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Title: Promoting Sustainable Water and Sanitation Practices on Construction Sites Using Bio-Digester Technology: Advancing Progress toward SDG 6

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शुद्धं जलं सुसंस्कारं, निर्मलं च वसुन्धराम्।
जीवनाय हितं कर्म, कृपया स्यान्नवो विधिः॥
विज्ञानेन समायुक्तं, जीवसंरक्षणाय च।
संधत्ते यं जनो धर्मं, स तु पथ्याय कल्पते॥

"Purified water, sanctified earth — Noble deeds for the welfare of life bring forth a new way with compassion. Endowed with knowledge, for the preservation of life, that mankind upholds as duty, indeed leads to the path of righteousness."

Abstract:
The challenge of ensuring proper sanitation on construction sites, particularly in remote and infrastructure-intensive regions of India, necessitates sustainable and innovative solutions. This research explores the implementation and effectiveness of bio-digester septic tanks infused with DRDO-developed anaerobic microbial inoculum as an alternative to traditional septic systems in labor camps associated with large-scale construction projects. Conducted at the Mindhola River bridge project site in Gujarat, the study compares conventional septic systems with bio-digesters in terms of installation time, cost-effectiveness, maintenance requirements, environmental impact, and safety.

Water and soil quality parameters—including pH, turbidity, TDS, TSS, BOD, COD, and coliform presence—were analyzed, showing that bio-digesters outperform traditional systems in almost all aspects. Additionally, the use of bio-enzymes prepared from kitchen waste was tested as an environmentally friendly cleaning agent, proving effective in maintaining microbial balance and reducing chemical dependency.

The bio-digester systems were not only quicker to install and more mobile but also reduced construction-related hazards and offered better long-term utility. These findings support the potential of bio-digesters as a viable sanitation solution aligned with Sustainable Development Goal 6 (Clean Water and Sanitation)**,** especially in underserved or remote project areas. The research highlights the need for policy-level support, industry-wide adoption, and awareness regarding the benefits of integrating such sustainable technologies in infrastructure projects.

Keywords: Bio-digester septic tank, Sustainable sanitation, SDG 6, Bio-enzymes, Construction site hygiene, Wastewater treatment, Traditional septic tank comparison, Remote infrastructure.

Introduction

Human waste disposal poses a significant challenge globally, especially in developing countries like India. Improper disposal not only leads to aesthetic issues but also poses serious threats of organic pollution and widespread infectious diseases. Contamination of groundwater and drinking water resources exacerbates the risk of epidemics.

As India progresses with extensive infrastructure projects such as roads and bridges spanning vast distances, ensuring proper sanitation for workers and their families in labor camps, particularly in remote locations and the outskirts of cities without proper drainage systems, becomes paramount.

Traditional septic tanks, although widely used, present significant drawbacks. Their construction can take approximately ten days, during which workers and their families who arrive to start projects often resort to open defecation due to inadequate facilities. This practice not only compromises hygiene but also exposes workers and their families, including children, to risks such as insect bites from venomous creatures like scorpions and snakes, as well as encounters with wild animals such as boars and stray dogs. Additionally, untreated waste contributes to diseases such as dysentery, diarrhoea, amoebiasis, viral hepatitis, cholera, and typhoid among workers, posing serious health risks. [1]

These traditional septic tanks require substantial maintenance and often contribute to pollution by releasing untreated effluent into open areas, creating unsanitary conditions around project sites and labor camps. Importantly, traditional septic tanks are often left unattended and abandoned after project completion, without being reused or maintained. This neglect not only undermines sanitation efforts but also leads to environmental degradation

The Defence Research & Development Organisation (DRDO) has developed an anaerobic microbial inoculum for bio-digester septic tanks for the armed forces deployed in high-altitude locations and glaciers, where sub-zero temperatures inhibit the natural biodegradation of organic matter. Accumulated human waste contaminates ice, a crucial drinking water source, posing significant health risks. When this ice melts, it further spreads contamination downstream to rivers and other water bodies. DRDO's developed anaerobic microbial inoculum is environmentally friendly, maintenance-free, and efficient, operating independently of conventional energy sources. The resulting effluent is odorless and largely free from pathogens. [2]

Bio-digester septic tanks provide a rapid, low-maintenance solution that can be easily relocated after project completion, addressing the shortcomings of traditional systems. They offer a sustainable alternative that can be swiftly installed and reused across multiple project sites, thereby converting the initial investment into a long-term asset. Moreover, bio-digester septic tanks can be enhanced with bio-enzymes, natural cleaners derived from kitchen waste. These enzymes aid in breaking down organic matter and reducing wastewater parameters, minimizing reliance on chemical cleaners that can harm beneficial bacteria, crucial for anaerobic processes

This report examines the advantages and implementation of bio-digester septic tanks infused with DRDO-developed anaerobic microbial inoculum in ensuring sustainable sanitation for extensive infrastructure projects such as road and bridge construction, where traditional systems have proven inadequate. It underscores the use of bio-enzymes as a cost-effective and eco-friendly substitute for chemical cleaners, promoting a healthier and more sustainable approach to waste management.

