Fecal Sludge Management: Wadhwan City

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Abbreviation

CPEEHO	Central Public Health and Environmental Engineering Organization
DENR	Department of Environment and Natural Resources
DOH	Department of Health
DPWH	Department of Public Works and Highways
FS	Fecal Sludge
FSM	Fecal Sludge Management
GDCR	General Development Control Regulations
GIDC	Gujarat Industrial Department Co operation
GMFB	Gujarat Municipal Finance Board
GPS	Global Positioning System
GUDM	Gujarat Urban Development Mission
IWK	Indah Water Konsortium
LGU	Local Governing Units
MWCI	Manila Water Company, Inc.
MWSI	Maynilad Water Services, Inc.
MOPH	Ministry of Public Health
NSKDC	National Safai Karmacharis Finance & Development Corporation
NGO	Non-Governmental Organization
NSSMP	National Sewerage and Septage Management Program
NWQMF	National Water Quality Management Fund
O&M	Operation and Management
PVC	Polyvinyl Chloride
SBM	Swachh Bharat Mission
SOP	Standard Operating Procedure
SPAN	National Water Services Commission
STP	Sewage Treatment Plant
ULB	Urban Local Body
UNDP	United Nations Development Programme
USAID	U.S. Agency for International Development
WQMA	Water Quality Management Area
WSIA	Water Services Commission Act 2006

Measurement Units

Cm	Centimeters
Cu. ft	Cubic Feet
Cu. m	Cubic Meter
Ft	Feet
HP	Horse Power
Kg	Kilogram
Km	Kilometer
L	Liter
LPCD	Liters Per Capita Per Day
M	Meter
Sq. Km	Square kilometer
Sq. M	Square Meter

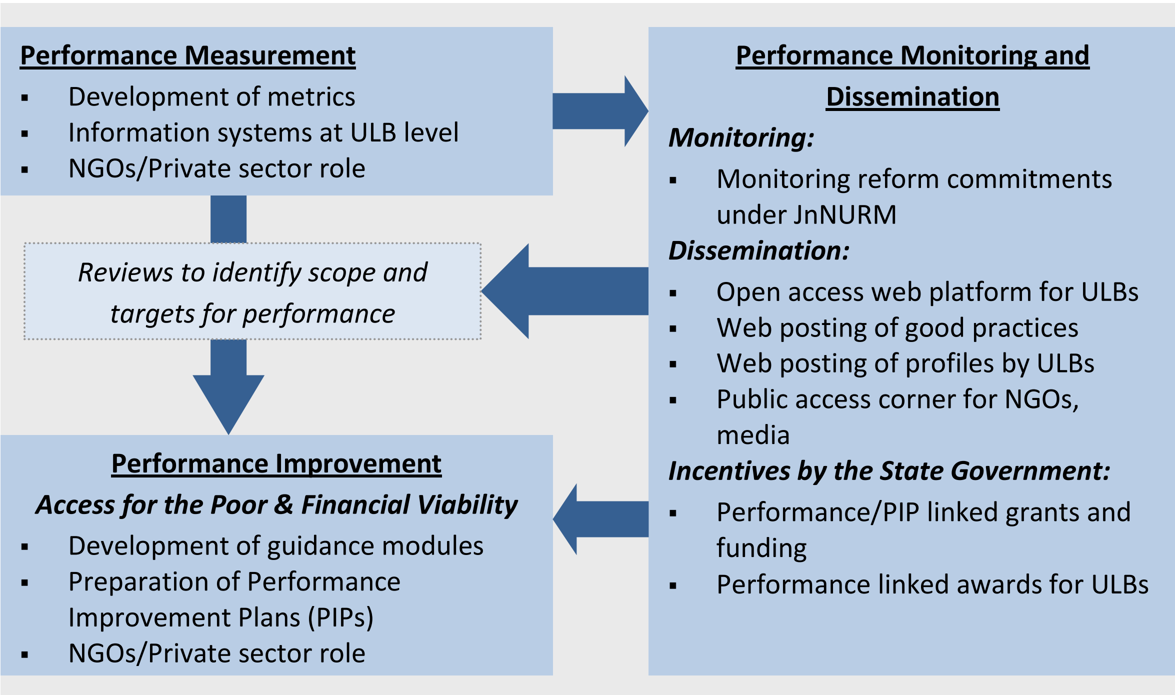
1. Introduction to the Performance Assessment System (PAS)

Performance Assessment System (PAS) is a seven-year action research project being implemented by Urban Management Centre (UMC) in Gujarat in partnership with CEPT University. The PAS Project funded by The Bill and Melinda Gates Foundation, has three main components: Performance Measurement, Performance Monitoring and Performance Improvement.

