Fecal Sludge Management in India – A State of Play Report

BILL & MELINDA GATES foundation

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Emergent Ventures India Pvt. Ltd.

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EXECUTIVE SUMMARY

India faces an acute problem of fecal sludge disposal and its responsible management. The Bill and Melinda Gates Foundation and Emergent Ventures India (EVI) are collaborating for establishing fecal sludge to energy as a viable solution for this issue. The focus of this endeavor is urban India. This report is the outcome of research work on the status of existing practices of fecal sludge management in India. It is broadly divided into five research areas as below:

Section 1 – FECAL SLUDGE MANAGEMENT IN URBAN INDIA
This section describes the processes in place for collection and disposal of fecal sludge in India. The mechanisms have been outlined individually for sewered and non-sewered areas. The section also gives useful case studies in decentralized septage management.

Section 2 – KEY PROGRAMS AND POLICIES
This section highlights the policies and programs of the Indian Government aimed at financing sanitation projects in the country. The section ends with a note on recommendations for inclusion of non-sewered sanitation solutions and associated private sector developers under these programs.

Section 3 – TECHNOLOGIES FOR FECAL SLUDGE TO ENERGY CONVERSION
The section talks about various technological options for converting fecal waste to energy, presenting insights from available research and highlighting areas that demand additional analysis.

Section 4 – CDM POTENTIAL OF FS TO ENERGY PROJECTS
This section presents an estimate of emission reduction potential of FS to energy conversion and a brief description of the process of CDM registration of such an activity.

Section 5 – CONCLUSIONS AND NEXT STEPS
This section summarizes key takeaways from the report and future steps for engaging stakeholders in FS to energy conversion.

1 FECAL SLUDGE MANAGEMENT IN URBAN INDIA

1.1 SOURCES OF FECAL SLUDGE

In urban India, sources of fecal sludge vary according to the sanitation facility available in residential settlements. Typical sanitation options that exist for different residential settlement types have been discussed below:

TABLE 1: SANITATION OPTIONS AVAILABLE IN SETTLEMENTS[i]

Settlement Type	Typical sanitation services available
High-income Residential	Septic Tanks (With or without soak pits), Sewer connections in some cases
Medium-income Residential	Septic tanks/Leach pits, Sewer connections in some areas
Low-income Residential	Septic tanks/Leach pits
Multistory Residential Apartments	Sewer connections/Shared septic tanks
Low-income Informal Settlements	Community/Public toilets ---->Septic tanks-->Open drains
Illegal squatter slum settlements	Shared toilets, Open defecation, Mobile Toilet Vans (MTVs)
Institutional buildings	Large septic tanks with soak pits

The National Family Health Survey-3 (NFHS, 2005-06) reported that 17% urban households in India did not have access to any toilets at home, 24% households were sharing toilets (technologies not specified), about 19% had their toilets connected to sewers, the majority had on-site installations – about 27.6% households had septic tanks and 6.1% had pit latrines that were classified as "improved". Another 5% toilets were as "Flush/pour flush not to sewer/septic tank/pit latrine" – in other words, human excreta from these installations were being let out untreated onto land and water bodies without any confinement or treatment. In other words, about 33% households had "improved" on-site systems and 5% of the households were on on-site unimproved toilets.

The National Sample Survey (65th Round, 2010) estimated that 8% of the urban households were dependent on pit latrines, and 29% dependent on toilets connected to septic tanks. Census of India 2011 indicates that only 32.7% of urban households are connected to a piped sewer system whereas 38.2% dispose off their wastes into septic tanks and about 7% into pit latrines. Further, about 5 million pit latrines are insanitary (have no slabs or are open pits); 1.3 million are service latrines – of which 0.9 million toilets dispose faeces directly into drains, 2,00,000 latrines are serviced by humans (illegally), 1,80,000 latrines serviced by animals. Finally, about 18.6% urban households still do not have access to individual toilets – about 6% use public/community toilets and 12.6% are forced the indignity of open defecation. According to a USAID study (2010) by 2017, the number of urban households with toilets connected to septic tank will increase to 148 million urban households. Therefore on-site pit latrines and septic tanks account for a substantial proportion of toilets in urban India – 48% of urban Indian households depend on onsite facilities (Census 2011), and this proportion is increasing[ii].

The graph below shows the projected increase in these numbers over the next five years. Even though the access to sewers is projected to go up, number of septic tanks and pit latrines would also increase. This is largely due to a projected decrease in the number of people practicing open defecation.

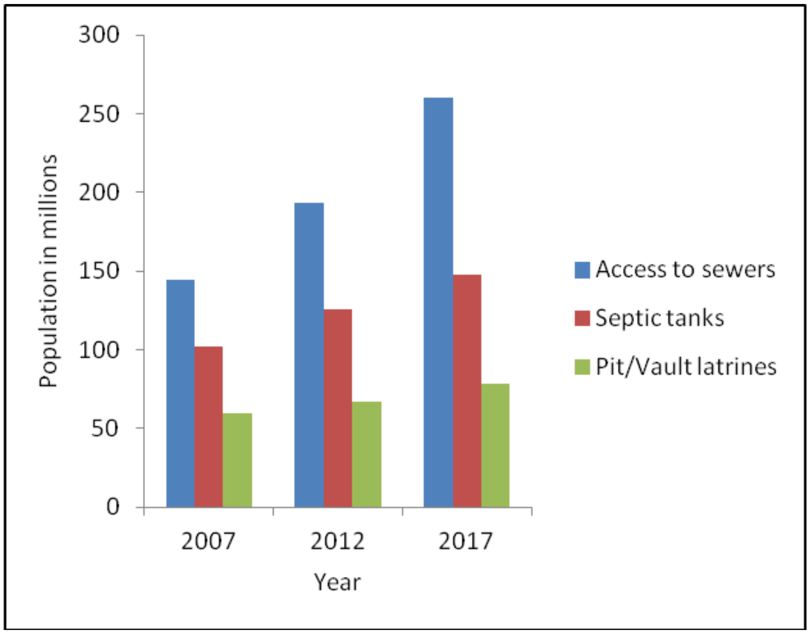

FIGURE 1: NUMBER OF RESIDENTS WITH ACCESS TO SANITATION OPTIONS

1.2 COLLECTION, TREATMENT, AND DISPOSAL OF FECAL SLUDGE

Fecal sludge is collected from on-site sanitation systems, such as latrines, non-sewered public toilets, septic tanks and aqua privies. Fecal sludge is also discharged into sewerage system from households connected to sewage lines. Sewage sludge includes both wastewater generated in toilets and wastewater generated in kitchen, bathroom, and laundry.

Depending on the place of origin, the various modes of generation and treatment of fecal sludge are described in the following sections.

1.2.1 FECAL SLUDGE FROM AREAS WITH SEWERAGE ACCESS

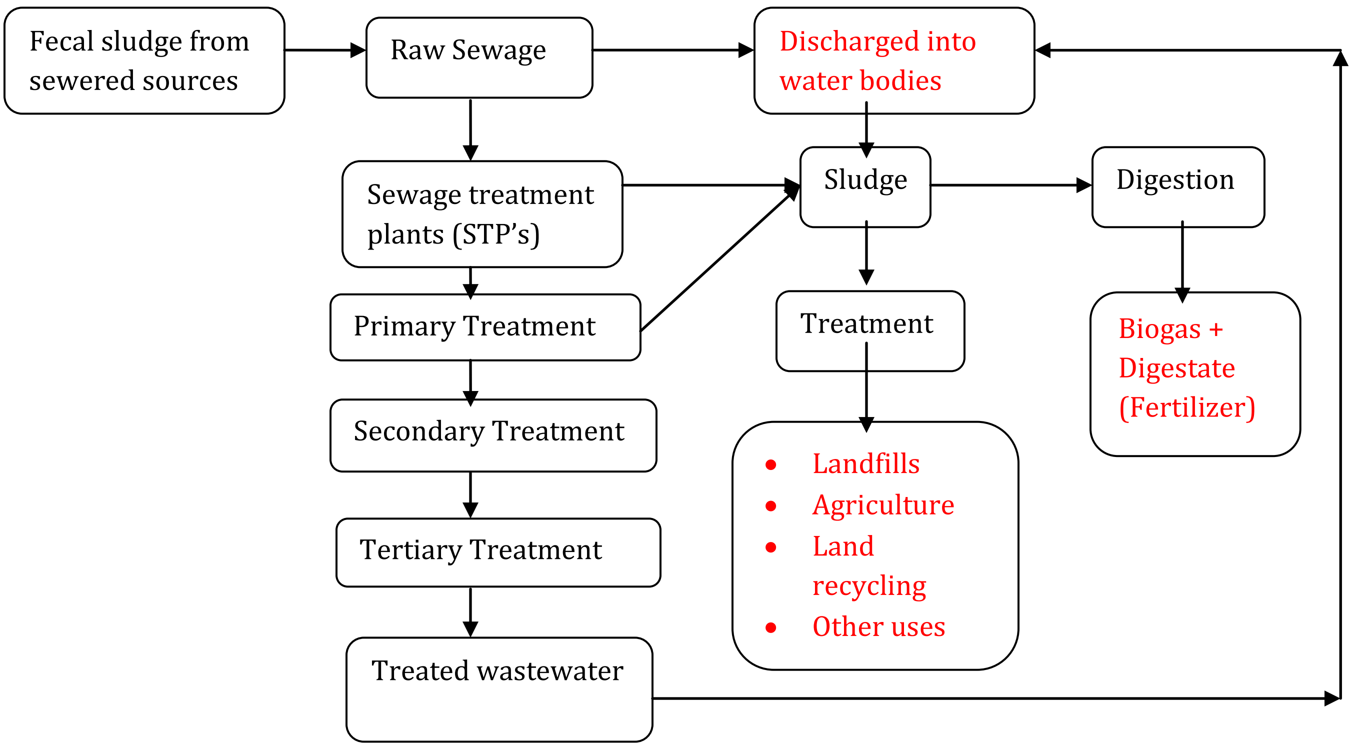

FIGURE 2: TREATMENT OF FECAL SLUDGE GENERATED FROM MUNICIPAL SOURCES

According to the report of the Central Pollution Control Board (2009), the estimated sewage generation from Class - I Cities and Class - II towns is 38,255 million litres per day (MLD) out of which only 117,88 MLD (31%) is being treated and the remaining 26,467 MLD is disposed into the water bodies without any treatment due to which three fourths of surface water resources are polluted[iii].

Across the country, 27 cities have only primary treatment facilities and 49 have primary and secondary treatment facilities. The level of treatment available in cities in terms of sewage being treated varies from 2.5% to 89% of the sewage generated. Only 6% of Indian cities have access to sewerage facilities[iv].

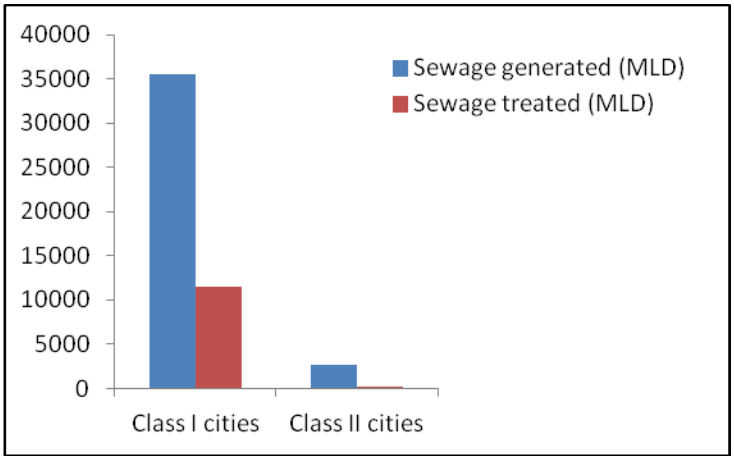

FIGURE 3: SEWAGE GENERATED VS SEWAGE TREATED IN INDIAN CITIES

The disparity shown above in sewage generated and sewage treated indicates a huge requirement of a sustainable fecal waste treatment system.

