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Applications of Microbial Nanotechnology in Faecal Sludge Management for Rural Areas of Chikkaballapur District

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Abstract

Faecal sludge is a combination of partly digested and semisolid human excreta that is typically gathered from on-site sanitation facilities and dumped into open sewers and bodies of water. To guarantee the secure gathering, transit, treatment, and disposal of onsite collected excreta and create a pollution-free environment, a well-planned FSM is necessary. With a growing global population comes increased energy and material use, which has an impact on the environment. Among these effects are an increase in solid waste generation, faecal sludge generation, and contamination of surface and groundwater. Both direct applications of nanoparticles for detecting, avoiding, and removing contaminants as well as indirect applications through improved industrial design processes and the creation of environmentally friendly products are possible with nanotechnology. In this research, a non-energy-consuming aeration system has been suggested to be added to the current treatment procedure in light of the present energy shortage. By enhancing the efficiency of the local cleaning systems and increasing the output and selling of the by-products of the sludge treatment process, nanoparticles can lower the possibility of human interaction with faecal-borne pathogens. Recycled water for use in industry and agriculture, soil cleansers made from composted or co-composted materials, and energy products like biogas, biofuel, charcoal pellets, industrial powdered fuel, or power are some examples of these goods.

Keywords: *Excreta, Faecal Sludge Treatment Plant (FSTP), Microbes, Nanotechnology and Pathogens*

1.0 Introduction

The Swachh Bharat Mission Grameen/SBM (G) in the first phase (year 2014-19) focused on achieving an Open Defecation-Free (ODF) status in all rural areas through the provision of Individual or Community toilets[1]. With the second phase of the SBM-G kicking in from February 2020, the focus is now on sustaining this ODF status through continued usage of these toilets and Solid and Liquid Waste Management (SLWM)[2]. The biggest challenge from the previous scheme observed is that the majority of the household toilets have been connected to single pits instead of twin pits or septic tanks as required which leads to the problem of managing the faecal waste once the pit fills up[2]. Faecal refuse Control is the process of managing refuse from the time it is created until it is ultimately disposed of. This involves the collection, transportation, handling, and disposal of waste, as well as the tracking and legal necessities for the waste management process, as well as waste-related developments in technology and economic processes[3]. Proper waste management is crucial for the creation of viable and liveable communities, but it is still challenging in many emerging nations and locations. According to a survey, effective waste handling

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is comparatively costly, usually involving 20% to 50% of the budgets of municipalities[4]. Operating this vital city carrier necessitates integrated frameworks that are socially beneficial, long-lasting, and environmentally sound. Most waste management strategies focus on municipal waste, which makes up the bulk of the waste generated by household, business, and industrial activities. However, some cities and regions within the business can create less waste by establishing policies and laws. Waste control measures incorporate the most efficient and ecologically conscious goods that can be generated, efficient disposal facilities, handling both imports and exports, and integrating technological advances and financial elements of a cyclical economy[2]. The Detailed Project Report (DPR) is prepared for the implementation of the black water/faecal sludge management projects proposed as a part of the LWM Strategy and Action plan for Billuru GP Chikkaballapur district state of Karnataka and the faecal waste is treated through microorganisms.

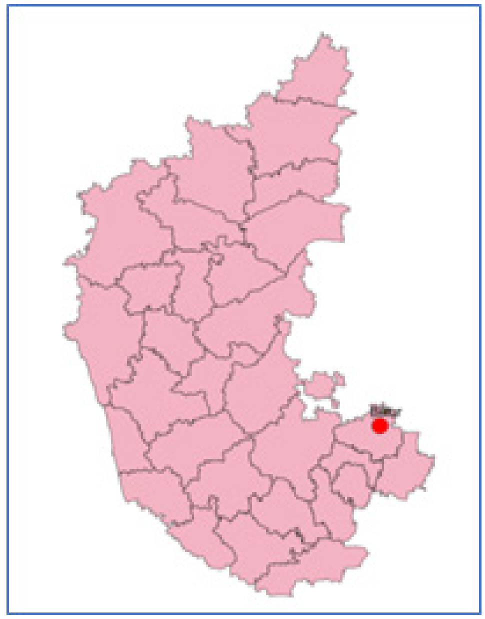

Figure 1. Billuru's position is indicated on a district map.