References
1. https://www.who.int/news-room/fact-sheets/detail/sanitation
2. http://drdoficciatac.com/biodigester/aboutus.asp

Objectives
1. To assess the effectiveness of traditional septic tanks versus bio-digester septic tanks in large- scale infrastructure projects.
2. To evaluate the feasibility and benefits of bio-digester septic tanks for remote and expansive project sites.
3. To provide a comparative analysis of cost, maintenance, safety of personnel in making traditional septic tanks, and environmental impact between traditional and bio-digester septic tanks.
4. To recommend sustainable sanitation solutions for future infrastructure projects.

Methodology
Site Selection & Survey
For this study, we selected a critical infrastructure project: a bridge construction project on the Mindhola River, which in future will be connecting Ubhrat and Navsari, managed by R&B (Road and Bridge) Govt. of Gujarat. The project was initially awarded to M/s Unique Construction and subsequently subcontracted to VMMCPL. This site presented a unique opportunity to evaluate sanitation solutions due to its remote location, absence of nearby habitats, and specific environmental challenges.

Survey and Site Selection Process:
Company Engagement: We approached M/s Vijay M Mistry Construction Private Limited, a company with three active projects in Surat, Gujarat. Two of these projects were nearing completion, while the third project, situated in a remote location, was still in the initial stages. We highlighted how participating in our study could benefit their ongoing and future projects by improving sanitation and reducing environmental impact.
Images of site in figure 1 & 2, attached below.
Site Criteria: We considered the following factors for site selection:
- **Remote Location:** The site is situated on the outskirts, far from urban areas, and lacks nearby villages or residential areas, making it an ideal setting to test the effectiveness of different sanitation systems.
- **Environmental Constraints:** The area had no existing drainage system and was located near Mindhola Creek, which flows into the Arabian Sea. This posed a significant challenge for wastewater management.
- **Limited Space:** M/s VMMCPL had to fit storage, camps, offices, and a mess hall within an approximate area of 100 x 80 meters. Additionally, the land was previously used for prawn farming.
- **Existing Infrastructure:** Traditional septic tank construction was about to start near the labor colony, with its outlet just 10 meters from the labor huts and 5 meters from the toilet area. This setup provided a baseline for comparing traditional and modern sanitation systems.

Survey Methodology:

- **Initial Assessment:** Conducted site visits and meetings with M/s VMMCPL site management to assess the suitability of the site and gather baseline information.
- **Stakeholder Engagement:** Engaged with workers and site managers to understand their current sanitation challenges and gather input on potential improvements.
- **Environmental Survey:** Evaluated the environmental conditions, including soil type, proximity to water bodies, and existing sanitation infrastructure.

Site Justification: The chosen site provided an ideal environment to compare the efficacy of traditional and bio-digester septic tanks. It allowed us to demonstrate how a bio-digester system could offer a sustainable, efficient, and environmentally friendly solution in remote and sensitive settings like the Mindhola River Bridge project site.

Fig.01 .Location the area selected for project work, where no drainage system, villages present.

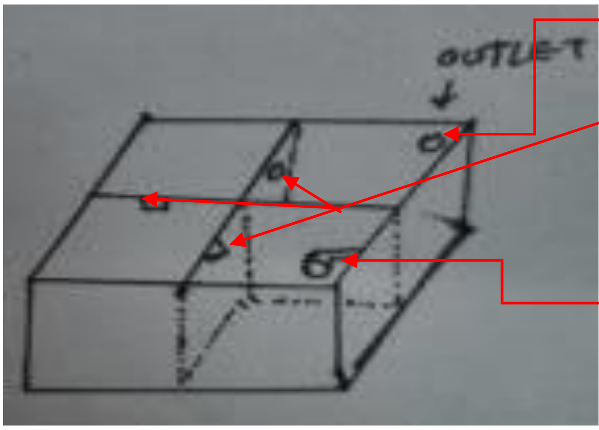
Installation Process

Traditional Septic Tanks (20000 litre -5m x 3m x 2.2m depth)

A traditional septic tank is an underground wastewater treatment structure typically made of concrete, fiberglass, or plastic. It is designed to receive and partially treat raw domestic sanitary wastewater. Heavy solids settle at the bottom of the tank while greases and lighter solids float to the top. The solids remain in the tank, and the partially treated wastewater (effluent) is discharged to a drainfield for further treatment and dispersal by soil organisms [3].