TABLE 2: DIFFERENCES IN SEWAGE MANAGEMENT SYSTEMS OF CLASS I & CLASS II CITIES OF INDIA

Parameter	Class I cities (Population > 100, 000)	Class II cities (Population: 50,000 – 100,000)
No. of cities	498	410
Sewage generated (MLD)	35,558	2,697
Sewage treated (MLD)	11554	234
Percentage of sewage treated	31%	8%
Raw, untreated sewage available for potential waste to energy plants	24,004 MLD	2,463 MLD
Main treatment technologies employed with other primary or tertiary treatment units[v]		
Activated Sludge process	59.5%	5.6%
Fluidized aerobic bio-reactor (attached growth)	1.1%	
Trickling Filters or Biofilters	3.3%	7.4%
UASB	26%	10.6%
UASB+Activated sludge process	1.5%	
Waste Stabilization Ponds	5.6%	71.9%
Oxidation Pond (single stage)	1.2%	
Anaerobic digester + Trickling filter	0.1%	
Karnal Technology (Effluent disposal through Plantation)	0.2%	4.5%
Primary treatment only	1.4%	

EXISTING PRACTICES FOR DISPOSAL OF SEWAGE SLUDGE

At present, sewage sludge and effluents from STPs are frequently disposed off on agricultural lands for irrigation/manure purposes. However this method is not recommended unless tertiary treatment is done since effluent from STPs also contains harmful substances that can adversely impact human health. The composition of the effluent from STPs depends on the wastewater treatment process and on the source of the sewage. In general it contains both toxic and non-toxic organic wastes.

TABLE 3: HARMFUL AND USEFUL SUBSTANCES IN SEWAGE SLUDGE

Harmful substances	Useful substances
• Toxic chemical compounds - pesticides, aromatic hydrocarbons, chloro-benzenes etc • Pathogens - Bacteria, viruses, and protozoa • Heavy metals – Zinc, copper, nickel, cadmium etc.	• Nitrogen • Phosphorus • Organic compounds • Materials of plant and animal origin, including proteins, amino acids, sugar and fats.

The high concentrations of Nitrogen, phosphorous, and organic compounds in sewage sludge make it a beneficial fertilizer for plants. An alternative method of disposal being considered by some STPs is anaerobic digestion and conversion to biogas and fertilizer. Various factors are driving this as shown:

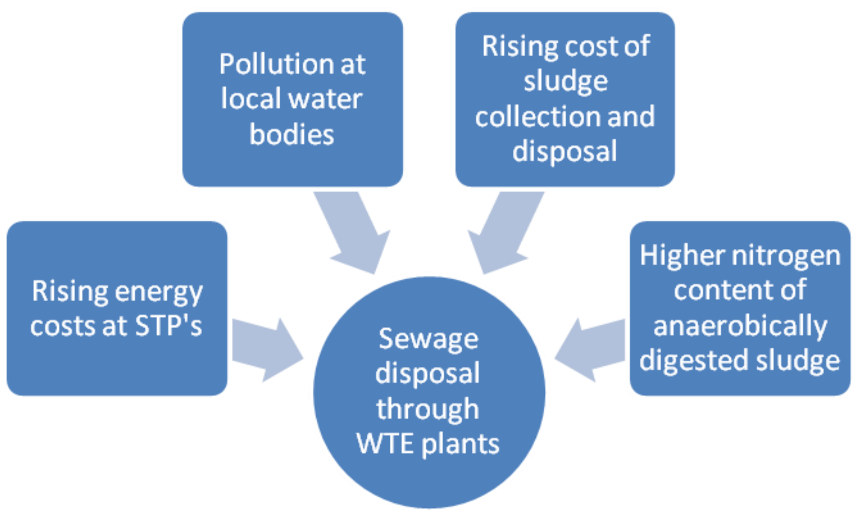

FIGURE 4: DRIVERS FOR INSTALLING WASTE TO ENERGY PLANTS AT STP'S

This method has been successfully implemented by the Surat Municipal Corporation at its Anjana STP.

TABLE 4: CASE STUDY OF WASTE TO ENERGY PLANT AT ANJANA STP

Waste to energy plant, Anjana STP, Surat Municipal Corporation	
Power generation capacity	0.5 MW
Sewage handling capacity	76 MLD
Year of Commissioning	February 2004
Project Developer	Chemtrols Engineering Ltd.
Project cost	26.0 million, 50% subsidy from MNES

This model can be replicated to other STPs across India, however its financial feasibility is to be ascertained.

1.2.2 FECAL SLUDGE FROM ON-SITE SANITATION SYSTEMS

Areas without sewerage access depend on on-site sanitation (OSS) systems that are currently limited to septic tanks in urban areas. Most of these systems are emptied manually or by private operators in a few areas without adequate protective gears and equipments.

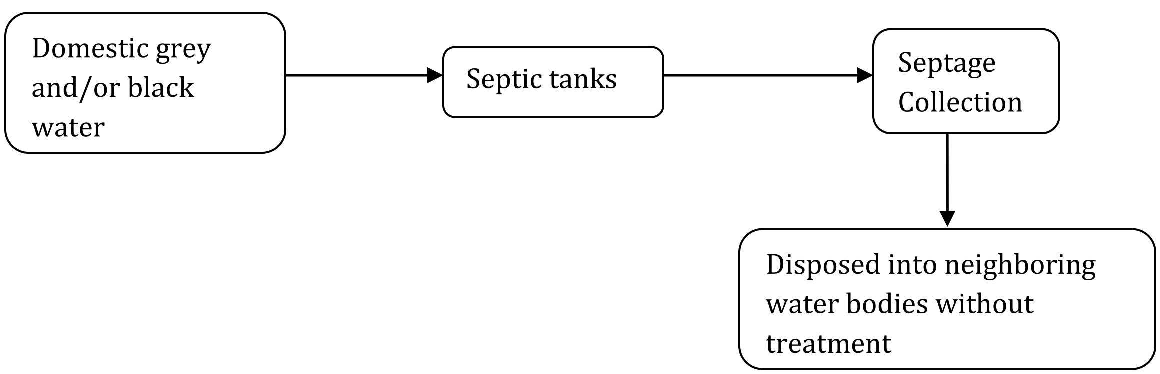

FIGURE 5: DISPOSAL OF FECAL SLUDGE GENERATED FROM ON SITE SANITATION SYSTEMS

There are an estimated 102 million septic tanks and 60 million latrines in cities in India. As per projections, by 2017 about 148 million urban people would have septic tanks[vi].
However, there are no known septage treatment facilities in the country. The size of a septic tank in individual houses in India ranges from 1 to 4 m^3, the size of a septic tank in office or apartment buildings ranges from 10 to 100 m^3. Septic tanks receive black and/or grey water and separate the liquid and solid components. The liquid effluent gets drained off to a soak pit to dispose it into the ground. The solids remain in the tank and are decomposed over several months.

Issues faced with septic tanks and septage management in India are summarized below:

- Construction of septic tanks are not as per the standards issued by Indian Standard Organization for construction of septic tanks
- ULBs are not adequately equipped with infrastructures required for cleaning of tanks
- Contamination of groundwater due to percolation of effluent and sludge.
- De-sludging is mostly done manually, causing spread of fecal born diseases.
- Grey-water containing harsh chemicals such as soap and detergents is also discharged in septic tanks, which imbalances the waste treatment process done by bacteria.
- Septage is irresponsibly disposed off on open lands, in absence of a strong regulatory framework and scalable treatment options

Septage management should be an integral part of sanitation schemes. State should make adequate budgetary provision for effective septage management. State governments should enforce implementation of septage management and monitoring program at the ULB[vii].

SEPTAGE COLLECTION AND DISPOSAL

In most cities, septic tank desludging and cleaning services are provided by private players or municipalities who collect the septage at the building level and transport it to disposal sites. In other cities, it is done manually by sanitary workers who deposit the septage within the family's compound, nearby lanes, drains, open land or waterways. In some cities, it is being supplied to nearby farmers for use as fertilizer. Given below are few case examples of septage management systems operating in India and outside.

TABLE 5: CASE STUDY OF SEPTAGE COLLECTION AND RECYCLING, BANGALORE

Commercial re-cycling of fecal sludge, Bangalore[viii]
➢ Private contractors in operation for emptying of septic tanks ➢ Fecal sludge is then given to farmers for application as fertilizer, farmers currently do not pay for this service but have reported increased crop yields ➢ Prices vary from INR 500 to INR 3000, for emptying of one septic tank ➢ Though no incidence of fecal-oral diseases was mentioned by farmers, a few reported boils on feet due to application of raw fecal sludge

TABLE 6: CASE STUDY OF SEPTAGE MANAGEMENT, MALAYSIA

100% Septage management achieved in Malaysia[ix]
➢ 27% Population of Malaysia dependent on septic tanks ➢ **Policy enablers for ULB**: Tariff of $1.70/month compared to $2.20/month for sewer-connected households, $14 - $50 per tank for special de-sludging requests ➢ Participation of individual septic tank owners in de-sludging activities

TABLE 7: CASE STUDY OF SEPTAGE MANAGEMENT, MANILA, PHILLIPINES

Septage management in Philippines
➢ 40% Population of Philippines dependent on septic tanks

➢ **Policy enablers for Private de-sludgers**: "Environmental fee" of 10% is charged by adding 10% to the water bill as de-sludging charges ➢ Laws make it mandatory for ULB's to provide septage collection & treatment facility in non-sewer connected areas

TABLE 8: CASE STUDY OF SEPTAGE MANAGEMENT, DHAKA, BANGLADESH

Septage management through connection to sewer networks
➢ An organization, DSK provides septage collection, transportation and discharge (into main sewer line) facilities in Bangladesh ➢ Expansion of services to include middle and higher income neighborhoods, schools, and other institutions has ensured a steady revenue stream for the organization

We can see from the above cases that appropriate regulatory mechanisms in other countries have led to effective use of existing septic tanks for non-sewered regions.

Certain organizations in India, like the SKG Sangha and the Sulabh International Social Service Organization have set up community biogas plants for converting fecal sludge to energy.

TABLE 9: CASE STUDY OF COMMUNITY TOILET LINKED BIOGAS PLANTS, SULABH INTERNATIONAL

Community toilet linked biogas plant, Sulabh International
➢ "Sulabh model" digester design approved by MNRE ➢ Biogas generated is used to power engines, lamps, and burners ➢ Sulabh has constructed five community toilets-cum-bath complexes linked with biogas digesters in Kabul, Afghanistan, in collaboration with the Kabul Municipality ➢ 200 biogas plants of 35-60 cu.m capacity set up so far in India

TABLE 10: CASE STUDY OF NIGHTSOIL FED BIOGAS PLANTS, SKG SANGHA

Nightsoil fed biogas plants, SKG Sangha
➢ Night soil fed biogas plants installed in states of Karnataka, Andhra Pradesh and Tamil Nadu ➢ Biogas plants in sizes ranging from 25 to 1,000 cu.m gas per day

Other on site sanitation solutions

Sulabh International has developed many on site sanitation systems, an example of which is a Twin pit toilet system.

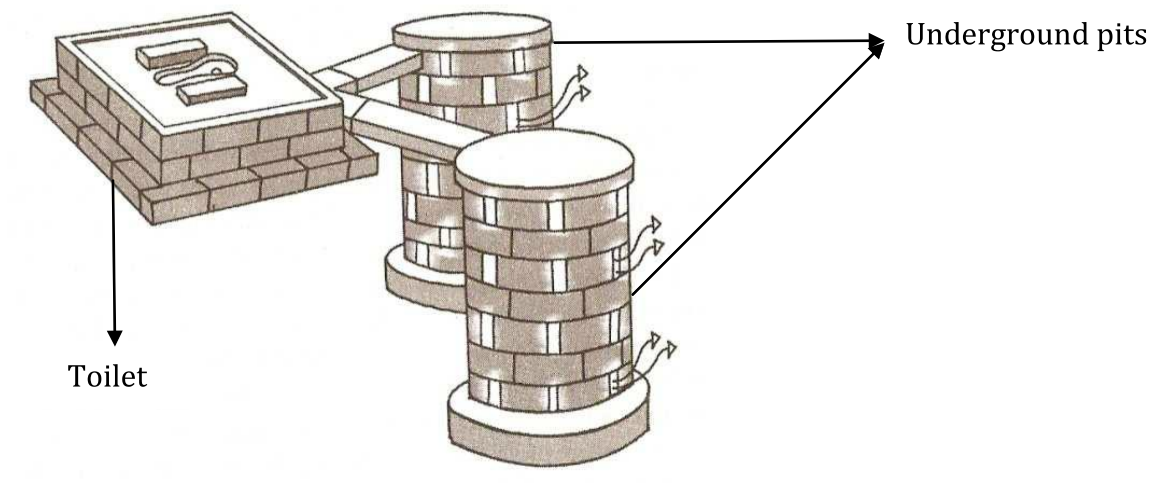

FIGURE 6: SCHEMATIC OF TWIN PIT TOILET SYSTEM

Sulabh has installed over 1.2 million of these systems and trained over 19000 masons to construct these toilets with locally available materials.

