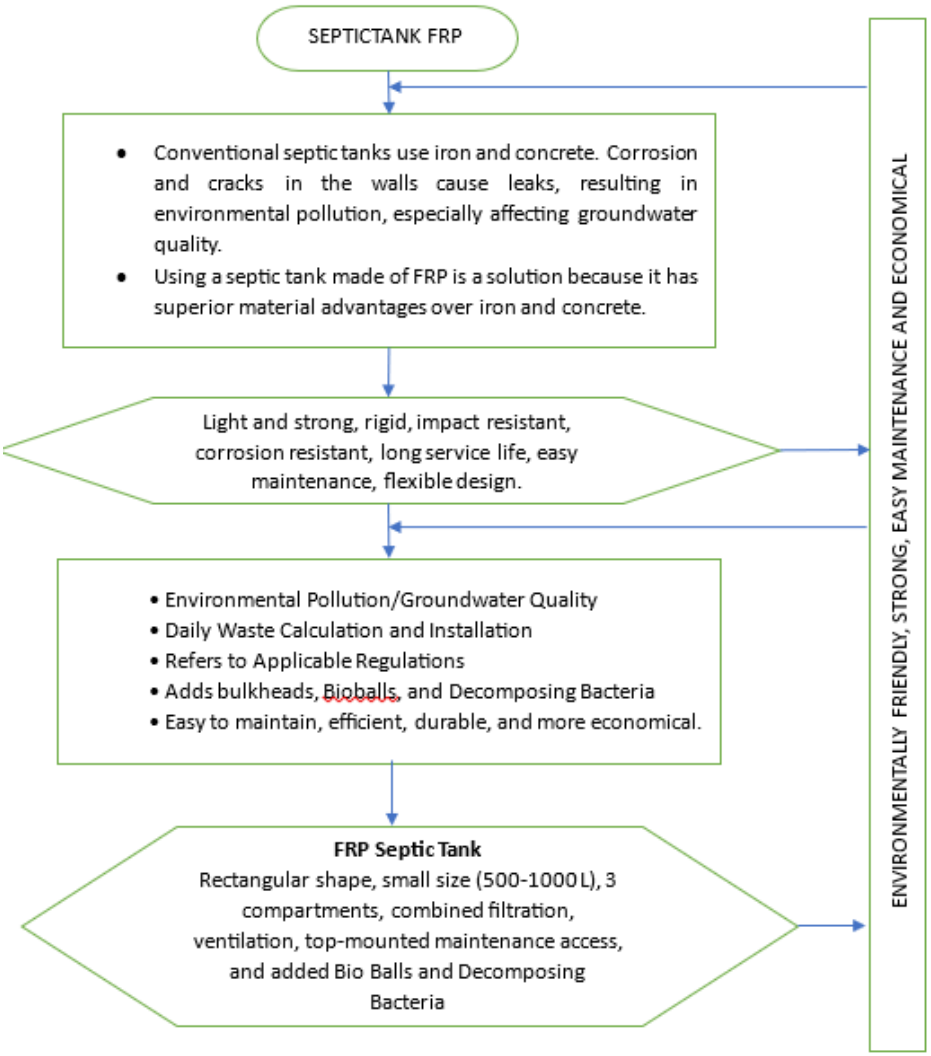

Figure 1. Flowchart Septic Tank FRP

The qualitative method was chosen because it can explore the experiences, perceptions, and social context of the users and technicians involved. According to Lincoln & Guba in Hays & Singh (2012), "Qualitative research is the study of a phenomenon or research topic within its context. This phenomenon tends to be exploratory in nature, as researchers examine topics that have never been investigated or need to be re-examined from a new perspective. This study uses comparative analysis to assess the similarities and differences between conventional septic tanks and FRP septic tank. Comparative analysis was conducted by comparing material aspects, waste processing efficiency, construction and maintenance costs, and environmental impacts.