The aim of the PAS Project is to measure, monitor and improve the performance of municipal water supply and sanitation services in 400 urban local bodies (ULBs) in the states of Gujarat and Maharashtra.

The project is monitoring and assessing the performance of all 167 cities in Gujarat since the last five years. UMC is working with the ULBs on various performance improvement and information system improvement initiatives.

Figure 1: About PAS Project



UMC has identified key thematic areas and is working with selected ULBs towards performance improvement. This will help decision-makers and local governments bring efficiency in service delivery, effective budget allocation and inclusive coverage.

1.1 Background of the Study

Proper treatment and management of fecal sludge is integral to safe sanitation practices which ensure health and well-being of citizens. According to the Census 2011 data on sanitation, around 30 million urban households, or more than one third of all urban India depends on on-site sanitation solutions for safe wastewater disposal. In Gujarat too, the reliance on on-site sanitation systems is very high. 105 out of the 167 cities in the state do not have any underground drainage system and are dependent on technologies such as single pits, twin pits and septic tanks for wastewater disposal.

Also in cities that have underground drainage network, it coverage is limited. With rapid development, more and more properties, especially in peripheral urban areas are making their own arrangements of wastewater disposal. A rapid assessment of septage management in Asia carried out by U.S. Agency for International Development (USAID) in 2010 revealed that about 148 million people in urban areas will have septic tanks by the year 2017. Though the National Urban Sanitation Policy (NUSP) emphasizes the need for proper collection, treatment and disposal of sludge from such on-site installations, very limited attention has been paid to the construction, management, maintenance and safe disposal of fecal sludge from these systems.

Most ULBs in India are not able to effectively monitor the regular cleaning and maintenance of septic tanks and pits. Some ULBs provide septic tank and pit cleaning as a municipal service but the supply of such desludging services is far from adequate. In many cities, private players have filled this gap by providing these services for a fee. The private contractors also sometimes sell the nutrient rich sludge to farmers in the vicinity of cities. However, the disposal of wastewater is often not regulated. The sludge is dumped in stormwater drains and open areas posing considerable health and environmental risks.

Recognizing the growing importance of safe fecal sludge management (FSM) practices, the Ministry of Urban Development (MoUD) recently released an advisory to provide guidance to states and cities on policy, technical, regulatory and monitoring aspects of FSM. The advisory is a useful resource on FSM for cities in India. In addition to the advisory, the guidelines on design and construction of septic tanks issued by the Bureau of Indian Standards (BIS) and the Central Public Health and Environmental Engineering Organization (CPHEEO) are also a good reference on technical design and maintenance of septic tanks. UMC has developed Standard Operating Procedures (SOP) for Routine Water Quality Surveillance[1] that borrow from these two resources as well as the team's extensive experience of working with cities in Gujarat to establish a uniform procedure for FSM in Gujarat and present the information in a handy, comprehensive and easily accessible format.

Like in other cities of India, FSM has been a neglected area in ULBs of Gujarat as well. The sector has not received any attention because of poor understanding of operation and management (O&M) requirements, lack of guidance, inadequate resources and skills, shortage of manpower and finance. Currently, out of the 167 ULBs, only 62 have a partial sewer system. Most cities from the Saurashtra region do not have any underground drainage system and are dependent on on-site sanitation systems. The toilets are connected to septic tanks/pits and the sullage/effluent is often discharged into road side stormwater drains, which are covered or open. Fecal sludge generated in small cities often ends up in garbage dumps, stormwater drains, water bodies or is used for agriculture. In cities that have sewerage network and functional sewage treatment plants (STPs), sludge is emptied in manholes or transported to STPs and treated along with the sewage conveyed through the underground network.