TABLE 11: KEY FEATURES OF TWIN-PIT TOILET BY SULABH INTERNATIONAL

Twin Pit Toilet system – Key features
➢ The pits are used alternately, each getting filled up in 3 years ➢ Two years after a pit gets filled, the excreta degrades to form an odorless, pathogen free compost that can be dug out and used as manure ➢ We visited Sulabh's facility in Delhi, where we witnessed this manure (termed as "Black Gold" by the organization's workforce

This twin pit toilet system eliminates the need for sewer connections or septic tanks and makes for an effective on site sanitation solution.

1.2.3 FECAL SLUDGE FROM OPEN DEFECATION

Around 665 million people in India defecate in the open, which is over 50% of the total population. About 100,000 tons of fecal matter is generated in the open every day[x]. Open defecation typically happens in one of the three locations:

- Open fields in villages, usually near farms
- Next to water bodies
- Open land areas near residences

The fecal sludge in open fields and in proximity to water bodies usually is not collected and gets naturally assimilated in the surrounding environment. Where the fecal sludge is on open lands near residences and roads, it is sometimes collected as part of the MSW collection and handling program.

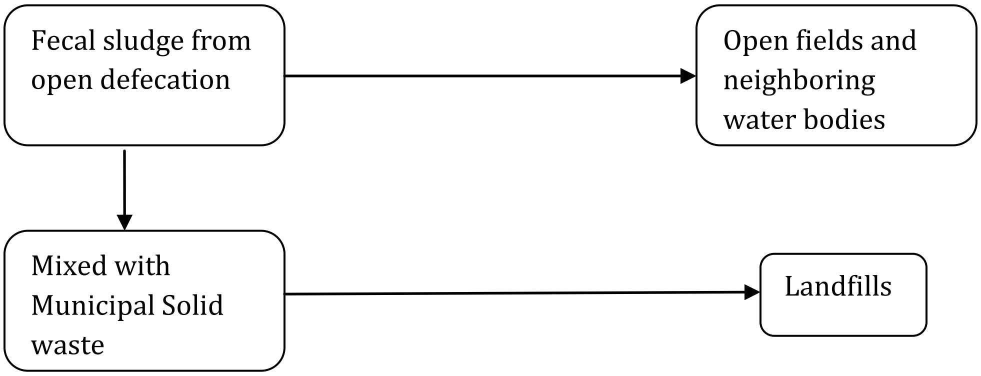

FIGURE 7: DISPOSAL OF FECAL SLUDGE GENERATED FROM OPEN DEFECATION

2 KEY PROGRAMS AND POLICIES

India is a signatory to the **Millennium Development Goals (MDGs)** that entail extending access to improved sanitation to at least half the urban population by 2015, and 100% access by 2025. This implies extending coverage to households without improved sanitation, and providing proper sanitation facilities in public places to make cities free of open defecation.

The Ministry of Urban Development (MoUD) is responsible for formulating policies, and supporting and monitoring programmes concerning urban development issues in the country. It also coordinates the activities of various Central Ministries, State Governments and other nodal authorities. Key policies and programs being implemented by the ministry are described below.

2.1 JAWAHARLAL NEHRU NATIONAL URBAN RENEWAL MISSION

Launched by the Government of India in December 2005 and to be implemented for a period of seven years, the JNNURM aims at providing central grants to ULBs for carrying out urban renewal projects. The mission has selected 63 cities eligible for receiving assistance for infrastructure development and aims to invest around USD 20billion. The mission makes it **mandatory** for the ULB's to provide basic services to the urban poor including security of tenure at affordable prices, improved housing, water supply and sanitation. The ULB's are also encouraged to implement projects on the PPP model. As of now, an assessment of the programme's impact is underway and an improved successor plan will be launched in the twelfth five year plan (2012-17)[xi].

Eligible sectors and projects under JNNURM are:

1) Urban renewal: Widening of roads, replacement of old and worn out pipes by new and higher capacity ones, renewal of the sewerage, drainage, and solid waste disposal system etc.
2) Water supply (including desalination plants) and sanitation
3) Sewerage and solid waste management
4) Construction and improvement of drains and storm water drains
5) Urban transportation including roads, highways, expressways, MRTS, and metro projects

6) Parking lots and spaces on PPP basis
7) Development of heritage areas
8) Prevention and rehabilitation of soil erosion and landslides
9) Preservation of water bodies

The highlighted sectors above concern the improvement of fecal sludge management in urban India.

2.2 NATIONAL URBAN SANITATION POLICY (NUSP)

With a vision to ensure that all Indian cities and towns become totally sanitized, healthy and livable, the policy aims at development of state sanitation strategies and city sanitation plans, creation of open defecation free cities & sanitary and safe disposal of all human and liquid wastes.

Policy goals
The overall goal of this policy is to transform urban India into a community-driven, totally sanitized, healthy and livable cities and towns.

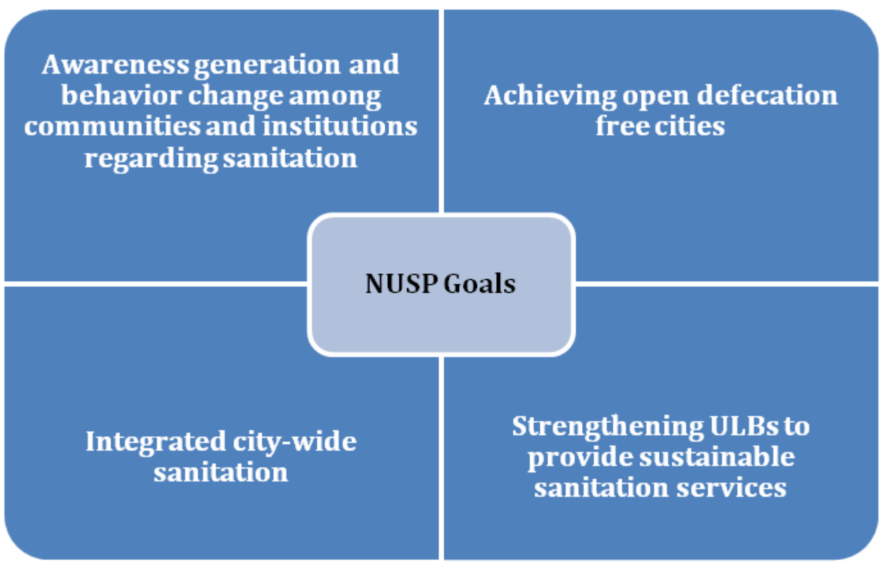

FIGURE 8: GOALS OF THE NATIONAL URBAN SANITATION POLICY

State level Sanitation Strategy
In order to achieve the above goals, the NUSP directs each state to formulate its own state level sanitation strategy that deals with the following:

- **Clear assignment of institutional responsibility, resources and capacities:** State Urban Sanitation Strategies must ensure clear ULB responsibility and availability of financial and personnel resources necessary for ULBs to discharge their functions. ULBs also to be accorded power over agencies that carry out sanitation related activities in the city but are not directly accountable to them, e.g. para-statals and PHEDs.

- **Setting standards at the State Level with relevant State Boards:**
  - Environmental Standards (e.g. effluent parameters, low energy intensive technology etc.): State Pollution Control Boards
  - Public Health Standards: State Health Department
  - Processes and design standards: Public Health & Engineering Departments
  - Service delivery standards: Urban Development Department

- **Planning and financing at the State Level:**
  - ULBs will be made responsible for planning and financing infrastructure, and leveraging private investments as may be required for achieving outcomes.
  - ULB's to be given powers for setting tariffs, inter-governmental fiscal transfers and devising targeting of subsidies
  - State governments will launch awards for best performing cities to bring about a competitive spirit in achieving total sanitation.

- **Reaching the un-served populations and the Urban Poor at the State level:**
  States will provide individual sanitation facilities preferentially, and community facilities where individual provision is not feasible. Every urban dweller should be provided with minimum levels of sanitation, irrespective of the legal status of the land in which he/she is dwelling, possession of identity proof or status of migration.

- **Service Delivery in cities:**
  ULBs are responsible for asset-creation and managing systems including service delivery. In this context, the ULB may bring in public, private and community agencies/groups to provide services on its behalf.

- **Monitoring & Evaluation at the State and City Levels:**
  The State government will be responsible for M&E of its cities' performance, and hence needs to devise data collection and reportage systems using outcome indicators.

- **Capacity Building & Training:**
  The state strategy needs to identify agencies that will train its state level, ULB personnel and orientation of elected representatives.

All cities have been provided guidelines to formulate a **City Sanitation Plan (CSP)**, which is a detailed roadmap towards achieving the goals mentioned in the policy. One of the key agencies, preferably the ULB, will become the City Sanitation Implementing Agency for the CSP for the city. The emphasis is on improving the efficiency of existing sanitation infrastructure and service delivery. The implementing agencies can apply for assistance for funding projects proposed as part of City Sanitation Plans through Govt of India schemes like JNNURM, UIDSSMT, 10% Lump Sum for NE States, Satellite Township Scheme, etc.

A team at GIZ has supported cities such as Shimla, to prepare and implement sanitation plans under the above policy and assess costs for these measures[xii]. Some of their suggested measures in the CSP for Shimla are given below:

TABLE 12: KEY HIGHLIGHTS OF CITY SANITATION PLAN, SHIMLA

Sanitation Problem	Key issues	Recommendations by GIZ team
Only 4.0 MLD sewage treated in Shimla despite installed treatment capacity of 35.6 MLD.	• Missing links in sewage grid • Lack of accountability due to functional overlap between govt. departments	• Contracting a private agency to Build, Refurbish, Operate, and Maintain the sewerage system • Decentralized wastewater treatment systems in areas that are newly developed or not sewer connected due to topographical constraints
Irresponsible disposal of septage from STP's and septic tanks into open drains	• Lack of systems for septage collection, conveyance, and treatment • Septic tanks not designed according to CPHEEO codes • Inadequate sludge disposal facilities at STP's	• Integrating septic tanks with a decentralized treatment system where sewerage system is not possible • Disposal of septage at existing STP's, where possible • Rehabilitation and upgradation of septic tanks • Institutionalization of septage clearance and regularization of private desludgers.
Open defecation due to poorly designed and operated public toilets	• 1 toilet seat per 190 persons (opposed to norm of 1 per 35 persons) • Lack of staff and inadequate water supply for cleaning	• Mobile toilets in areas with large floating population
Weak institutional frameworks	• Lack of capacity building and skill upgradation for ULB staff	• Corporatization of units for higher efficiency • Performance linked incentive programs to enhance service delivery

2.3 URBAN INFRASTRUCTURE DEVELOPMENT SCHEME FOR SMALL AND MEDIUM TOWNS

The scheme was launched by MoUD in 2005 for duration of seven years. It applies to all cities/towns as per 2001 census, excepting the ones covered under (JNNURM). It has a budget of around USD 20 billion and covers projects under the same areas as the JNNURM.

As on 30th April 2011, 1037 projects have been approved under this scheme, 174 of which are on sewerage systems[xiii].