Installed in Dec - 2023 (worked started in Nov - 2023, but not continuous work due to curing and improper skilled manpower requirements)

Design of traditional Septic tank:



Location: Near labour camps to accommodate 350 workers.

Construction Process:

- **Excavation:** Excavator was used for digging a 5.5m x 3.5m x 2.3m pit.
- **Foundation Preparation:** PCC (Plain Cement Concrete) laid down.
- **Construction:** Involved shuttering, bricks, reinforcement, concrete pouring, curing, and slab work.
- **Manpower:** 02 laborers and 01 mason for a 10-day construction period.
- **Resources:** Concrete materials (aggregate, sand, cement , bricks, water. shifting and stacking etc), shuttering items, rebar, props, cutting machine, electrical connection, pipes, and bonding solutions.

Images of septic tank construction in figures from 01 to 06, attached below.

- **Maintenance**: :

Traditional septic tanks require regular maintenance to remove sludge and scum. Untreated wastewater can overflow into open areas if not properly managed, leading to environmental pollution and health risks for nearby communities. Proper disposal of this waste is essential to prevent contamination (3).

Photograph of Construction of Traditional Septic Tank:

Fig. 01. Layout marking with white lime powder for excavation of the traditional septic tank.

Fig 02. Excavation for the traditional septic tank using an excavator at the marked location.

Fig 03. Excavated area being hard barricaded to prevent personnel, heavy machinery, or wild animals from approaching the pit.

Fig 04. PCC (plain cement concrete) done on the excavated area for the base.

Fig. 05. Partition walls in the septic tank are constructed using masonry work.

Fig. 06. Complete construction of the traditional septic tank for personal use.

- **Bio-Digester Septic Tanks (1000 litre) Installed in Dec-23:**

A bio-digester septic tank uses anaerobic bacteria to decompose human waste into water and gas. It requires minimal maintenance and produces effluent that is odorless and largely free from pathogens [4].

Bio-Digester Working: Bio-digesters use anaerobic bacteria to break down human waste. The bacteria convert organic matter into methane and carbon dioxide, reducing the volume of waste and producing a nutrient-rich effluent that can be safely discharged. The process is eco-friendly and requires minimal maintenance [4].

Desig of Bio Digester Septic Tank

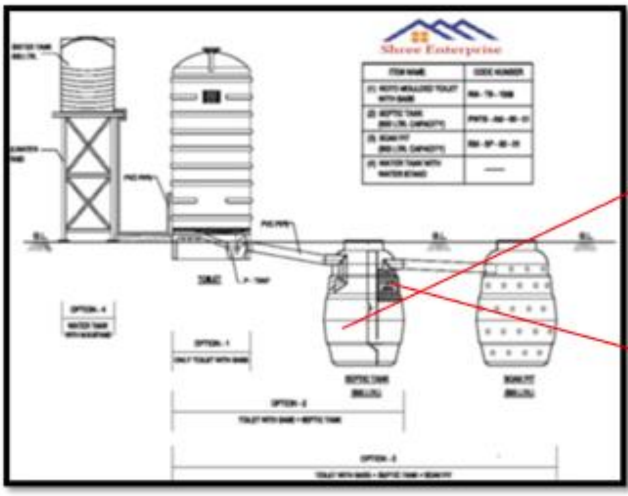


Fig. 01. 1st Compartment infused with DRDO-developed anaerobic microbial inoculum

2nd compartment is with a filter for further filtration and preventing bacteria from flowing outside with treated water.

- **Location:** Near Office area of same site for direct comparison, capacity daily 12-15 Number of Personal.
- **Installation Process:**
  - **Excavation:** A 2m x 2m x 2.5m pit dug using a backhoe.
  - **Foundation Preparation:** 1m x 1mx 100 mm PCC laid.
  - **Placement:** Bio-digester tank lifted and placed on the PCC area & back filled with Sand around it.
  - **Preparation of Soak Pit:** Discarded water tank filled with aggregate and sand used as a soak pit.
  - **Manpower:** 2 labourers for a one-day installation.
  - **Resources:** Pipes, bonding solutions, and accessories.

Bio Digester Septic Tank Installations Photos

Fig 01. Excavation of pit using backhoe bucket in early morning

Fig 02. PCC done in the pit for the base, on which biodigester tank will be placed

Fig 03. Bio Digester tank was placed in the pit using backhoe bucket

Fig 04. Bio Digester tank was adjusted and sand filling started beside the tank foe the support & as per manufacturer guidance.