Cities in Gujarat also do not have any reliable data on number of households dependent on each of these above mentioned systems. Anecdotal evidence suggests that cities are moderately aware of the functioning and difference between these systems.

The Prohibition of Employment as Manual Scavengers and their Rehabilitation Act, 2013, prohibits manual cleaning of pit toilets and septic tanks. Adopting mechanical processes for cleaning of septic tanks such as suction emptiers is

[1] http://www.umcasia.org/UserFiles/umc/file/SOP%20for%20routine%20water%20quality%20surveillance_July%202014.pdf

seen as the only way to eliminate manual scavenging. Regrettably, part of septic tank/pit cleaning in some cities is carried out manually. Based on PAS/Service Level Benchmarks (SLB) data of 2013 on urban water supply and sanitation services, 85 cities in the state provide mechanized septic tank/single pit cleaning as a municipal service. However, currently, there is no infrastructure in any of the ULBs in Gujarat for adequate fecal sludge treatment. The Gujarat Municipal Finance Board (GMFB) has provided sludge sucking machines to the ULBs but sometimes these are inadequate and not functional. Septic tank cleaning, hence, is often addressed by the private sector with little monitoring and regulation from the ULB.

It is feared that the new Act may result in the already secretive business of fecal sludge emptying being practiced surreptitiously and drive up the cost of emptying. Hence, it becomes essential that the ULBs recognize and register sludge emptying services as legitimate business, regulate their operations and enforce the use of mechanized suction machines. Simultaneously, ULBs need to augment their infrastructure and resources directly or through contracting out emptying, transport and treatment of sludge.

The management of urban fecal sludge in India today poses serious challenges in the face of rapid growth in toilet usage with on-site sanitation due to lack of underground sewer system. The treatment facilities in Gujarat, as elsewhere in India, for septage are highly insufficient and the untreated septage is rapidly polluting the streams, sea creeks, and water bodies. Concurrently, it has been observed that the farmers know the nutritional value of the fecal matter and hence, it is being used widely. Instances from field visits support its usage in agriculture albeit the farmers not admitting to its usage due to stigma attached to it. The use of human excreta in agriculture is increasingly recommended to close the loop of resource use and this being the most sustainable way to maintain soil health and productivity.

The state of Gujarat has taken a massive programme to modernize its cities with underground sewerage and sewage treatment plants. Out of a total of 167 ULBs of Gujarat about 70 have already initiated the construction of sewage system and treatment facilities. In the current phase of transition from on-site management to underground sewage system, it is imperative to put in place a FSM plan for safe disposal of the human waste.

It is with this view that city of Wadhwan was selected for preparing a FSM plan. Currently, the city has on-site sanitation management practices. The underground sewer lines are being laid in the city, but the treatment plant initiation is halted for exploration of appropriate technology. In the interim period, it is hoped that this FSM plan will be useful and can be taken forward.

1.2 Profile of Wadhwan

Figure 2: Location of Wadhwan

Wadhwan is a Class B Municipality in the Surendranagar District of Gujarat. During the British Raj era, Wadhwan state was one of several princely states governed by the Jhalas. The city is located on banks of one of the major rivers of Saurashtra region of Gujarat, 'Bhogao'. It is spread on both the banks of the River. The old city is walled city that is known as 'Gadh' or fort area. It has numerous educational institutes established by Mr. C. U. Shah, a renowned industrialist. The area covered by the city is 20.01 square kilometers (sq. km). It is located at the Surendranagar – Bhavnagar railway line. It lies on State Highway 17 between Ahmedabad – Chotila and State Highway 20 between Dhrangdhra – Dhandhuka. The soil type is partially sandy, rocky within the city and black cotton at the periphery. The source of water in the city is the Dholidhaja dam. The groundwater table ranges from 25 to 150 feet (ft). The current water supply in Wadhwan is 100 liters per capita per day (LPCD). Water is accessed from the Dholidhaja dam. For pressure type sewerage system, where the diameter of pipes is less and the flow is more, the water supply should be 150 LPCD. The City has a plan for augmenting additional supply from the Dholidhaja dam. The water tax is Rs. 50 and Rs. 105 per month for residential and non-residential respectively. Out of which, the recovery of tax is only 50 percent. The sanitation tax is not levied as on-site sanitation practices are prevalent.