The units of analysis in this study are households and public facilities that use conventional and FRP septic tanks. The selection of analysis units was done purposively, taking into account variations in location, soil conditions, and intensity of use. Data collection techniques were carried out by (1) In-depth interviews with septic tank users, technicians, and manufacturers, (2) Direct observation of the physical condition of the septic tank, including maintenance and level of damage, and documentation in the form of photos, technical notes, and maintenance reports. For data analysis techniques, data were analyzed through the stages of (1) Data reduction: filtering relevant information from interviews and observations, (2) Categorization: grouping findings based on material aspects, efficiency, costs, and environmental impacts, and (3) Thematic interpretation: compiling a comparative narrative that highlights the advantages and disadvantages of each septic tank.

RESULTS AND DISCUSSION

The study results in a design concept for a septic tank using fiberglass-reinforced plastic. The study utilizes an Objective Tree, Function Structure, and Morphology Chart. These three elements generate design criteria that can be conceptualized into drawings.

Objective Tree

Figure 2. Objective Tree Septic Tank FRP

Function Structure

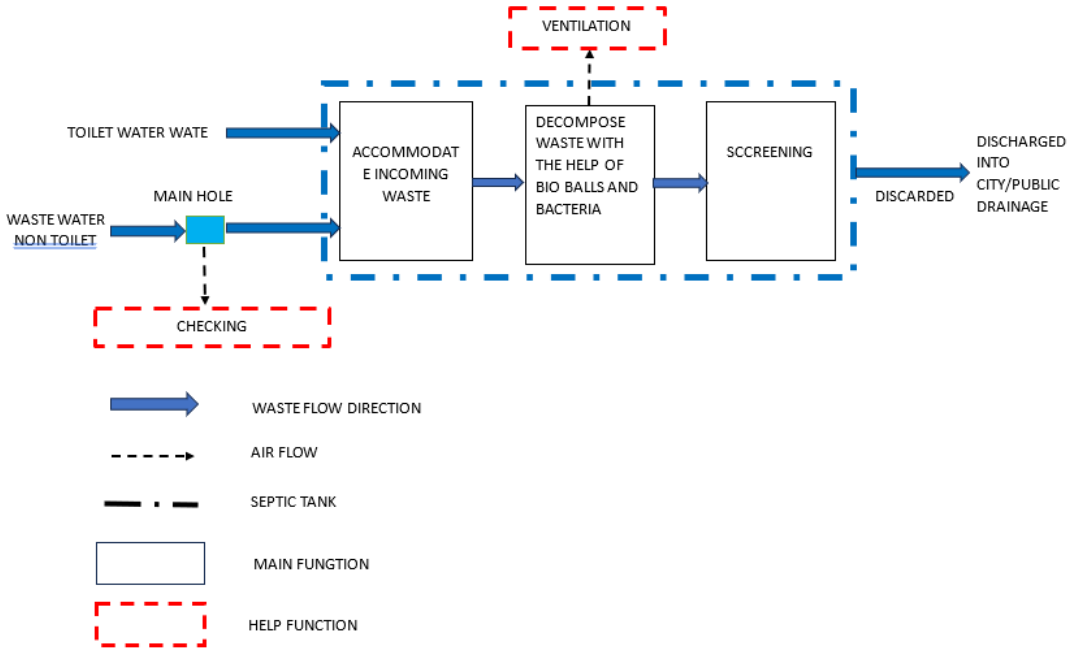

Figure 3. Function Structure

Morphology Chart

Table 1. Morphology Chart

No	Parameter	Opsi 1	Opsi 2	Opsi 3	Opsi
1	Form	Silinder	Rectangle	Square	Tree Angel
2	Dimension	Small (500-1000L)	Medium (1000-3000L)	Large (3000-5000L)	Costum (according to the need)
3	Compartment/partition	1	2	3	Modular
4	Screen Method	Sand Media	Media Geotextile	No Screen	Combination
5	Ventilation System	Passive Ventilation	Active Ventilation	No Ventilation	Integration Ventilation
6	Insulation Material		Busa Polystiren	Polyurethane	Natural Material
7	Waste Discarded	Pipe PVC	Pipe HDPE	Gravitation Flow	Pump System
8	Maintenance Access	Top Access	Near Access	Bottum Access	No Access
9	Additional	Use Bacteria	Bio Balls	Decomposing Bacteria and Bio balls	No Additional