Fig 05. Complete connection Setup of bio digester was done and taken in operational use

Fig 06. Below Soak pit area made and barricaded using GI sheet to prevent any wild animal entering.

Bio Enzyme Preparation from kitchen waste to clean the septic tank to boost microbial activity in septic tank. As normal chemical cleaner damage the bacteria involve in microbial activities in septic tank and economically spending on plastic container carrying cleaner**.**

The preparation of bio-enzymes is an eco-friendly and cost-effective approach for maintaining bio-digesters and ensuring sustainable sanitation practices at construction sites. Bio-enzymes are natural cleaners made from organic waste, which help in breaking down organic matter and maintaining a healthy microbial ecosystem in the bio-digester. Here's the step-by-step process done for preparing bio-enzymes:

Ingredients and Ratio:

- **Kitchen Waste (Lemon and Citrus Peels):** lemons and citrus fruits waste generated from company mess/Kitchen was used which are rich in natural acids and enzymes, which are effective in breaking down organic material.
- **Jaggery (Available in kitchen):** This is an unrefined sugar that serves as a natural food source for microorganisms, helping to accelerate the fermentation process.
- **Water:** Acts as a medium for fermentation and helps in the dilution of the bio-enzymes.

The ingredients are mixed in a 3:1:6 ratio: 3 parts of kitchen waste (lemon and citrus peels) 1 part of jaggery & 6 parts of water

Fig.01 Bio Enzyme day 1 photo which was prepared from kitchen waste (lemon, Citrus peels (orange)

2. **Keeping for Fermentation Process:**

Fig.01 Bio Enzyme day 1 photo which was prepared from kitchen waste (lemon, Citrus peels (orange)

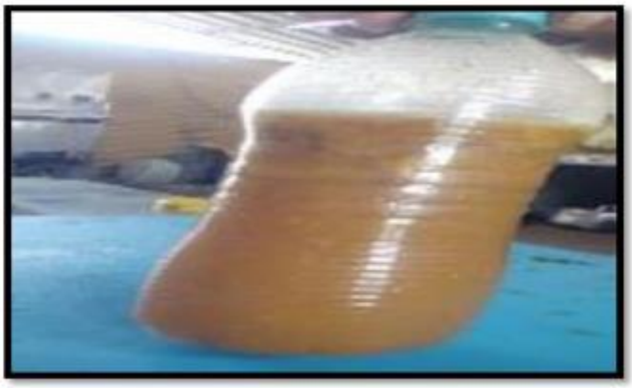


Fig.02 Bio Enzyme after 90 days photo which was prepared from kitchen waste

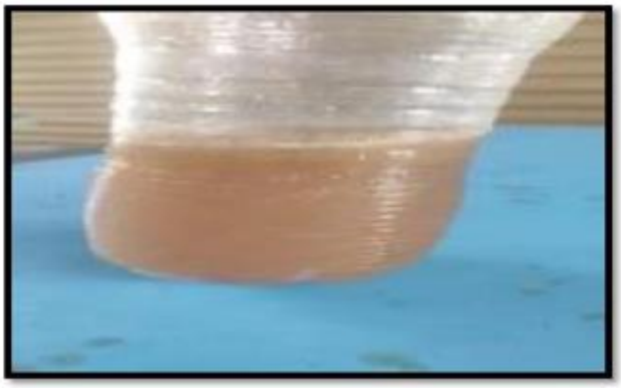


Fig.03 Filtered Bio Enzyme, for final use after removing lemon, citrus waste.

- **Mixing:** Combine the kitchen waste, jaggery, and water in a 1 litre bottlrr. Ensure that the container is not filled to the brim, allowing some space for the gases produced during fermentation.
- **Sealing and Storing:** Seal the bottle tightly and store it in a warm place, away from direct sunlight. The warmth helps in speeding up the fermentation process.
- **Duration:** Let the mixture ferment for 90 days. During this period, the microorganisms will break down the organic waste, producing bio-enzymes that are rich in natural acids and other compounds beneficial for cleaning, daily once in a day slightly cap of bottle need to open to remove the gas created in bottle. (kitchen staff were doing it)
- **Usage: Dilution:** After 90 days, the bio-enzyme solution is ready for use. Can be use by dilute it with water in a 1:10 ratio before application.