Table 1: City Profile-Wadhwan

Total population	80,260
Total number of households	17,744
No. of slums	6
Slum population	2,470
No. of households in slums	580
Number of wards	12
City area in sq. km	20.01
Total number of registered properties	24,184

Source: PAS 2014-15

Table 2: Demography

Ward	Population	No. of Households
1	7,607	1,599
2	9,718	2,211
3	5,080	1,052
4	7,805	1,588
5	5,926	1,145
6	5,246	1,031
7	5,395	1,178
8	4,911	1,118
9	4,970	1,114
10	7,523	1,523
11	5,907	1,200
12	5,667	1,070
Total	75,755	15,829

Source: Census of India 2011

Table 3: Sanitation Coverag

Total number of households	15,829
Households with individual toilets	12,954(82%)
Toilets connected to underground sewers	698 (5%)
Toilets connected to septic tanks	11,544 (89%)
Toilets connected to soak pits	633
Toilet connected to open drains	19
Households using other sanitation facilities	60
Households practicing open defecation	2,815

Source: Census of India 2011

Figure 3: Map Showing the 12 Wards of Wadhwan Municipality

Source: Satellite Image from Google Earth Accessed on 16 June, 2015

1.3 Rationale for Undertaking FSM in Wadhwan

In the city of Wadhwan, 82 per cent of the households have latrine facilities within their premises.[2] On-site sanitation systems are the most prevalent sanitation facilities. Fecal sludge raked out from these on-site sanitation systems is haphazardly dumped in the Bhogao River or on the fringe of the city. Presently, the city lacks a FSM plan for the safe removal, conveyance, disposal and treatment of fecal sludge. The building bye-laws and General Development Control Regulations (GDCR) guidelines formulated by Surendranagar and Wadhwan joint Urban Development Authority have no mention of the rules and regulations for sanitation facilities or FSM.

With the ultimate aim of ensuring safe conveyance and collection of sewage, the Government of Gujarat is developing underground sewerage network in more than 50 ULBs of the State this year and will be developing such infrastructure for the rest all ULBs in coming couple of years.[3] The construction of an underground sewerage network in Wadhwan city is also underway with support of Gujarat Urban Development Mission (GUDM). With a premise that the task of installation of this network throughout the city will take a long time, there is a requirement for an interim solution of having a safe FSM system in place. In fact, the justification for an interim solution is manifold. The households that have constructed their sanitation facilities anew may not be willing to forego the money spent on the facility by taking the connection to the underground sewerage network. In all likelihood, a person might take an illegal connection to the sewer line, which might jeopardize the whole system.

In densely populated areas, relocating the pit, when it is full, is not a viable solution. Wadhwan, like most other urban settlements, is expanding rapaciously but the provision of underground sewerage network for the future localities has not been accounted for. Lastly, the experience from the conversion of on-site sanitation systems to a complete underground sewerage system in Class 'B' cities such as Botad shows how the system can result in an arrant failure. The underground sewerage network at Botad functioned for just four years before it became defunct, resulting in the entire city to revert to on-site sanitation systems.

This FSM plan is an interim solution in the context of Wadhwan. It is an attempt to eliminate manual scavenging and upgrade the existing system of fecal sludge removal, transport and disposal.

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[2] Census 2011

[3] http://www.gujaratcmfellowship.org/document/Fellows/Initial-Proposal-for-Sewage-Treatment_Shwetal-Shah_25Jan2011.pdf

2. Value Chain of Septage Management: Literature Survey

Following is a brief description of on-site sanitation practices

Septic Tank:

A septic tank is a fully plastered unit that either constitutes a single pit or has two or three chambers. The unit has an inlet pipe, outlet pipe and a vent pipe. The sludge from a septic tank should be removed once in two or three years as per Central Public Health and Environmental Engineering Organisation (CPEEHO) recommendations. If the duration between the cleaning is longer, the sludge hardens at the bottom, thereby, hindering its removal. As per Swachh Bharat Mission (SBM) guidelines, septage should be removed once every two or three years. As per the Standard Operating Procedure for Fecal Sludge Management for Municipalities in Gujarat by UMC in 2015, septic tanks must be emptied once in two or three years or even earlier intervals when they are overloaded.