2.0 Methodology

2.1 Site of the Study

The location code for Billur is 623930, according to statistics from the 2011 Census. In the Chikkaballapur region of Karnataka, India, the hamlet of Billur is situated in Bagepalli Taluk. It is 34 kilometres from the tehsildar office in Bagepalli's sub district and 76 kilometres from Chikkaballapur district headquarters. Billur hamlet is a gram panchayat, according to statistics from 2009. There are 419.58 hectares of land in the town as a whole. There are 1,532 individuals living in Billur in total, 785 of whom

Table 1. Population data (Source: Panchatantra)

Sl No	Hamlet	Total Masculine	Total feminine	SC population	ST population	Total disabled
1	Babenayakanapalli	254	238	491	0	0
2	Bandarlapalli	131	133	64	0	0
3	Bhoyipalli	298	294	64	299	0
4	Billur	981	975	501	268	10
5	Chamalavaripalli	17	18	0	0	0
6	Gandamvaripalli	44	43	4	12	0
7	Mallepalli	100	100	58	0	0
8	Narayanareddypalli	4	4	8	0	0
9	Ugranampalli	335	333	73	44	0
10	Vyangyarlapalli	242	248	271	81	0
11	Yarraganapalli	125	112	116	24	0

are men and 747 women. Billur Hamlet has approximately 383 homes (Figure 1 and Table 1).

2.2 Demographics

2.2.1 Climate

The rainy season in Chikkaballapur is warm, humid, and cloudy, while the dry season is hot and partially gloomy. The average annual weather ranges from 59 to 94 degrees Fahrenheit, rarely falling below 53 or rising above 100. From March 10 to May 22, the summer season, with an average daily maximum temperature above 91°F, lasts for 2.4 months. In Chikkaballapur, April is the warmest month of the year, with an average high of 94°F and a low of 72°F. Between October 7 and January 11, which is the length of the cold season, the daily maximum temperature typically falls below 82°F. In Chikkaballapur, December is the coolest month of the year, with an average low of 60°F and a high of 80°F.

2.2.2 Groundwater Level

From field level observation and surveys it was found out that bore well depth in the village was around 400 – 500 feet below ground level. Below is a map of the groundwater levels across Karnataka (Source: KSNDMC, June 2020). The average depth of groundwater in the district is found to be less than 60 mbgl (Figure 2).

2.2.3 Soil Type

Soil type in this region is a mixture of red loamy and sandy soil.

3.0 LWM Strategy and Action Plan for Billuru Gram Panchayat

The Table 2, gives a summary of the baseline situation assessment that was carried out for the preparation of the Liquid Waste Management (LWM) Strategy & Action

Table 2. Brief of Baseline Assessment

Category		Baseline Assessment
Water supply		**55 Lpcd supply**. Groundwater depth ~**450 fbgl** (Source: PDO interview, and verified in households with bore wells)
Blackwater Management	**Toilets and Access to Toilets**	100% toilet coverage Pour flush squatting pans
	Containment	**100% single pit coverage**. Construction material: Stone Masonry/Cement Concrete Rings
	Collection / Conveyance	**No GP/Taluk level vehicle available**.
	Treatment	**No treatment facility is available at GP**, Taluk, or nearby TMC, CMC.
	Disposal/ Reuse	Collection from the bulk generator is **purchased by a farmer**; it is pit-composted and used in the **plantation;** The truck operators **tend** to dump in the **outskirts** otherwise
Greywater		Few households use the greywater in their kitchen gardens Many households **discharge in the storm drains** that lead to the lakes.
Land Parcel		Ownership is with Billuru Gram Panchayat. 1-acre area available for FSM.

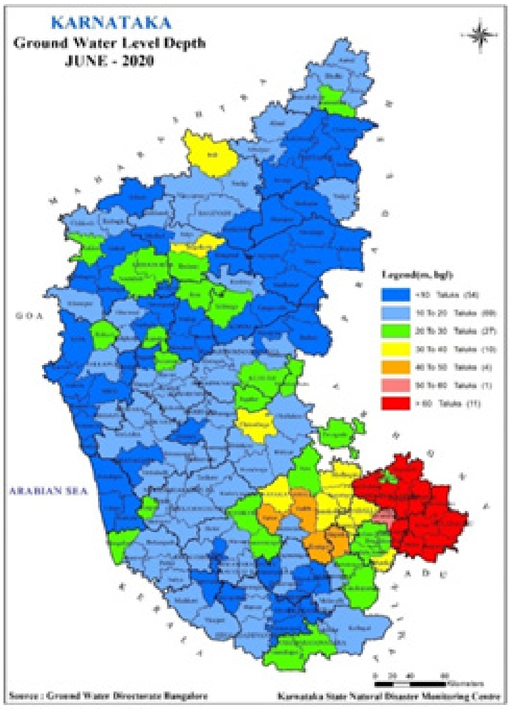

Figure 2. Karnataka groundwater level map (Circle showing the location of Billuru).