1.2 Data Collection

Data Collection:

During sample Collection from Traditional septic tank outlet WSH (20000 litre) was used by maximum 20 Personal & Bio digester septic tank (1000 litre) was used by 17 Personal per Day (which is over utilisation of bio digester septic tank)

- **Sampling:** Water samples from both traditional and bio-digester septic tanks were collected for analysis on 25th May 24. {Sample collected from effluent exit point}

- **Tests Conducted:** pH, turbidity, total dissolved solids, total suspended solids, biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total coliform count.
- **Comparison Metrics:** Cost, installation time, maintenance, environmental impact, and water quality.
- **Bio Enzymes Added for cleaning before Sample collection:** Not taken in use as Bio enzyme was under preparation – Fermentation Process.

Bio Enzymes Use on Site -

When bio-enzyme was used for cleaning, it was found effective in cleaning when personnel just sprinkled it and immediately cleaned the wash basin area with a cloth

- **Parameters Monitored**: Water quality, odor, installation time, maintenance frequency, and overall satisfaction.

3.4. Tools Used**:**

- **Water Testing at Govt. approved lab as per IS**: To measure water pH, dissolved oxygen, and the presence of harmful bacteria (physical, chemical & biological test).
- **Odor Detection/Human Olfactory Detection:** Our team used their sense of smell to detect and evaluate odors around the tanks. We used a simple scale to rate the smell from each tank, ensuring that the assessment was consistent.

- **Time Logs**: To record installation and maintenance times.
- **Cost Records**: To compare the costs of installation and maintenance for both septic systems.

3.5 Techniques:

- **Water Sampling**: Water samples were collected from both systems to compare effluent quality.
- **Visual Inspections**: Periodic inspections were conducted to assess physical conditions and detect any issues with the septic systems.
- **Interviews**: Conducted with workers and site management to gather insights on the practical benefits and challenges of each system.
- **Comparative Analysis:** Compared key factors like installation time, cost, water quality, and odor levels between the bio-digester and traditional septic tanks.

References

3. Bureau of Indian Standards (1986). Indian standard code of practice for installation of septic tanks (IS: 2470). Retrieved from India Water Portal (https://www.indiawaterportal.org/articles/indian-standard-code-practice-installation-septic- tanks-2470-bureau-indian-standards-1986)
4. Re-Leaf (2021). Septic Tank Guide: Size, Cost, Maintenance, and More. Retrieved from Re- Leaf. (https://releaf.in/)

2. Results

2.1 Water Quality Parameters

Parameter	Unit	Traditional Septic Tank	Bio-Digester Septic Tank
pH	--	7.33	7.23
Turbidity	NTU	37.59	22.41
Total Dissolved Solids (TDS)	mg/L	1488	1196
Total Suspended Solids (TSS)	mg/L	49	31
Biochemical Oxygen Demand (BOD)	mg/L	116	54.14
Chemical Oxygen Demand (COD)	mg/L	454	222
Total Coliform	/100ml	Present	Present

* Lab (GPCB approved lab, Recognition by CPCB, FDA), result attached as Annexure I

Comparison as per - The Environment (Protection) Rules, 1986, **PRIMARY WATER QUALITY CRITERIA FOR CLASS SW-II WATERS & GENERAL STANDARDS (CPCB) FOR DISCHARGE OF ENVIRONMENTAL POLLUTANTS PART-A: EFFLUENTS [5]**

Physical Characteristics

Parameter	Unit	Traditional Septic Tank	Bio-Digester Septic Tank	Permissible Limit (Irrigation)	Permissible Limit (Sewer Systems)	Permissible Limit (Marine Coastal Areas)	Permissible Limit (Class SW-II Waters)
pH	--	7.33	7.23	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0	6.5 to 8.5

Turbidity	NTU	37.59	22.41	Not specified	Not specified	Not specified	30 NTU (measured at 0.9 depth)
Total Dissolved Solids (TDS)	mg/L	1488	1196	2100 mg/L	Not specified	Not specified	Not specified
Total Suspended Solids (TSS)	mg/L	49	31	100 mg/L	600 mg/L	100 mg/L	Not specified
Colour and Odour	--	High noticeable colour & unpleasant	Less noticeable colour and non-	Not objectionable	Not objectionable	Not objectionable	No noticeable colour or offensive

Parameter	**Unit**	**Traditional Septic Tank**	**Bio-Digester Septic Tank**	**Permissible Limit (Irrigation)**	**Permissible Limit (Sewer Systems)**	**Permissible Limit (Marine Coastal Areas)**	**Permissible Limit (Class SW-II Waters)**
		odour	ctionable odour				odour.
Floating Matters	--	None	None	---	---	---	Nothing obnoxious