Single Pit Latrine:

A pit latrine consists of a pit which has perforated walls and is open at the bottom. The pit latrine system can have a single pit or a double pit. The liquid portion of the feces infiltrates into the soil through the perforations. In Wadhwan most of the single pits had a pent pipe, which is usually not noticed elsewhere. As per UMC's SOP, single pit latrine must be emptied once in two or three years or even earlier intervals when they are overloaded. The CPEEHO manual[4], and SBM guidelines[5] consider the single pit latrine as insanitary and hence, disapprove of its construction.

Double Pit Latrine:

An improved version of the single pit latrine is the double pit latrine, wherein once one of the pits is full, the feces are diverted to the other pit. The decomposition of sludge in a full pit takes place while the other pit is in use. The SBM guideline rests the decision of emptying with the household that can itself gauge the appropriate time for the emptying. According to the UMC's SOP, the pit, which is full should be left untouched and emptied only after one or two years so that the contents of the pit turn into humus. As per the CPEEHO guidelines, the pit, which is full and not being used, should be emptied one and half to two years, when most of the pathogens die off.

2.1 Safe Evacuation cum Transport Technologies for Fecal Sludge

Mechanized Emptying:

Mechanized emptying constitutes of equipment, which is vacuum based and has an engine to supply the stipulated power. Physical exertion by the operator is minimal in such cases. The suction of fecal sludge and its transport are fully mechanized. Mini tankers such as Dung Beetle, Vacutug (UnHabitat), Micravac are used for narrow streets that are inaccessible by the conventional vacuum trucks/tankers in other parts of the world

- <u>Vacuum Tanker</u>: The most widely used machine for the emptying and conveyance of fecal sludge is the vacuum tanker. The equipment consists of a vacuum pump, tanker and a suction hose. In some cases, water-jetting facility is added to this apparatus in order to fluidize the solid and dense sludge that usually gets congregated at the bottom of the septic tank. Vacuum tankers specifically don't perform adequately in pit

[4] CPEEHO Manual published in November 2013 by Ministry of Urban Development, New Delhi
[5] SBM Guidelines published in December 2014 by Ministry of Urban Development, New Delhi

latrines as all the liquid infiltrates the ground and the substrate left is hard and has less moisture content. Due to the large size of these tankers, the number of trips to remove fecal sludge from a given sanitation facility is much less compared to the other machines. One of the crucial limitations of these machines is that they can perform only in areas, where the roads are wide and well planned. They fail to access narrow and unplanned streets.

A Vacuum Tanker

Source: Photo taken at Wadhwan on 16 June, 2015

- Vacutug: Vacutug is a mechanized vacuum pump developed by UN-Habitat. Five versions of this machine have been developed since its inception. In general, each successive mini-tanker has been a direct improvement of the previous iteration, with the Vacutug Mark II being the most widely used mini tanker.[6]

Table 4: Versions of Vacutug

Version	Capacity (liters)	Relative Width	Travel Distance	Mounting & Propulsion	Cost (USD) Excluding Shipping
Mark I & II	500	Very narrow	Short-Haul	Mounted on self-propelled chasis	10,000
Mark III	1,900	Average	Long-Haul	Mounted on trailer chasis or propelled by tractor or pick-up truck	20,000
Mark IV	700	Narrow	Medium-Haul	Mounted on chasis or motor cycled tricycle	15,000
Mark V	1,000	Narrow	Medium-Haul	Mounted on chasis or motor cycled tricycle	15,000

Source: Fecal Sludge Management: Systems Approach for Implementation and Operation, Edited by Linda Strande, Mariska Ronteltap and Damir Brdjanovic

[6] Thye (2009)

Reports vary on whether the Vacutug is able to cover its operating costs. In Maputo, Mozambique, operations were suspended when operators were unable to break even[7]. In Dhaka, Bangladesh, significant efforts were required in order to cover running costs. In its first trial in the Kibera slum in Nairobi, Kenya, however, the Vacutug earned a 36 per cent profit on its overheads.[8]