Plan for Billuru GP. The identified gaps and issues across the sanitation value chain have been listed below:

As per the summary of the baseline assessment, the key identified gaps and issues and the solutions against

Figure 3. GPs considered in the cluster FSM interventions (Radii of 5, 10, 15 and 20 km).

Table 3. Priority-wise projects against gaps and issues

Category		Identified Gaps and Issues	Solutions/ Projects	Priority
Blackwater Management	Containment	No **appropriate containment systems** for **safe sludge management**	Mandatory **twin pit systems** for new households Old containment systems to be corrected over time	3
	Collection / Conveyance	No GP/Taluk level **desludging vehicle** available. TMC vehicle overcharging services.	Purchase of a **desludging vehicle** Shared resources among adjacent GPs	1
	Treatment	No **treatment facility available** at GP, Taluk, or nearby TMC, CMC.	**Planted Drying Bed** (pre-treatment + dehydration + percolate treatment) based treatment system Shared resources among adjacent GPs	1
	Disposal/ Reuse	**Some amount** of collected **FS** is **composted and reused** **Rest is** open **dumped** on an **open land** on the outskirts	The treated contents are to be used for land application with the help of microorganisms to decompose waste into compost	2

Table 4. Mother GP and associated cluster GPs

Mother GP	Associate GP	Dist. from Mother GP (Km)	No. of Villages	Population	No. of HH's
Billuru	Billuru	0	12	5767	1572
	Racheravu	6	14	6477	1642
	Thimmapalli	10	7	9499	1800
	Chakavelu	12	3	6595	1365
	Pathapalya	14	5	6405	1126
	Puligallu	15	10	6250	1336
	Thollapalli	16	9	7150	1890
	Somanathapur	16	9	7317	1671
	Nallagutlapalli	16	7	7317	1671
	Gorthapalli	17	4	5573	1509
	Guluru	19	5	6405	1126
Total			**85**	**74755**	**16708**

them in the order of their priority are listed below in Table 3.

Given the proximity of the following Gram Panchayats and lack of demand for desluding, they can be clustered for planning future initiatives to optimize the investment in the projects (Table 4 and Figure 3).

4.0 Design Parameters

The main important parameters considered while designing FSTP are listed below

4.1 Mean Cell Residence Time

A substantial sludge and hydraulic retention period have to be provided in each of the treatment components recommended to ensure efficient biological degradation of the corresponding sludge and supernatant.

4.2 Atmospheric Conditions

To evaluate the efficacy of the treatment system, local climatic conditions need to be considered account of when designing treatment modules:

- Thermostat, to guarantee treatment effectiveness
- Rainfall, which will ensure the fact that the particulates in the sewage drying beds are dried.
- Humidity, for gauging drying time.

The aforementioned variables are taken into account when designing and detailing the treatment components. The procedure will be carried out in the mesophilic region of 20 to 45°C, which is conducive to many beneficial microbes that are in charge of breaking down the organic material[3].

4.3 Odour

Odour issues at the plant have been linked to the processing of faecal sludge. The smell of a rotting egg, which denotes the presence of hydrogen sulphide and other gases, is the odour of faecal sludge that is most distinctive. Utilizing vent pipes and establishing good sanitation practices in the construction while it is in use are crucial for minimizing odour-related issues.

5.0 Site Selection Criteria

For the faecal sludge management strategy to be implemented successfully, the location of the faecal sludge treatment facility must be identified. Before choosing a treatment location, the following factors are taken into account

5.1 Location's Ease and Travel

Accessibility to the treatment site and the distance from the emptied containment to the treatment facility can present significant challenges in collecting and transportation operations. Financially, it is not viable to move comparatively tiny amounts of faeces over long distances on congested roads. For private carriers, a location that's too far away implies fewer journeys per day, less income, and higher gasoline expenses[4].

5.2 Electricity Dependability

This criterion was not deemed crucial for the current location as the recommended approach does not require electricity.

5.3 Neighbourhood

A treatment facility might create an offensive odour while offloading. As a result, it must be placed at an appropriate distance from residential areas, which is 100m in the case of a sewage treatment plant. There are fields surrounding the current FSTP location plan, and there isn't a single building within 200 meters of it.