Chemical Characteristics

Parameter	**Unit**	**Traditional Septic Tank**	**Bio-Digester Septic Tank**	**Permissible Limit (Irrigation)**	**Permissible Limit (Sewer Systems)**	**Permissible Limit (Marine Coastal Areas)**	**Permissible Limit (Class SW-II Waters)**
Biochemical Oxygen Demand (BOD)	mg/L	116	54.14	100 mg/L	300 mg/L	100 mg/L	3 mg/L (restricted for bathing)
Chemical Oxygen Demand (COD)	mg/L	454	222	Not specified	500 mg/L	250 mg/L	Not specified

Biological Characteristics

Parameter	Unit	Traditional Septic Tank	Bio-Digester Septic Tank	Permissible Limit (Irrigation)	Permissible Limit (Sewer Systems)	Permissible Limit (Marine Coastal Areas)	Permissible Limit (Class SW-II Waters)
Total Coliform	/100 ml	Present	Present	1000 MPN/100 ml	Not specified	1000 MPN/100 ml	100/100 ml (MPN) (average value not exceeding 200/100 ml in 20% of samples and in 3 consecutive samples in monsoon months)

2.2 Soil Quality Analysis:

Physical Characteristics: (Bio Digester Septic tank)

- Soil present was Brownish fine clay & silty clay
- Within two days, water above soil get evaporated & there are dark brownish color exist due to clay soil with slight moisture, beside overflow water.
- There found local plants started growing in overflow water from soak pit.
- Water color found transparent as it goes far from bio digester. (highlighted with Mark Circle in Fig.01)
- Moisture below 15 cm in the edge side area of the outlet water spread was not found. However, the clay soil texture remained the same compared to areas without water stagnation. This indicates continuous evaporation and a lack of absorption.

Fig.01. Snap of water overflow from soak pit of Bio digester septic tank

Physical Characteristics: (Traditional Septic tank)

- Outlet water was channelizing into the creek, through the drain, which was used to fill the prawn farming plot with water. There all time water present, due to high tide of river water inflow and get stagged.

- No visible fecal matter found on outlet water, only odor exist.

Fig.02. Snap of water overflow from soak pit of traditional septic	Due to rainwater, logging has been increased- at time of photo

Plant Installation Impact: Positive impact on effluent quality, with plants absorbing and further treating water. The water texture found more transparent once it move from the algae & local plant species.

4.3. Result After Using Bio-Enzyme for Cleaning:

The bio-enzyme, made from kitchen waste, proved effective in cleaning the septic tank. However, due to unforeseen circumstances, M/s VMMCPL had to demobilize and leave the project site. As a result, no further samples were collected after using the bio-enzyme for cleaning the toilets. Nevertheless, the initial use of bio-enzyme showed positive results in maintaining hygiene and cleanliness physically.
Reference: 5. https://cpcb.nic.in/GeneralStandards.pdf

3. Analysis and Interpretation of Results

3.1 Comparison of Water Quality

- **Usage and Water Quality**: Despite serving fewer individuals (17 compared to 20), the bio- digester septic tank (1, 000 litre) maintained superior water quality compared to the traditional septic tank (20, 000 litre) over 5 months of use. This suggests that the bio-digester system is more efficient in treating wastewater, leading to better overall water quality.
- **pH Levels**: Both the traditional septic tank and the bio-digester system maintained acceptable pH levels (7.33 and 7.23, respectively), which fall within the permissible range for irrigation (5.5 to 9.0),

sewer systems (5.5 to 9.0), marine coastal areas (5.5 to 9.0), and Class SW-II waters (6.5 to 8.5). This indicates that neither system contributes to significant acidity or alkalinity in the water, making it safe for various uses including contact water sports and commercial fishing.