Implementation Framework:

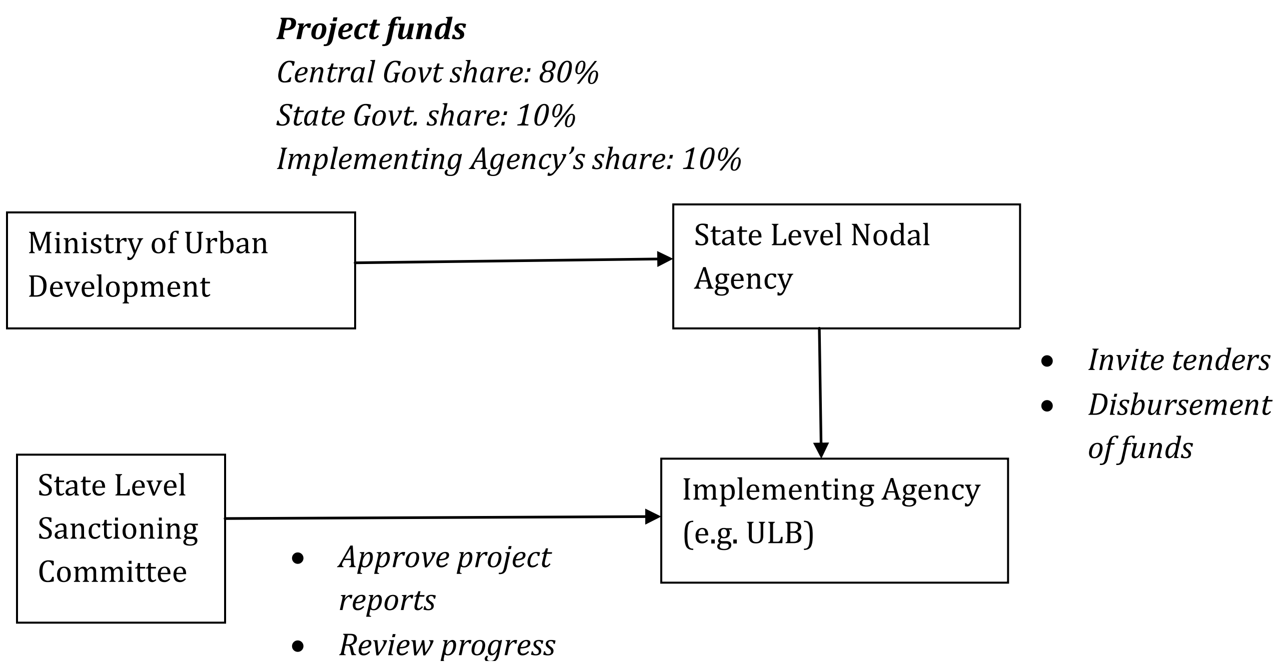

FIGURE 9: IMPLEMENTATION FRAMEWORK OF THE UIDSSMT

The State Level Sanctioning Committee will assign higher priority to projects relating to water supply including sanitation, sewerage, solid waste management, road network and drainage.

2.4 POLICY FOR NON-SEWERED SOLUTIONS

All sanitation projects under the JNNURM or the UIDSSMT policies have been related to refurbishment or construction of sewerage networks in cities. Due to non-availability of a scalable non-sewered solution in urban areas, no non-sewered projects have been seen as being funded under these schemes. Unlike STPs, these solutions cater to a small number of individuals and need to be set-up in large numbers, making the monitoring and evaluation of these projects more difficult. This is another reason why these solutions have not been successfully implemented under the above frameworks.

On site sanitation systems like the two pit latrines have been setup under the Total Sanitation Campaign, a rural sanitation program launched by Indian Government in 1999. Mr. P.K Jha, an ex – Director General at Sulabh International prepared a paper on "Technology options for on-site sanitation" for the "Ministry of Drinking Water and Sanitation" for this program[xiv]. These on site sanitation solutions and technology options for non-sewered sanitation can be implemented in urban areas as well, with the support of a proper policy framework.

2.5 IMPLEMENTATION MECHANISMS IN SANITATION PROJECTS

Currently, sewage management systems in India are controlled and implemented by government bodies, with various organizations at the central, state, and local levels.

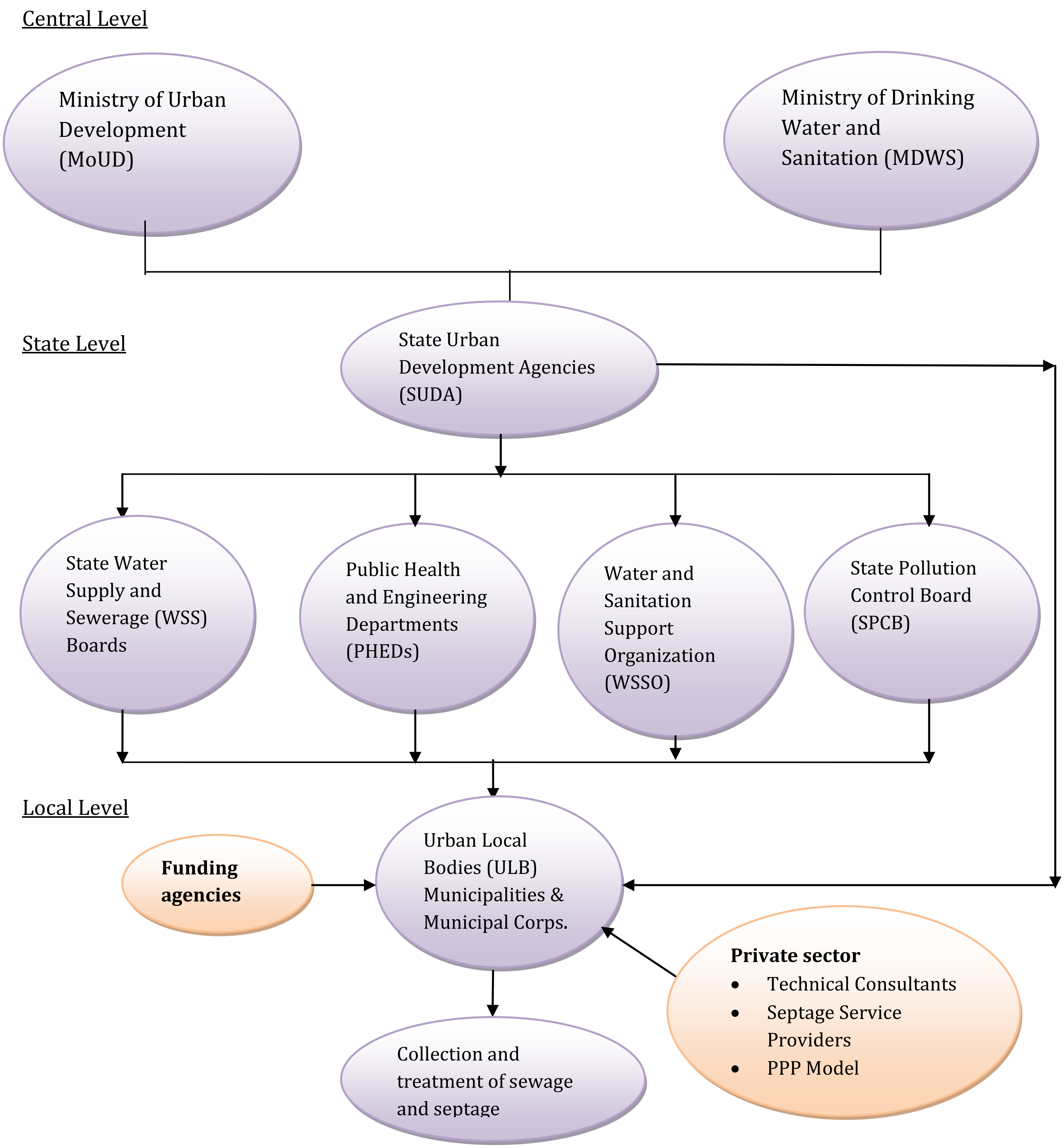

FIGURE 10: SEWAGE MANAGEMENT IMPLEMENTATION STRUCTURE

2.5.1 ROLE OF GOVERNMENT BODIES

TABLE 13: ROLES OF GOVERNMENT BODIES IN SEWAGE MANAGEMENT

Government body	Roles
Ministry of Urban Development (MoUD)	• Nodal Ministry in charge of various aspects of Urban Development including Urban Water Supply and Sanitation. • Formulates policies and strategies pertaining to various aspects of Urban Development including Water Supply, Sanitation and Municipal Solid Waste Management in the Country • Provides technical and financial assistance to the States.
Central Public Health and Environmental Engineering Organization (CPHEEO)	• Technical wing of the Ministry of Urban Development • Provides policies, strategies and guidelines for water supply and sanitation to the States & UTs Governments • Acts as an Advisory body at Central level to advise the concerned State agencies and Urban Local Bodies (ULBs) in implementation, operation & maintenance of urban water supply, sanitation and Solid Waste Management projects and helps to adopt latest technologies in these sectors.
Ministry of Drinking Water and Sanitation (MDWS)	• Planning, implementation and monitoring of centrally sponsored programmes and schemes for safe drinking water and sanitation in rural areas; • Support R&D initiatives, IEC and HRD activities for all stakeholders in drinking water and sanitation sector; • Technical support to States through seminars, interactions, documentation of best practices and innovations; • Provide inputs to other Departments/ Ministries for formulation of policies impacting water and sanitation issues;

State Urban Development Agencies (SUDA)	• Delegate Water Supply and Sewage (WSS) responsibilities to state level Public Health and Engineering Departments (PHEDs), State WSS Boards, city-level WSS boards, and ULBs. • Regulation of revenues, providing budgets, and disbursement of funds to WSS projects. • Technical support to ULBs.
State Water Supply and Sewerage (WSS) Boards	• Manage service provision in each particular state • Provide technical services to ULBs
Public Health and Engineering Departments (PHEDs)	• Provide technical support to ULBs • Support during the construction and development of WSS projects. • Design, fund, and build infrastructure for WSS projects
Water and Sanitation Support Organization (WSSO)	• Funding, Planning and regulation, Technical support, Monitoring & Evaluation (M&E), Training, Inter-sectoral coordination with ULBs for WSS projects.
State Pollution Control Board (SPCB)	• Approval of sites selected by ULBs for septage management.
Urban Local bodies (ULB)	• Formulate their own bye-laws and rules for management of septage in the city • Responsible for wastewater discharge, collection, and treatment. • Inspect onsite system and pumping of septic tanks, make arrangements to collect baseline data – type of latrine disposal, effluent disposal arrangement, size, age, when it was last cleaned, availability of access, arrangement for disposal of effluent (if any) of existing installations. • Plan for workable desludging schedules. • Coordinate with existing service providers and ensure that collection, transport and disposal of septage is carried out in a manner safe to households, environment and public health.

2.5.2 ROLE OF PRIVATE SECTOR

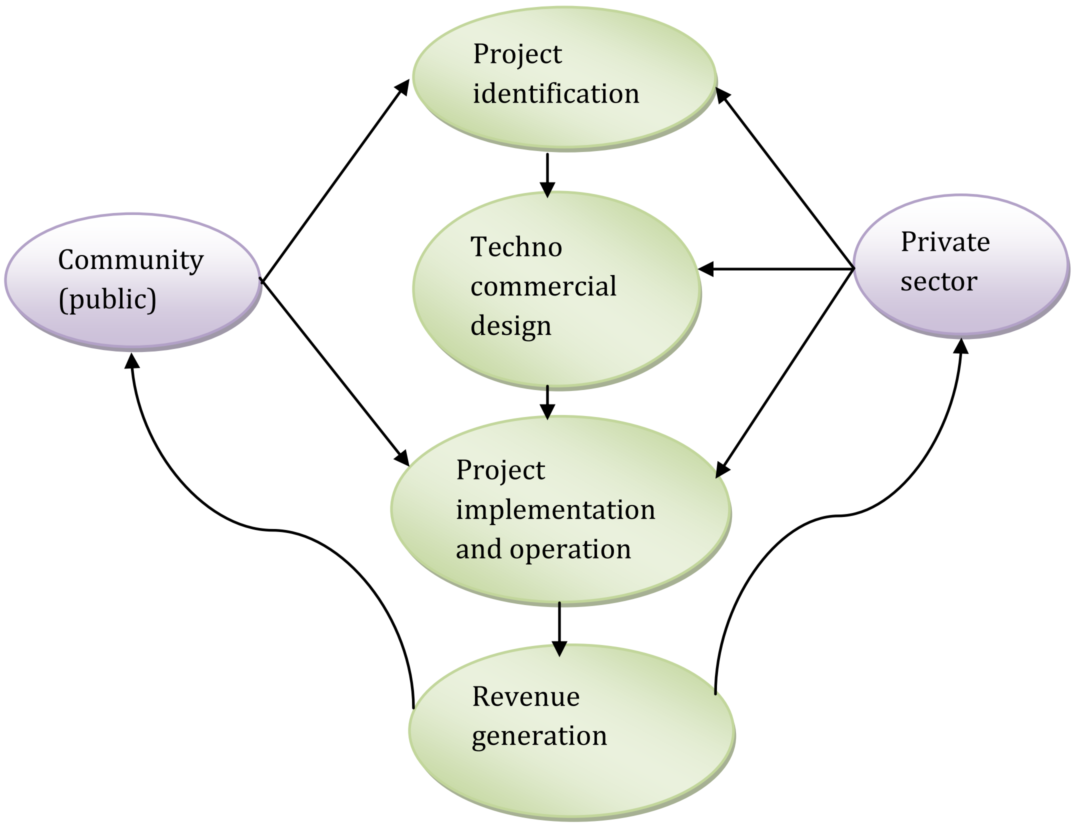

FIGURE 11: ROLE OF THE PRIVATE SECTOR IN FS MANAGEMENT

- Private sector consultants and contractors take up the task of planning, designing, execution, operation and maintenance of the WSS projects.
- Provision of septage services in India is currently conducted only by private sector.
- Desludging and sludge transport services are conducted by private sector.
- A clear state policy and legal framework are needed to facilitate private sector participation in Fecal Sludge Management service. The state government should declare a state policy facilitating such participation.