5.4 Provision of Land

Lack of land or the high cost of land frequently causes delays in construction projects. At the solid waste management site property, the Billuru Gram Panchayat has suggested a faecal sludge treatment plant.

5.5 Earth Science

A geotechnical investigation has been carried out at the location at which the FSTP is going to be constructed. This is always recommended to assess the geological conditions at the location, such as the type of soil, flooding patterns, and groundwater level, as these factors may have a direct impact on the technology decisions adopted[5].

6.0 Design Criteria

6.1 Remedy

The recommended treatment concept for handling faecal sludge in Billuru had been designed primarily

1. Area availability for treatment plant
2. Reusability of by-products
3. Implementation cost
4. Operations and Maintenance requirements
5. Aesthetics

As shared human resource is adopted for solid waste and liquid waste in Billuru, the design ensures minimal energy consumption as well as low operation and maintenance requirements.

6.2 Treatment Stages and Modules Adopted

In this take a look at, and try has been made to provide a proposal for fecal waste management for the Billuru Gp FSTP Project. Figure 4 shows the steps involved in solving fecal waste management in to form of a flowchart.

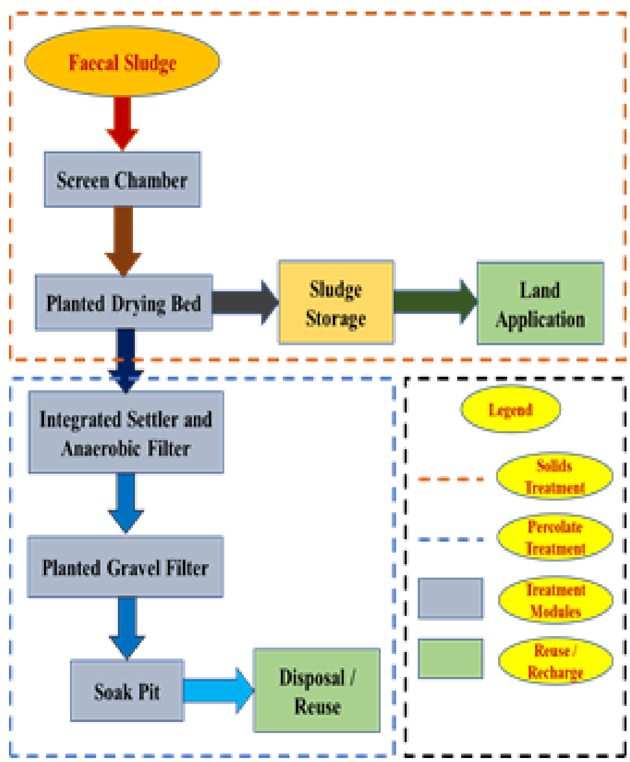

Figure 4. Schematic for blackwater treatment in Billuru.

Table 5. Treatment stages and module adopted

S. No.	Treatment Stages	Treatment Modules
1.	Pre-treatment	Screen Chamber
2.	Sludge Stabilisation/ Dewatering	Planted Drying Beds
3.	Liquid Wastewater Treatment	Integrated Settler and Anaerobic Filter, Horizontal Planted Gravel Filter
4.	Post-treatment and Disposal	Soak Pit
5.	Supporting civil infrastructure	Approach road, Toilet Block, and Roof for PDB

6.3 Data Collection

The process of collecting the quantity of generated waste from fecal waste management for the Billuru Gp FSTP Project is known as data collection. In this stage, Collection of the information takes place regarding the amount of waste generated from the fecal sludge treatment plant for two to three months of establishment (Table 6).

Table 6. Generated waste versus years

Sl. No.	Year	Month	Quantity(Kg)
1	2022-23	November	43
2		December	44
3		January	52

6.4 Mulching

The composting process is considered to be an environmentally friendly way of disposing of biological waste from the aspect of environmental protection with landfilling. Compost obtained only from biological waste can be used in organic agricultural production. Substrates used in composting are most commonly of plant, animal, or microbiological origin.

6.5 Microbial Activity

Microorganisms serve as the primary agents in the biological movement of nutrients, which is essential for living. The chemical composition of an element is altered through biotransformation; an organic alteration[3]. Biotransformation is capable of creating new atoms and transforming basic molecules into more complicated ones[5].