- **Turbidity**: The bio-digester septic tank exhibited significantly lower turbidity (22.41 NTU) compared to the traditional septic tank (37.59 NTU). The permissible limit for Class SW-II waters is 30 NTU. The traditional septic tank exceeds this limit, potentially making it unsuitable for contact water sports and commercial fishing, where clear water is essential. The bio-digester, with turbidity well below 30 NTU, demonstrates superior clarity, which is crucial for both aesthetic and health reasons in aquatic environments.
- **Total Dissolved Solids (TDS) and Total Suspended Solids (TSS)**: The bio-digester system showed lower levels of TDS (1196 mg/L) and TSS (31 mg/L) compared to the traditional septic tank (TDS: 1488 mg/L, TSS: 49 mg/L). The permissible limit for irrigation is 2100 mg/L for TDS and 100 mg/L for TSS. Both systems are within these limits for irrigation. However, for marine coastal areas, the permissible limit for TSS is 100 mg/L, which both systems meet. Lower TDS and TSS levels in the bio-digester indicate more effective filtration and decomposition, resulting in clearer water with fewer suspended particles, enhancing its suitability for a range of uses.
- **Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)**: The bio- digester septic tank demonstrated much lower BOD (54.14 mg/L) and COD (222 mg/L) values compared to the traditional septic tank (BOD: 116 mg/L, COD: 454 mg/L). For irrigation, the permissible limit for BOD is 100 mg/L, which the traditional system exceeds, indicating it could cause environmental pollution and affect plant growth. But the bio-digester system is within this limit, suggesting it would have a lesser environmental impact. The COD limit for sewer systems is 500 mg/L, which only the bio-digester system meets. Lower BOD and COD values in the bio-digester system reflect better organic matter decomposition and reduced environmental pollution, making it more effective in reducing the biochemical load.
- **Total Coliform**: Both systems had detectable coliform bacteria, but levels were lower in the bio-digester system. Coliform presence indicates potential contamination. The permissible limit for marine coastal areas and Class SW-II waters is 1000 MPN/100 ml. The exact coliform levels were not specified for the traditional and bio-digester tanks, but it is noted that bio- digester systems generally have lower contamination levels. Lower coliform levels in the bio- digester system suggest better pathogen reduction, which is essential for the safety of water intended for bathing, contact water sports, and commercial fishing.
- **Odor**: The traditional septic tank exhibited objectionable Odor, making it unsuitable for environments where Odor control is critical. The bio-digester septic tank had no noticeable or unpleasant Odor, meeting the requirements for all specified uses. This is crucial for maintaining the aesthetic and environmental quality of the water, especially in areas used for recreational activities and commercial fishing.

3.2 Comparison of Soil Quality

- **Moisture Management:** Bio-digester soil retains moisture well, supports plant life; traditional septic tank soil have risks of stagnation and nutrient buildup.
- **Effluent Impact:** Bio-digester effluent is clearer, indicating better treatment; traditional septic tank effluent can lead to soil and water pollution if not properly maintained..

- **Environmental Health:** Bio-digester promotes healthier soil and plant growth; traditional tank poses risks of contamination and soil degradation.

3.3 Safety

Traditional Septic Tank:

- **Construction Risks:** Takes a long time to build, leading to open defecation and risks from insects (Scorpio, snakes) and wild animals (Boar, dogs etc) as per current site.
- **Safety Measures**: Needs precautions like sloping or shoring to prevent accidents during working inside excavated pit to ensure soil don't collapse on personal working under pit.
- **Worker Exposure:** Workers spend a lot of time in risky conditions like working in excavated pit for PPC, Shuttering, reinforcement , Concrete, shuttering opening etc)

Bio-Digester Septic Tank:

- **Quick Installation:** Can be set up often in just a day.
- **Construction Process:** Requires less digging space, & only mainly laying a PCC foundation for the tank (directly from above Tank is placed on PCC.
- **Less Risk:** Workers are exposed to fewer dangers like open defecation, insect bites, and encounters with animals.

3.4 Cost-Benefit Analysis

- **Traditional Septic Tank:**
- **Cost:** 90000 Rs was construction cost & can't be reuse on other site.
- **Personal can use :** 350 No's
- **Installation Time:** 7 days with experience team
- **Maintenance:** Required once tank is filled, as there was 20 Manpower using, no issue occurred..
- **Environmental Impact:** High, with untreated effluent discharge.
- **Area :** Takes large area for installation (5.5 m x 3.5 m) just for Septic tank(as soil can collapse for safety needed more excavation for safe working)
- **Portable Bio-Digester Septic Tank:**
- **Cost:** Rs. 21000 & portable, can be reuse on other site.
- **Personal can use :** Upto 15 No's
- **Installation Time:** 1 day, without experience team, only guidance needed.
- **Maintenance:** No maintenance or overflow of unhygienic treatment found in 5 month of extensive use.
- **Environmental Impact:** Lower, with better effluent treatment and less risk of pollution.
- **Area :** Takes small portion (1.5m x 1.5m) just for Septic tank
  *As M/s VMMCPL has left the project due to some circumstance, the traditional septic tank will be abandoned or need to remove as per client instruction by dismantling which will be of of total loss of resource.

Conclusions

The bio-digester septic tank system presents a superior alternative to traditional septic tanks, particularly for large-scale infrastructure projects. It offers substantial advantages in terms of installation time, cost-effectiveness, maintenance requirements, construction footprint, environmental impact mitigation, and safety considerations.