2.5.3 PUBLIC PRIVATE PARTNERSHIP (PPP)

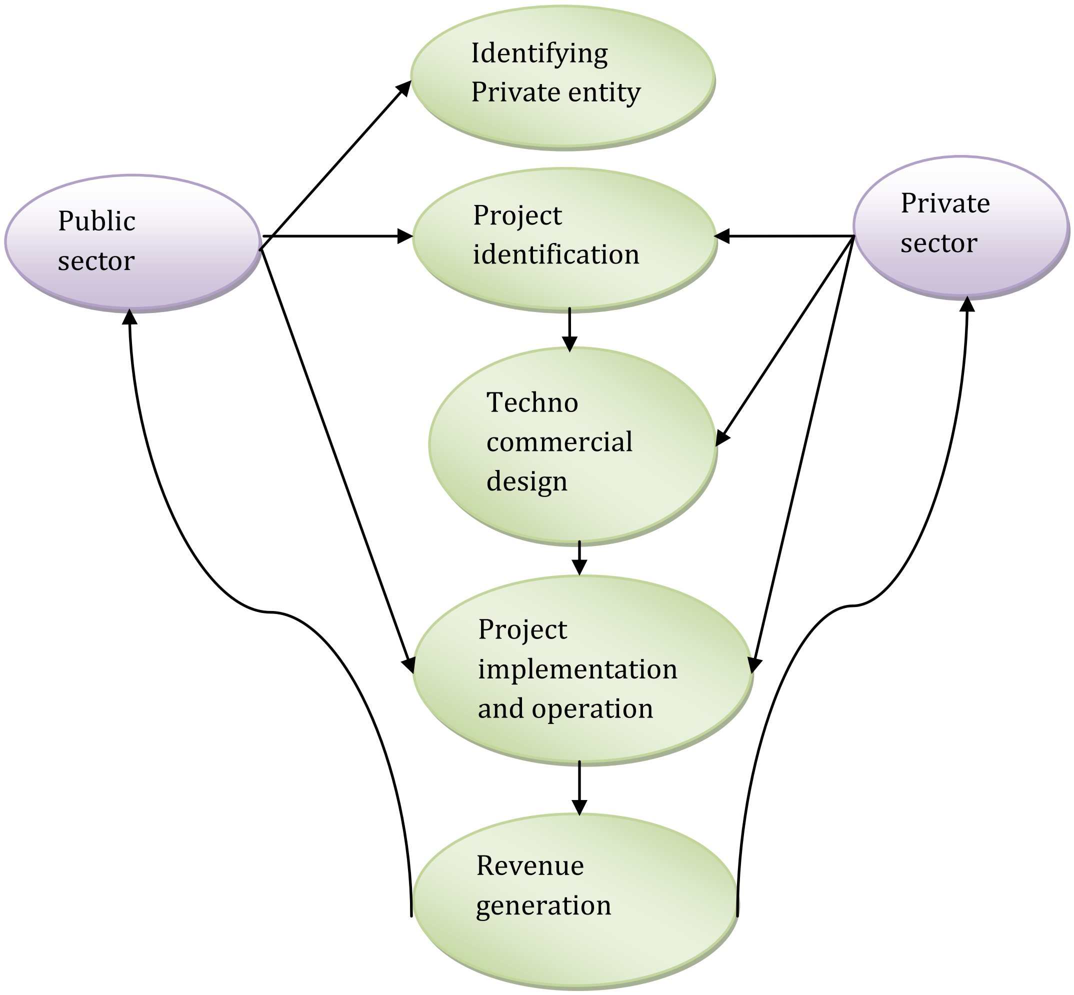

FIGURE 12: PRIVATE PUBLIC PARTNERSHIP IMPLEMENTATION MECHANISM

- Public-Private Partnership (PPP) describes a government service or private business venture which is funded and operated through a partnership of government and one or more private sector companies.
- PPP typically involves a contract between a public sector authority and a private party, in which the private party provides a public service or project and assumes substantial financial, technical and operational risk in the project.
- Application of PPP is a complex issue, which needs to be addressed by the government through its administrative and financial reforms. Key issues are: 1) policy framework

development for PPP 2) target setting, 3) tariff design, 4) role of government, and 5) contractual arrangements of PPP projects

2.5.4 POLICY ENABLERS FOR PRIVATE SECTOR PARTICIPATION IN FS MANAGEMENT

There are already a few regulatory frameworks in place for promoting renewable energy in India. These can be tapped for encouraging implementation of fecal sludge to energy projects. Some of these frameworks are:

1) RPO (Renewable Purchase Obligation): The Renewable Purchase Obligation is being implemented throughout the country to create demand for renewable energy. Under the Electricity Act 2003, the National Electricity Policy 2005 and the Tariff Policy 2006, State Electricity Regulatory Commissions (SERCs) are obligated to purchase a certain percentage of power from renewable energy sources. The targets for some Indian states are provided below:

TABLE 14: RENEWABLE PURCHASE OBLIGATION FOR INDIAN STATES

S.No	State	RE Source	2010-11	2011-12	2012-13	2013-14
1	Gujarat	Wind	4.5%	5.0%	5.5%	
		Solar	0.25%	0.5%	1.0%	
		others	0.25%	0.5%	0.5%	
		Total	5%	6%	7%	
2	Maharashtra	Solar	0.25%	0.25%	0.25%	0.50%
		Non-solar	5.75%	6.75%	7.75%	8.5%
		Total	6%	7%	8%	9%
3	Uttaranchal	Solar	0.25%	0.5%	1.0%	
		Non-solar	3.75%	4.5%	5.0%	
		Total	4%	5%	6%	
4	Manipur	Solar	0.25%	0.25%	0.25%	
		Non-solar	1.75%	2.75%	4.75%	
		Total	2%	3%	5%	
5	Mizoram	Solar	0.25%	0.25%	0.25%	
		Non-solar	4.75%	5.75%	6.75%	
		Total	5%	6%	7%	
6	Jammu & Kashmir	Total	1%	3%	5%	
7	Uttar Pradesh	Solar	0.25%	0.5%	1%	
		Non-solar	3.75%	4.5%	5.0%	
		Total	4%	5%	6%	
8	Tripura	Solar	0.1%	0.1%	0.1%	
		Total	1%	1%	2%	

9	Jharkhand	Solar	0.25%	0.5%	1%	
		Non-solar	1.75%	2.5%	3.0%	
		Total	2%	3%	4%	
10	Himachal Pradesh	Solar	0%	0.1%	0.1%	
		Non-solar	10%	11%	12.5%	
		Total	10.10%	11.10	12.10%	
11	Orissa	Solar		0.10%	0.15%	0.20%
		Non-solar	1.0%	1.2%	1.4%	1.6%
		Co-gen	3.50%	3.70%	3.95%	4.20%
		Total	4.5%	5%	5.5%	6%
12	Assam Draft	Solar	0.05%	0.1%	0.15%	0.2%
		Total	1.4%	2.8%	4.25	5.6%
13	Tamil Nadu		14%			
14	Delhi		1%			
15	Andhra Pradesh		5%			
16	Karnataka		11%			
17	West Bengal		10%			
18	Rajasthan		9.5%	9.5%		
19	Madhya Pradesh		10%			
20	Punjab		4%			
21	Haryana		10%			

FS to energy projects can be setup with state electricity bodies under this framework. Provision of preferential electricity tariffs will encourage active private sector participation.

2) PAT (Perform, Achieve and Trade) Mechanism: The Ministry of Power introduced the PAT Mechanism in 2007, notifying electricity consumers in nine industrial sectors to reduce their energy consumptions. Consumers have been given specific energy consumption targets and any additional savings can be traded with consumers falling short of their target. Under this scheme, industrial consumers can be encouraged to set up FS to energy projects for meeting their compliance targets.

3) Accelerated Depreciation Incentive: The Accelerated Depreciation is a tax incentive provided to wind power developers. Under the scheme, wind projects can reduce the assessed value of their wind assets on their financial balance sheets for a tax benefit. FS to energy can be considered a renewable power source at par with wind energy for accessing this incentive.

4) Generation based Incentive (GBI): This incentive was also provided to wind power producers who were given an incentive of INR 0.50 per unit generated subject to a cap of INR 6.25 million per MW of installed capacity. Similar incentives linked to waste processed or energy recovered can be introduced for FS management.
5) Capital subsidy: The Ministry of New and Renewable energy provides financial assistance for waste to energy projects under the following categories:

TABLE 15: CAPITAL SUBSIDY FOR WASTE TO POWER PROJECTS IN INDIA

Wastes/Process/Technology	Capital subsidy
1. Industrial waste to Biogas	
i. Biomethanation of low energy density and difficult industrial waste (i.e. dairy, tannery, slaughter house, sugar (liquid), bagasse wash, textile (liquid), paper (liquid) and pharmaceutical industry).	INR 10 million/ MWeq. (12000 Cu.m. biogas per day)
ii. Biomethanation of other industrial wastes.	INR 5 million/ MWeq. (12000 Cu.m. biogas per day)
2. Power Generation from Biogas	
i. Boiler + Steam Turbine Configuration	INR 8 million / MW
ii. Biogas Engine / Turbine Configuration	INR 10 million / MW
3. Power Generation from Solid Industrial Waste (Boiler + Steam Turbine Configuration)	INR 8 million/MW

The above categories can be expanded to include septage/fecal waste to energy as a renewable power option.

Also, for encouraging private participation in septage collection and management (energy recovery), the following enablers can be put in place:

1) Providing easy access to nearest sewerage network for disposal of septage
2) An appropriate tariff structure to ensure a steady revenue stream for private operators/ULB's
3) Other incentives such as tax benefits, subsidy on land costs etc.

3 TECHNOLOGIES FOR CONVERTING FECAL SLUDGE TO ENERGY

Possibilities exist for fecal sludge to be treated by various technologies – anaerobic digestion, fermentation, gasification, pyrolysis and hydrothermal combustion. However, for any of these technology options to be successful, a robust system is required for the handling and collection of FS.

Various Models for FS Procurement

Handling and collection of fecal sludge poses a major problem in India. According to the operating model, some existing mechanisms can be tapped for this activity:

1) **Procurement from septic tanks using own infrastructure: -** In India 38% of urban households have septic tanks. This number of septic tanks is expected to grow steeply in the next few years, but there is no separate policy or regulation for septage management in India at present[xv]. Hence septic tanks have been considered as one of the source for FS procurement. Further the collection of FS by using own tankers is financially viable compared to the FS collection from third party septic tank emptier. Hence the same has been considered in this FS procurement model. In this model, the financial return could be maximized by outsourcing tankers for other activities like transportation of waste water, sewage etc.

2) **Procurement from MTV: -** In urban India, approximately 17% people lives in slums[xvi], where they don't have proper access to sanitation. In that case, mobile toilet vans along with community based toilets could be the based feasible option. Deployment of MTVs in the slum areas will provide access to fresh human excreta.