Design

Table 2. Planning Criteria

PLANNING CRITERIA	
PARAMETER	MARK REGULATION
Wastewater Discharge per Capita	120 Liter/people.day
Assumed Number of People in One Residence	5 People
Type of wastewater collected in the septic tank	Toilet, Laundry Waste, Kitchent Sink dan Washtafel.
Waste residence time in the Septic Tank	1 – 3 Day
Inlet Pipe Diameter	4 Inch (100mm)
Outlet Pipe Diameter	4 Inch (100mm)

Conceptual Planning

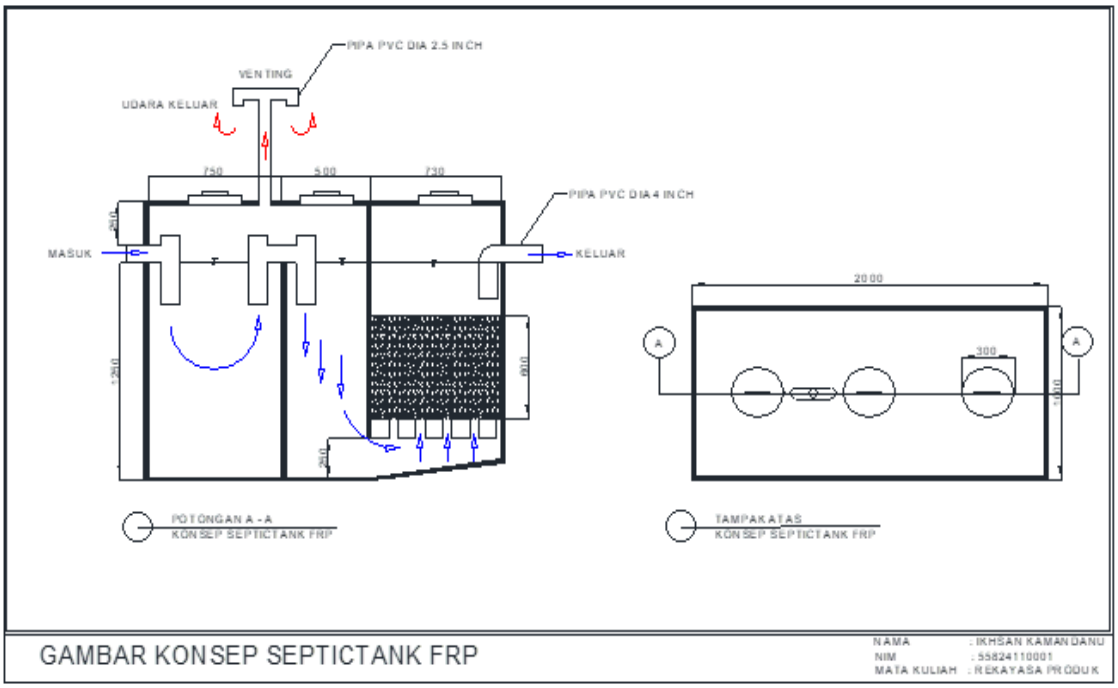

Figure 4. Drawing Concept Septic Tank FRP

CONCLUSION

The use of FRP (Fiber Reinforced Plastic) in residential septic tank construction offers several significant advantages. Due to its lightweight and strong properties, FRP septic tanks can be designed more efficiently without sacrificing durability. The rigidity of FRP also contributes to the septic tank's shape stability, preventing deformation that can occur due to soil pressure or other loads.

Furthermore, FRP's resistance to corrosion and chemicals makes it an ideal choice for wastewater treatment, enhancing the safety and reliability of the disposal system. Its longer lifespan compared to conventional septic tanks, such as those made of concrete or steel, provides long-term economic benefits.

Ease of maintenance and flexible design are also added advantages, allowing FRP septic tanks to be adapted to limited space in densely populated residential areas. With all these advantages, the use of FRP in septic tank construction has proven to be an efficient and effective solution, supporting more sustainable and environmentally friendly waste management practices.

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