Key Advantages:

- **Installation and Mobility**: Bio-digesters are quick to install and can be relocated and reused after project completion, providing long-term economic and operational benefits. This mobility allows for efficient optimization of infrastructure across different sites or project phases.
- **Environmental Impact**: These systems effectively manage wastewater, minimizing environmental pollution and complying with stringent government standards. Operated within their designed capacity (typically up to 15 individuals), bio-digesters maintain lower parameters such as turbidity, TDS, TSS, BOD, and COD, ensuring minimal ecological disruption.
- **Sanitation and Health**: Bio-digester systems enhance on-site sanitation and hygiene standards, reducing health risks for workers and surrounding communities. Their efficient decomposition of organic matter contributes to cleaner water bodies and safer working conditions.
- **Operational Efficiency**: Compared to traditional systems, bio-digesters require less maintenance and incur lower operational costs over their lifecycle. Their modular design facilitates easy scaling and adaptation to varying project demands without compromising performance.
- **Environmental Sustainability**: As a long-term asset, bio-digesters support sustainable development goals by conserving water resources and reducing the carbon footprint associated with wastewater treatment. Their adaptability and efficiency promote environmentally responsible practices in construction and infrastructure projects.
- **Safety Considerations**: Bio-digester systems offer improved safety over traditional septic tanks by reducing construction hazards. Their quick installation process and minimized excavation requirements decrease risks such as open defecation, insect bites, and encounters with animals, enhancing overall safety on construction sites.

Recommendations

- **Adoption of Bio-Digesters**: Construction companies should standardize the use of bio-digesters for sanitation in remote and large-scale projects. These systems offer a quick, cost-effective, and sustainable solution for worker hygiene and environmental protection, with the added benefit of being relocatable for future use.
- **Utilization of Bio-Enzymes**: Promote the use of bio-enzymes made from kitchen waste as an economical and environmentally friendly alternative to chemical cleaners. Bio-enzymes help maintain a healthy microbial balance in septic systems, improving waste breakdown and reducing dependency on harmful chemicals that can disrupt the anaerobic process essential for effective waste management.
- **Plantation in Outlet Water Discharge Areas**: Encourage the planting of vegetation in areas where treated water from bio-digesters is discharged. Plants can absorb nutrients and contaminants from the water, further purifying it and contributing to the local ecosystem. This approach not only enhances water quality but also promotes greenery and biodiversity around the construction site.
- **Reuse of Treated Water for Dust Control**: Implement the practice of reusing treated water from bio-digesters for dust control on construction sites. This not only helps in water conservation but also reduces environmental pollution and maintains a cleaner work environment by controlling dust levels.
- **Promote Vegetation:** Plant more around bio-digester for better natural filtration.

- **Policy Changes**: Advocate for government policies that support the adoption of sustainable sanitation solutions like bio-digesters and bio-enzymes. Such policies should encourage the construction industry to invest in environmentally friendly practices that address public health and reduce environmental impacts.
- **Social Aspects:** Improved sanitation facilities enhance the quality of life for workers, reducing the need for open defecation and improving overall hygiene. Better sanitation can also lead to higher worker morale and productivity.
- **Medical Aspects**: Proper sanitation facilities reduce the risk of diseases such as dysentery, diarrhea, and cholera among workers. Improved hygiene reduces exposure to harmful pathogens, leading to better health outcomes for laborers and their families.
- **Government Role**: The government should advocate for the widespread adoption of bio-digester septic tanks in future outdoor infrastructure projects. Furthermore, it should implement training programs and raise awareness about creating bio-enzymes from kitchen waste. These initiatives will promote sustainable waste management practices and encourage healthy microbial activity.

Summary

This report highlights the significant benefits of bio-digester septic tanks over traditional systems in large-scale infrastructure projects.

The implementation of a bio-digester septic tank at the Mindhola River Bridge construction site has demonstrated significant advantages over the traditional septic tank:

- **Shorter Installation Time**: The bio-digester was installed in just one day compared to the 12 days required for the traditional septic tank construction.
- **Lower Maintenance Requirements**: Unlike the traditional septic tank, the bio-digester produces minimal sludge and eliminates foul odors, reducing the need for frequent maintenance.
- **Environmental Impact**: The bio-digester effectively treats wastewater, resulting in water that is cleaner and safer for the environment. This is in contrast to the traditional septic tank, which often led to slight odors and potential pollution when effluent was released.
- **Cost Efficiency**: The bio-digester system, combined with the use of bio-enzymes, offers a more cost-effective solution by reducing dependency on chemical cleaners and minimizing long-term maintenance costs.
- **Space Efficiency**: The bio-digester system requires less space and is more adaptable to the constraints of the project site compared to the traditional septic tank setup.
- **Safety Considerations:** Bio-digester systems improve safety over traditional septic tanks by reducing construction hazards. Their quick installation and minimized excavation decrease risks like open defecation, insect bites, and encounters with animals, enhancing overall construction site safety.

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