3) **FS Collection and transportation – outsourced:-** In this model, FS will be procured from third party septic tank emptier. Emptier will sell the FS emptied from household septic tanks to project developer. Project developer doesn't own the infrastructure required for FS collection and transportation. Project developer however processes FS procured from emptier to convert into fuel grade in-house.

A preliminary analysis of above mentioned technologies as given in the following sections.

3.1 ANAEROBIC DIGESTION

The Process

Anaerobic digestion is a series of processes in which micro-organisms metabolize biodegradable material in the absence of oxygen. It has been widely used to treat waste streams because of the volume and mass reduction of the waste that takes place during the process. The end product of the process is a gas that has considerable calorific value and a biologically stable substrate that has high nutrient content and can be used as manure. The diagram below shows the basic schematic of the digestion process.

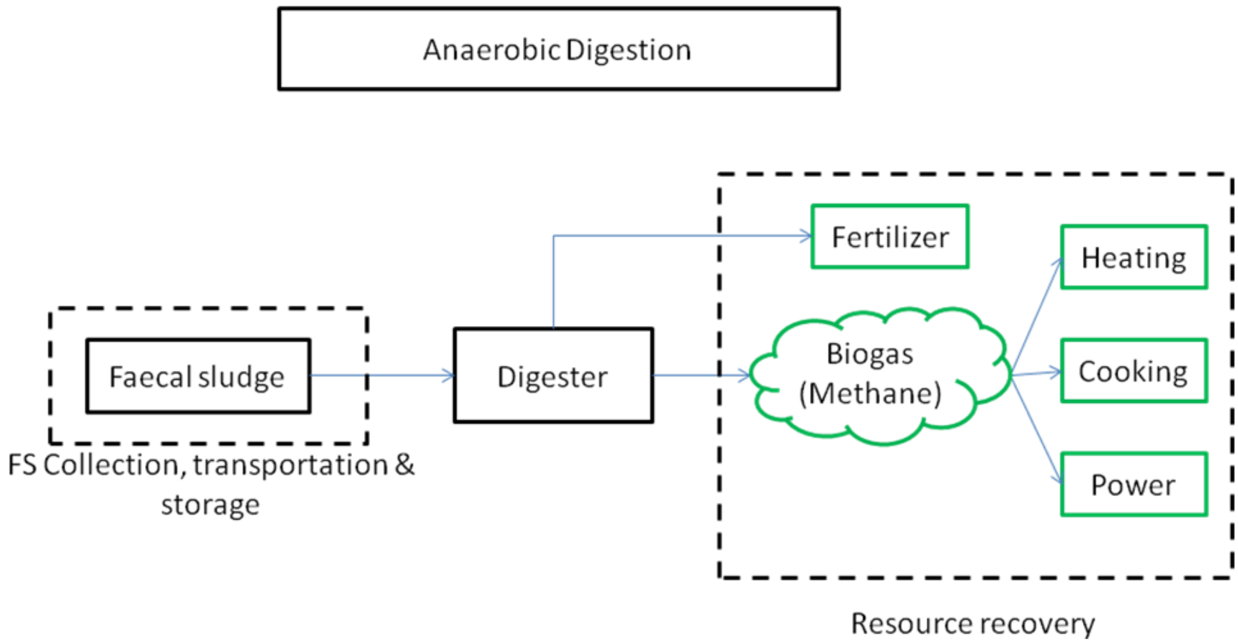

FIGURE 13: BASIC SCHEMATIC OF ANAEROBIC DIGESTION PROCESS

Successful cases

TABLE 16: OPERATIONAL PLANTS IN ANAEROBIC DIGESTION OF FECAL WASTE

S. No	Developer	Type of waste	Location	Biogas production	Status
1	ICRC and the local expert partner "Biogas Sector Partnership Nepal (BSP-N)[xvii]	Human excreta + Kitchen waste	Nepal	22,890 L/day	Jan 2007 and still running
2	Sulabh International[xviii]	Human excreta	Delhi	35-60 Cu.m./day	1985 and still running

Sulabh International also offers services in design and construction of biomethanation plants.

Major challenges observed in anaerobic digestion

Anaerobic digestion is the most favorable and proven technology for energy generation from FS. However there are certain challenges with various process parameters of anaerobic digestion:-

Temperature
In India, there temperature varies a lot with season and hence the maintaining a temperature range of 30 to 38 degree C is essential for optimum biogas production. Biogas production is bound to go down during winter months of the year.

Long retention period
Retention time (also known as detention time) is the average period that a given quantity of input remains in the digester to be acted upon by the methanogens. Considering the climatic conditions of India, a retention time of 30 days for mesophilic is desirable. Thus, a digester should have a volume of 30 times the slurry added daily.

Maintaining optimum C/N ratio
The C/N ratio of human excreta is eight which is much lower than the optimum C/N ratio. Hence the FS should be mixed with other types of waste with higher C/N ratio on continuous basis. The rate of mixing should result in optimum C/N ratio otherwise this may result in lower production of gas.

Socio-cultural issue
Human excreta are malodorous and associated with social and cultural taboos. There are misconceived perceptions among people about biogas generated from human waste. People generally consider it as unhygienic and impure. They do not accept use of biogas for religious purposes.

Biogas yield from settled sludge
Settled sludge of septic tank has high content of solid. It can be used for biogas generation provided such solid content has higher contents of non degraded part. In case of older settled sludge, solid contents are already in degraded form making less scope for further degradation by microbes and thus less chance of production of biogas. However, in case of fresh sludge from septic tank, biogas can be produced without much difficulty, after removing liquid part. However, such fresh sludge is rarely observed in case of septic tank. Most of the septic tanks are emptied only when tanks are filled and there is blockage of passage of water through toilet pan into the tanks. Any sludge of more than one year duration has very low biologically non degraded solid contents making unsuitable for biogas generation. Hence the septic tanks should be cleaned on frequent basis.

Power potential from anaerobic digestion of FS
The first objective is to estimate the amount of fecal sludge available for energy recovery in urban India. As per census 2011, the urban population is 377 million[xix] and only 32.7% of urban households are connected to the piped sewer system. Considering uniform distribution of number of person per household, about 253 million urban populations are not connected to piped sewer system. Now the amount of fecal sludge generated from the populations not connected to piped sewer system can be estimated for urban India.

TABLE 17: TOTAL AMOUNT OF FECAL SLUDGE GENERATED FROM POPULATION NOT CONNECTED TO PIPED SEWER SYSTEM IN URBAN INDIA

Total amount of fecal sludge generated – An Estimate
Urban Indian population – 377 million
Urban households connected to piped sewer system – 32.7%
Population not connected to piped sewer system in urban India– 253 million
Average fecal waste (urine+faeces) generated by an Indian - 250 g/person/day[xx]
Total dry solids - 63 g/person/day (Assuming moisture level of 75%)[xxi]
Total solids available for energy recovery - 0.0158 million Tonnes/day

TABLE 18: POWER POTENTIAL FROM ANAEROBIC DIGESTION OF FECAL WASTE

Power potential from anaerobic digestion of fecal waste (An estimate)		
Parameter	**Value**	**Units**
Biogas production[xxii]	1	Cu.ft/person/day
Unit conversion – biogas production	0.028	Cu.m/person/day
Population not connected to piped sewer system in urban India	253.72	million
Total biogas production	7,164,162	Cu.m/day
Conversion of Biogas to electricity	0.413[xxiii]	Cu.m biogas/kWh
Number of Units Produced each day	17,396,168	kWh/day
Auxiliary consumption	12%[xxiv]	%
Total no of days in a year	300	
Number of Units Produced each year	5,218,850.5	MWh/year
Net power available (after auxiliary consumption)	4,592,588.5	MWh/year
Estimated installed capacity	725	MW
Power generation per unit fecal waste processed	1.097	kWh/kg of fecal sludge (dry)
Persons required per unit of power generation	14.58	Person/kWh

Hence there is a potential for approximately 725 MW power generation from FS generated from population not connected to piped sewer system in urban India. The estimation above assumes that technological challenges of using fecal waste for anaerobic digestion process are effectively dealt with.

3.2 HYDROTHERMAL CARBONIZATION

The process

Hydrothermal carbonization is a technology to produce dried, uniform solid fuel from bio-resources such as food residues, sewage sludge, animal manures, fecal sludge, agricultural residues, high moisture content solid wastes like sewage sludge and MSW. It uses high-temperature and high-pressure steam to convert waste of various shapes and characteristics into a uniform product which is almost odorless, free from pathogens and can be used as fuel for heating or power generation.

This process takes the sludge with the moisture content of 80% into a rector and at 200 deg C and 2MPa saturated steam is supplied to the reactor. Mixing process is then conducted by a stirrer in the reactor for about one hour while holding the temperature and pressure. After finishing the holding period and discharge of the steam, wet uniform product can be extracted, which is mechanically dehydrated down to the moisture content of 50-60% due to improved drying performance of the product. The dehydrated solid residues also show significantly improved drying performance, and 48 hours natural drying is enough to obtain fuel with the moisture content less than 10%[xxv]. This system also called RRS is developed by Tokyo Institute of Technology[xxvi].

The basic process is illustrated as below:

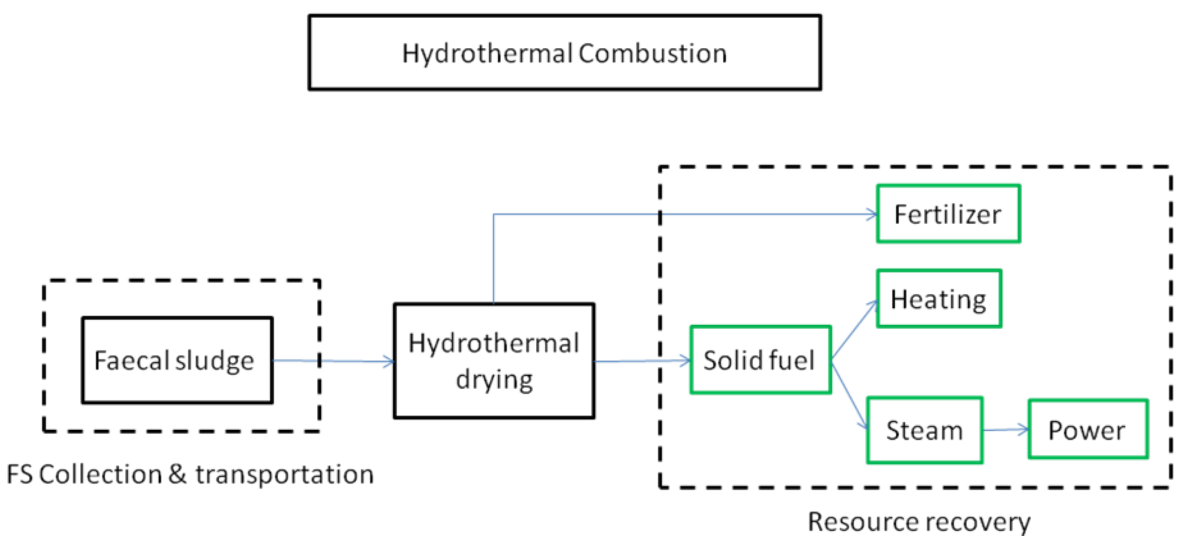

FIGURE 14: BASIC SCHEMATIC OF HYDROTHERMAL COMBUSTION PROCESS

Case examples

There does not exist any hydrothermal combustion facility running on fecal sludge however there are many organizations using other types of sludge. The list of these cases is provided below:

TABLE 19: ORGANIZATIONS WORKING IN HYDROTHERMAL TREATMENT OF WASTE

Developer	Type of waste	Location	Description of the technology employed
Delta Thermo Energy[xxvii]	MSW	Allentown, Pennsylvania, US	The company plans to build a plant on the Little Lehigh Creek to turn Allentown's trash (MSW) into energy (electricity) using hydrothermal decomposition.
Tokyo Institute of Technology	MSW	Japan	Developing a method to produce solid fuel from MSW by employing a hydrothermal treatment system[xxviii].
Commercial plant[xxix]	Medical waste	Hokkaido, Japan	Commercial scale plant has been built and operated in Japan to process medical waste from surrounding medical facilities.

Major challenges

There is no proven operational data on the use of FS as raw feed in hydrothermal carbonization process. There are some publications which recommend the operating temperature, pressure and holding time for efficient drying of FS sludge by using hydrothermal carbonization process. However this is still a matter of further research.