6.6 Microorganisms Involved

Since fungus and actinomycetes are more visible, it has been long forgotten how important non-mycelia microbes are to the composting process. Nitrogen, phosphate, and magnesium are excreted by bacteria, which makes decomposition faster and more effective. Compost heaps contain a variety of microorganisms, with psychrophiles, mesophiles, and thermophiles dominating. Psychrophilic bacteria generate less energy compared to other types of bacteria and are most active when the temperature is around 13°C. Mesophilic bacteria play a comparable function to psychrophilic bacteria and are most active between 21 and 32°C. The primary role is assumed by thermophilic bacteria, which continue to decompose in the decomposition process when the temperature of the compost mound increases above 45°C. Bacillus thrives best at temps between 50 and 65°C, and stearothermophilus, which is almost exclusively found in the culture at such temperatures, predominates at temperatures above 65°C.

Actinomycetes take part in the breakdown of substrates that are more challenging to decompose and favour a neutral or slightly alkaline pH of compost mixes. The majority of actinomycetes do best when the waste mound is adequately moist and oxygenated. Thermus/ Deinococus species thrive on organic materials at temperatures between 40 and 80°C, with 65 and 75°C serving as their ideal development range. Thermus species likely evolved to the hot compost system and played a significant part during the high heating period of the compost mixture. Historically, these species were only found in geothermal locations. Fungi break down leftovers in compost because they obtain nutrients from decaying plant matter, which enables bacteria to decompose even in the absence of cellulose[6]. To break down more difficult-to-degrade materials like lignin, hemicellulose, and cellulose, they develop hyphae that they use to enter the compost's materials.

7.0 Results and Discussions

Figure 5. Fecal sludge layer, organic waste layer, and final compost.

7.1 Practical Determination of Carbon Content

1. Weigh 1g of solid waste with electronic balance to 500ml of conical Flask and keep it on a wire gauge.
2. Addition of microbes-Cyanobacteria inoculum (biomass).

Figure 6. Determination of organic carbon.

3. Add 10ml of potassium di chromite and 20ml of sulphuric acid with the help of a 100ml measuring cylinder and then keep it aside for 30min.
4. Add 100ml of distilled water to and add 10ml of pure ortho-phosphoric acid
5. Add 2-3 drops of di-phenyl amine indicator into the flask.
6. Titrate it with 0.5N ferrous ammonium sulfate and note down the initial reading.
7. Colour change from violet to dark green stop titration and note down the reading.
8. Note down the final titrated reading and initial titrated reading and find out the percentage of carbon content on solid waste (Figure 6).

A precise representation of compost advancement events can be generated by tracking different physiological microbial profiles throughout the process of decomposition. Initial profiling demonstrated that variations in the C/N ratio and temperature were linked with an anticipated decline in microbial biomass. Midway

Table 7. Composting rate of two pits with balanced and unbalanced C: N ratios

Parameters	Bin 1	Bin 2
Weight	2 kg	2 kg
Carbon/Nitrogen ratio	Balanced (30:1)	Unbalanced (23:2)
Composting time	4 Days	7 Days
Image		

through the mesophilic stage of composting, the bacterial community continued to expand and more enzymes emerged, which led to proper humification. Finally, during the chilling or maturation stage of decomposition, the microbial bulk gradually decreased. Generally speaking, compared to the bacterial community, the fungal density seen throughout the procedure was smaller. Certain process adjustments, such as adding bulking agents like sawdust, wood shavings, and rice husk to the base, can help the microbiota grow effectively. This would maintain the purity of compost and improve the C/N ratio.

Table 7 shows the composting rate of two pits with balanced and unbalanced C:N ratios. From the results, it can be seen clearly that the carbon and nitrogen ratio in the balanced pit composts quickly compared to the unbalanced pit. In Bin 1, waste weight of 5kgs with a balanced C:N ratio takes 4 days to compost, and in Bin 2 with the same weight of takes 7 days to compost recently, the entire world has been facing a waste management problem which is becoming bigger day by day due to increasing population. With a lack of C:N ratio balance knowledge in the waste.

8.0 Conclusions

1. This study has provided a plethora of opportunities and experiences in waste management.
2. It not only gives theoretical knowledge regarding waste management but also practical knowledge of the composting process concerning the rate of composting and balancing the C:N ratio.
3. It is applicable in all regions where the composting process occurs at a slower rate.
4. This study can be used in developing countries for quantitative and morphological waste analysis, as a starting point for further development of waste management programs.

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