Following are major hindering factors:-

1. As discussed above, the HTC process requires high energy in drying. This may not be economical when the price of heavy fuel oil goes up or calorific value of FS goes down or market price of FsDF is less.
2. Any change in operating parameters like pressure, temperature or holding time may result in poor quality of FsDF.
3. Fecal sludge consists of large quantity of pathogenic microorganisms and falls under the lower alkaline range in terms of pH[xxx]. In order to reduce or minimize the amount of microbes in the fecal sludge, alkali treatment is performed and the pH of the sludge is increased till 11-12. This high alkali FS will lead to agglomeration problem.
4. Dioxin formation:- Dioxin formation might take place when plastic is heated beyond 250 degC in this process. This is harmful and should be treated before emitted into atmosphere.

Power potential from combustion of FS fuel produced from Hydrothermal carbonization

TABLE 20: POWER POTENTIAL FROM HYDROTHERMAL COMBUSTION OF FECAL WASTE

Power potential from hydrothermal treatment of fecal sludge (An estimate)		
Parameter	**Value**	**Unit**
FS calorific value[xxxi](obtained after hydrothermal drying)	3000	kcal/kg
Specific fuel consumption	1.1089[xxxii]	kg/kWh
Total solids in fecal waste generated by urban population not connected to piped sewer system in India	0.0158	million ton/day
Total fecal sludge generated per year	5.788	million ton/year
Auxiliary consumption	22%[xxxiii]	%
PLF	80%	%
Total no of days in a year	365	days/annum
Hours in a day	24	h/day
Power generation potential	5,219,596	MWh/year
Net power available (after auxiliary consumption)	4,071,285	MWh/year
Estimated installed capacity	580	MW
Power generation per unit raw fecal waste processed	0.90	kWh/kg of fecal waste (dry)
Persons required per unit of power generation	17.74	Person/kWh

It is assumed above that fecal sludge generated can be sufficiently dried during hydrothermal treatment, while maintaining the auxiliary power consumption of 22% (Assumed equivalent to that of an incineration facility). The specific fuel consumption above has been assumed to be equivalent to that of a rice husk based hydrothermal combustion system. This assumption is plausible since the calorific value of dried fecal sludge is comparable to that of dry rice husk (3000 kcal/kg)[xxxiv].

3.3 FERMENTATION

The process

Fermentation is the process by which micro-organisms breakdown organic matter to simpler organic compounds such as alcohol and organic acid as well as inorganic compounds like carbon dioxide and hydrogen. The fermentation takes place inside the anaerobic digester. The process is stopped after acetogenesis stage by using inhibitors and controlling the operation parameters. Acetic acid produced after acetogenesis stage is further converted to fatty acids by using engineered strains of Saccharomyces or Escherichia (microorganism). Fatty acid is used as raw feed with methanol for production of biodiesel in bioreactor. Methanol can be produced from methane generated from anaerobic digestion of residual stream.

The diagram below shows the basic schematic of the fermentation process for production of biodiesel from fecal sludge.

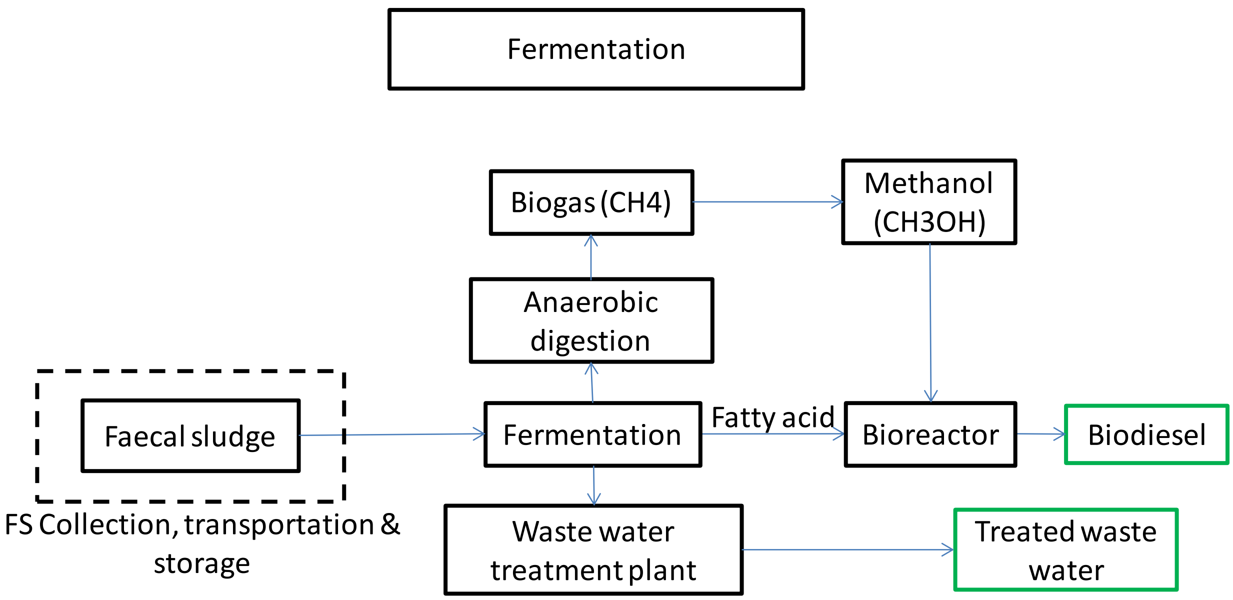

FIGURE 15: BASIC SCHEMATIC OF FERMENTATION PROCESS

Major challenges

The production of biodiesel from FS requires production of acetic acids from Acetogenesis stage of fermentation. The process of digestion should be stopped after Acetogenesis stage otherwise it leads to production of methane. The acetic acid gets converted into fatty acids in the presence of engineered microorganism. This fatty acid is utilized for production of biodiesel in bioreactor.

There are various challenges associated with each stage:-

Process up to Methanogenesis stage

Fermentation is a continuous process and it forms methane after acetogenesis stage. However this should be inhibited by controlling operation parameters like pH, temperature etc and/or by adding chemical inhibitors otherwise acetic acid is not produced.

Separation of acetic acid from the fermented broth

Fermented broth is a mixture of microbial cells, unutilized sludge, organic acids like acetic acid, etc. Separation of purified and concentrated acetic acid requires many separation techniques like membrane technology and this involves additional cost. Separation of chemical inhibitors used in fermentation from acetic acid is also a challenge.

Process for conversion from acetic acid to fatty acid
Conversion of acetic acids to fatty acids is being performed from engineered strains of Saccharomyces or Escherichia. Microorganisms always have a tendency to use up the Acetyl CoA formed from acetic acid in TCA /citrate cycle or Gluconeogenesis cycle. This leads to production of other types of by-products. Engineered microorganisms are mutated forms of microbes wherein the acetyl CoA is converted to fatty acid by following the fatty acid metabolism pathway instead of the /citrate cycle or Gluconeogenesis cycle. However the effectiveness of such engineered microorganisms is subjected to further research. Engineered microorganisms are very sensitive to operation parameters such as pH, temperature etc. Any change in operation parameters will alter the process for production of fatty acids from acetic acid.

Socio-cultural issue
Human excreta are malodorous and associated with social and cultural taboos. There are misconceived perceptions among people about products generated from human waste. People generally consider those as unhygienic and impure.

Fatty acid yield from settled sludge
Settled sludge of septic tank has high content of solid. It can be used for fatty acid production provided such solid content has higher contents of non degraded part. In case of older settled sludge, solid contents are already in degraded form making less scope for further degradation by microbes and thus less chance of production of fatty acids. However, in case of fresh sludge from septic tank, biogas can be produced without much difficulty, after removing liquid part. However, such fresh sludge is rarely observed in case of septic tank. Most of the septic tanks are emptied only when tanks are filled and there is blockage of passage of water through toilet pan into the tanks. Any sludge of more than one year duration has very low biologically non degraded solid contents making unsuitable for fatty acid production. Hence the septic tanks should be cleaned on frequent basis.

Biodiesel production potential from Fermentation of FS
The bio-diesel production capacity from the estimated quantity of FS (dry) as calculated in table 15 has been provided below:

TABLE 21: BIODIESEL PRODUCTION POTENTIAL FROM FERMENTATION OF FECAL SLUDGE

Biodiesel production potential from Fermentation of fecal sludge (An estimate)		
Parameter	**Value**	**Unit**
Biodiesel yield from FS solid[xxxv]	10%	%
Total solids in fecal waste generated by urban population not connected to piped sewer system in India	0.0158	million ton/day
Total fecal sludge generated per year	5.788	million ton/year
Biodiesel production	578.8	million liter of biodiesel per year

It is assumed above that fecal sludge generated can be sufficiently used for the fermentation process.

3.4 GASIFICATION

The process[xxxvi]

The gasification process converts carbon containing matter into producer gas by means of a thermo-chemical reaction. This constitutes thermal degradation of fuel in the absence of oxygen leading to formation of solid, liquid and gaseous products. The products of the process are Producer gas and ash/tar/char (depending on gasifier type)[xxxvii]. Producer gas is primarily hydrogen, carbon monoxide and other gaseous constituents, the proportions of which can vary depending upon the conditions in the gasifier and the type of feedstock[xxxviii]. The typical composition of producer gas is CO 15-22%, H2 10-20% with other gases making the rest. The basic process is illustrated as below:

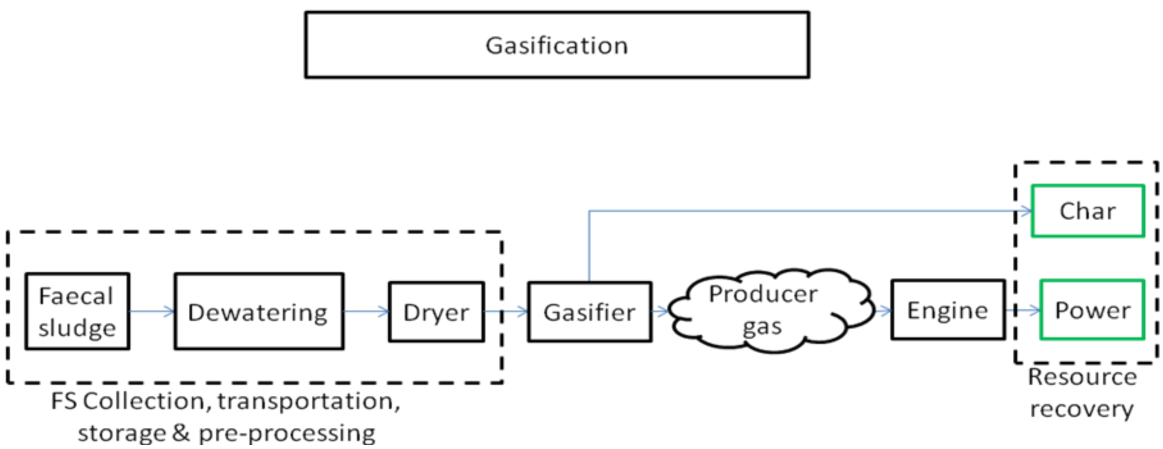

FIGURE 16: BASIC SCHEMATIC OF GASIFICATION PROCESS

Case examples

A successful case for biomass gasification of fecal sludge has not been identified. However, the technology has been implemented by private developers using biomass as fuel. Some of these developers are given below. Their models can be further studied for feasibility of including FS as a feedstock.

TABLE 22: PROJECT DEVELOPERS FOR GASIFICATION TECHNOLOGY

S. No	Company name
1	M/s. Ankur Scientific Energy Technologies Pvt. Ltd.
2	M/s. Cosmo Powertech Pvt. Ltd.
3	M/s. Grain Processing Industries (I) Pvt. Ltd.
4	ABETS, Dept of Aerospace Engineering
5	M/s. Netpro Renewable Energy (India) Ltd.
6	M/s. Chanderpur Works,

7	M/s Infinite Energy Private Limited
8	Rishipooja Energy & Engineering Company
9	Southern Carbons (P) Ltd.
10	Husk Power Systems

Major challenges

There is no proven operational data on the use of FS derived fuels in gasifiers anywhere in the world. The effect of FS derived fuel on the gasification efficiency, composition of producer gas, presence of tar, ash fusion problems and life of equipment is not known completely. As stated earlier, gasifiers are required to be customized to meet the state of fuel type.

There are many technical challenges with gasification process itself which might accentuate with FS[xxxix]:-

1. The high ash content and lower ash fusion temperature of FS can result in clinker formation inside the gasification chamber. This will require frequent cleaning of gasification system and hence will result in higher O&M cost.
2. Getting the producer gas is not difficult, but obtaining it in the proper state is the challenging task. The physical and chemical properties of producer gas such as energy content, gas composition and impurities vary time to time. All the gasifiers have fairly strict requirements for fuel size, moisture and ash content. Inadequate fuel preparation is an important cause of technical problems with gasifiers[xl].
3. Fecal sludge consists of large quantity of pathogenic microorganisms and falls under the lower alkaline range in terms of pH[xli]. In order to reduce or minimize the amount of microbes in the fecal sludge, alkali treatment is performed and the pH of the sludge is increased till 11-12. This high alkali FS will lead to agglomeration problem.
4. The usual tar composition from the outlet of the biomass gasifiers[xlii] are usually 1000 mg/m3. High tar content in the producer gas will have negative impact on the gas engine. Hence the producer gas from the gasifier has to be cleaned properly to achieve the standard[xliii] of 50 mg/m3. The cleaning of producer gas from gasifiers is a tedious and expensive process. Lesser tar composition can be achieved by using high efficient gasifier technology or cleaning process.
5. Poor carbon conversion of fuel means low utilization of fuel in gas conversion and high carbon in ash residues.

Power potential from gasification of FS

Power generation capacity from the estimated quantity of FS (dry) as calculated in table 15 has been provided below:

TABLE 23: POWER POTENTIAL FROM GASIFICATION OF FECAL WASTE

Power potential from gasification of fecal sludge (An estimate)		
Parameter	**Value**	**Unit**
Gasifier efficiency[xliv]	75%	%
Engine efficiency[xlv]	32%	%
Overall efficiency	24.00%	%
FS calorific value[xlvi]	3,000	kcal/kg
Specific fuel consumption	1.196	kg/kWh
Total solids in fecal waste generated by urban population not connected to piped sewer system in India	0.0158	million ton/day
Total fecal sludge generated per year	5.788	million ton/year
Auxiliary consumption[xlvii]	12%	%
PLF[xlviii]	80%	%
Total no of days in a year	365	day/annum
Hours of operation in a day[xlix]	6	hr/day
Average running hours/yr	2,190	Hour/annum
Power generation potential	4,838,776	MWh/year
Net power available (after auxiliary consumption)	4,258,123	MWh/year
Estimated installed capacity	2,761	MW
Power generation per unit raw fecal waste processed	0.836	kWh/kg of fecal sludge (dry)
Persons required per unit of power generation	19.14	person/kWh

The above estimation assumes a technical feasibility of using FS as a fuel for the gasification process.

3.5 PYROLYSIS

The Process

Pyrolysis is the thermal decomposition of FS into liquids, gases, and char (solid residue) in the complete absence of oxygen. Pyrolytic products can be used as fuels or be utilized as feedstock for chemical or material industries. Materials suitable for Pyrolysis processing are coal, animal and human waste, food waste, paper, cardboard, plastics, rubber and biomass.

The basic process of producing bio-oil using FsDF is illustrated as below:

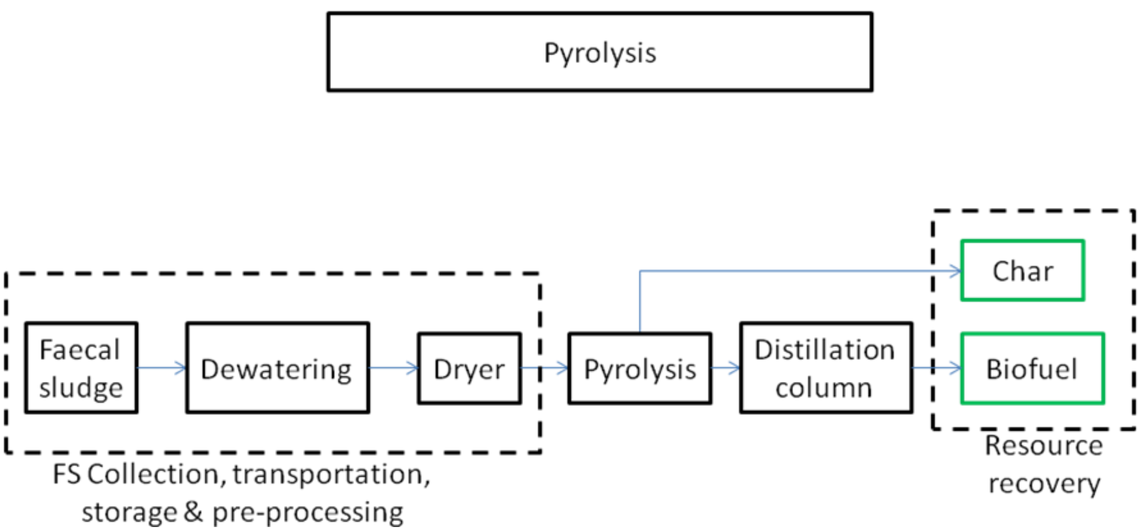

FIGURE 17: BASIC SCHEMATIC OF PYROLYSIS PROCESS

Case examples

There is no case available for pyrolysis of fecal sludge. However, the technology has been extensively used for biomass processing by many organizations, few of which are given below:

TABLE 24: ORGANIZATIONS ENGAGED IN PYROLYSIS OF BIOMASS[i]

Organization or Company	Capacity (Dry Biomass Feed)
DynaMotive, Canada (Placeholder1)	400 kg/h (11 tons/day)
Wellman, UK	250 kg/h (6.6 tons/day)
RTI, Canada	20 kg/ h (0.5 tons/day)
Red Arrow, WI; Ensyn design	1500 kg/h (40 tons/day)
Red Arrow, WI; Ensyn design	1700 kg/h (45 tons/day)
VTT, Finland; Ensyn design	20 kg/h (0.5 tons/day)
BTG, Netherlands	200 kg/h (5.3 tons/day)
Pyrovac, Canada	3500 kg/h (93 tons/day)
Fortum, Finland	350 kg/h (9.3 tons/day)

Major challenges

There is no proven operational data on the use of FS as raw feed in Fast Pyrolysis process. However there are some publications which recommend the fast Pyrolysis of chicken litter and the composition of chicken litter and FS somehow similar. But this is still a matter of further research.

Temperature

The yield of volatile products (gases and liquids) increases with increasing heating rate and temperature while solid residue decreases. The time required to obtain a certain conversion level decreases with increasing temperature. An increase in Pyrolysis temperature increases the yield of gaseous products and this increases the bio-oil yield after condensation of gas.

Pressure

Pressure has a significant influence on Pyrolysis of biomass. Higher pressure increases the residence time of the volatiles in the reaction zone, resulting in increased yield of low molecular weight gas and decreased tar and liquid products due to cracking reactions. At low pressures, and hence short residence times, tar molecules and heavy liquid products will escape before undergoing further decomposition. This will result in lower formation of gaseous product and hence decrease in bio-oil yield. Hence the operating pressure should be high for maximum bio-oil yield.

Gas Flow rate

Gas flow rate through the reactor affects the contact time between primary vapour and hot char and so affects the degree of secondary char formation. Low flows favor char yield and are preferred for slow Pyrolysis; high gas flows are used in fast Pyrolysis, effectively stripping off the vapors as soon as they are formed.

Bio Oil Instability

Bio-oil is relatively unstable compared to fossil fuels. This is primarily due to slow chemical reactions that produce more polymeric compounds, which gradually increases the molecular weight average of the Pyrolysis liquids and consequently the liquid viscosity. Various reactions between the components of the Pyrolysis liquids and with the storage environment can occur. This can affect the quality of bio-oil over a period of time.

Moisture content

Presence of moisture (greater than 15-20%) in feedstock may lead to higher moisture content in bio-oil and this may lead to phase separation in bio-oil over a period of time. The Pyrolysis liquids are also highly corrosive due to the presence of organic acids derived from feedstock.

Bio-oil production potential from Pyrolysis of FS

The bio-oil production capacity from the estimated quantity of FS (dry) as calculated in table 15 has been provided below:

TABLE 25: BIODIESEL PRODUCTION POTENTIAL FROM FERMENTATION OF FECAL SLUDGE

Bio-oil production potential from Fermentation of fecal sludge (An estimate)		
Parameter	**Value**	**Unit**
Bio-oil yield from FS solid	23%	%
Total solids in fecal waste generated by urban population not connected to piped sewer system in India	0.0158	million ton/day
Total fecal sludge generated per year	5.788	million ton/year
Bio-oil production	1331	million liter of bio-oil per year

Bio-oil yield has been assumed similar to bio-oil yields from Chicken litter provided in the reference document[li].

4 CDM POTENTIAL OF FS TO ENERGY PROJECTS

The following are the Approved CDM methodologies applicable in the waste management and wastewater sector[lii]. However, the existing methodologies do not include fecal sludge as a waste to be treated.

TABLE 26: CDM METHODOLOGIES FOR WASTE TO ENERGY TECHNOLOGIES

Cases	Methodologies
Alternative treatment – Composting	AM0025, AM0039, AMS-III.F., AMS-III.AF.
Alternative treatment – Burning	AM0025, AMS-III.E, AMS-III.L, AMS-III.R, AMS-III.Y
Alternative treatment – Aerobic	AM0083, AM0093
Landfill gas	ACM0001, AMS-III.G.
Lagoons and biodigester- Biogas	ACM0014, AMS-III.H, AMS-III.AO.
Manure and comparable animal waste	AM0073, ACM0010, AMS-III.D
Aerobic wastewater treatment	AM0080, AMS-III.I
Biogenic methane	AM0053, AM0069, AM0075, AMS-III.O

AM, ACM – Methodologies for large scale plants.
AMS – Methodologies for small scale plants

In order to fit the fecal sludge in above methodologies, the methodologies might require a revision. The process for proposing a revision in methodologies is detailed at the following links:

http://cdm.unfccc.int/Reference/Procedures/methSSC_proc02_v01.pdf (Small scale plant)

http://cdm.unfccc.int/Reference/Procedures/meth_proc06_ver01.pdf (Large scale plant)

Assuming that the entire fecal waste generated from households not connected to piped sewer system in urban India can be treated in a methane generating facility using anaerobic digestion technology, the CER potential has been estimated as follows:

Power generation per unit of raw fecal waste processed = 1.09 kWh/kg of fecal waste (dry) (Calculations shown above)

Taking the grid emission factor of 0.9528 tonnes of CO_2 per MWh, emission reduction potential is 1.042 tonnes of CO_2e per ton of fecal waste processed.

5 CONCLUSIONS

On the basis of research done so far, we can conclude the following:

- Given the fact that over 26 billion liters per day of untreated sewage is dumped into water bodies in India, the potential for fecal sludge to energy conversion is immense.
- Sewage Treatment Plants (STPs) in India have a capacity to treat around 12 billion litres of sewage daily. However, sewage sludge generated by these plants has high pathogen levels for safe disposal. STPs can operate in combination with anaerobic digestion technology to destroy pathogens and generate useful energy.
- In 94% of the Indian cities, there exist no sewage networks and septage (from septic tanks) is collected by private contractors who dispose it irresponsibly. In this scenario, an improved septage management system and implementation of on-site sanitation solutions demand greater importance in government policy.
- Government programs such as JNNURM and UIDSSMT have provisions for allocation of funds for sanitation projects undertaken by implementing agencies at the state level. These funds can be utilized by potential sanitation project developers. A favorable regulatory framework and proven resource recovery solution will encourage participation of private developers in these programs.
- Anaerobic digestion of fecal sludge to produce biogas is a technology being practiced in a few locations across India and other developing nations. According to results of secondary research conducted, these plants are functioning properly.
- Gasification, Fermentation, Pyrolysis, and Hydrothermal combustion have not been used for processing fecal sludge, but have been extensively applied for other wastes such as MSW, biomass, tyres, sewage sludge etc. Fecal sludge cannot be used in these technologies directly due to its high moisture content. However, it can be processed after subjecting it to appropriate pre-treatment processes (e.g. dewatering, hydrothermal drying) to reduce its moisture levels.

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