A Vacutug

Source: Investigation into Methods of Pit Latrine Emptying (O Riodon, 2009)

- Dung Beetle: The Dung Beetle is a machine developed by a Dutch company J.Hvidtved Larsen and deployed in Ghana. This machine uses a two wheel tractor based drive, with the driver sitting on the tank and steering using the long handles on the machine. These machines have been successfully used for many years in Ghana. The specifications for the machine are as follows:
  - Type: Two-wheeled universal "walking" tractor.
  - Engine: Two-cylinder four-stroke 16 hp diesel engine with electric starter.
  - Transmission: Four-speeds forward plus one reverse. Engageable differential lock.
  - Power Take Off: Independently operating. Vacuum pump powered through V-belt.
  - Maximum Speed: 12 kilometers (km) per hour.
  - Brakes: Handle operated drum brakes on front wheels with separate parking brake. Pedal operated drum brakes on rear wheels.
  - Turning Radius: 3.05 meter (m) within kerbs, 3.3 m within walls.
  - Body: Self-supporting tank, twisting angle through pivot point limited to + 20 degrees.
  - Overall length: 3.5 m.
  - Overall width: 1.1 m.
  - Total weight empty: ~675 kilogram (kg), fully loaded including driver ~1,550 kg.
  - Vacuum pump capacity is 4,300 l per minute.
  - Maximum Vacuum in Tank: - 0.8 bar.
  - Positive Pressure: 0.5 bar.
  - Sludge Tank: Net operating volume approximately 800 l.

[7] BPD 2008
[8] UN-HABITAT 2005

- Valves: Suction valve 3” ball valve, top mounted, discharge valve 3” ball valve, bottom mounted.[9]

A Dung Beetle

Source: Investigation into Methods of Pit Latrine Emptying (O Riodon, 2009)

Semi-Mechanized Pit/Septic Evacuation Technologies:

Human powered pit emptying or semi-mechanized pit emptying refers to the mechanism, where manual power is supplied to the mechanical equipment to rake out the excreta from the sanitation facilities. These technologies only assist in the evacuation. The conveyance of the sludge does not fall in the purview of the equipment. Usually, these systems are preferred, where the fecal sludge extracted is disposed on-site. Otherwise, the sludge can be carried in drums or a cart, which proves to be tedious.

Mapet: Mapet is a semi-mechanized pit latrine emptying equipment which was developed by a Dutch non-governmental organization (NGO) called Waste. This system consists of a hand pump and a 200 l vacuum tank, both mounted on push carts. A ¾ inch hose joins the pump and the tank, and a four meter long four inch pipe is used to carry the sludge from the pit. Additionally, there are some other items which augment the system:

- A mixing rod for stirring the waste to an appropriate viscosity.
- A hook for picking out rags and other waste that would block the suction hose.
- A spade and hoe for digging the hole for sludge disposal.
- A chisel and hammer for widening the squatting hole or making a hole in the latrine wall for the suction hose.

[9] O Riordian (2009), Investigation into Methods of Pit Latrine Emptying

A Mapet

Source: EAWAG/SANDEC (2008)

The Gulper: The Gulper is a semi-mechanized pit emptying equipment, which was developed by Steve Sugden of the London School of Hygiene and Tropical Health. This system consists of a vertical pipe which has a foot valve at the bottom connected by a rod to the handle at the top of the pipe. This equipment is operated by two men, who push and pull the handle in an up and down fashion. The foot valve is imbedded in the sludge at the bottom of the sanitation facility. As the handle is moved up and down, the valve opens and closes, respectively, pulling up the sludge and discharging it through an angled spout which is connected to the pipe.[10] Practical implementation from Bangladesh has shown that the Gulper reaches a depth of only 80 cm down the pit and is not effective in removing dense sludge.

A Gulper

Source: Investigation into Methods of Pit Latrine Emptying (O Riodon, 2009)

[10]Fecal Sludge Management: Systems Approach for Implementation and Operation, Edited by Linda Strande, Mariska Ronteltap and Damir Brdjanovic.

The Nibbler: The Nibbler is a semi-mechanized pit emptying equipment, which was also developed by Steve Sugden of the London School of Hygiene and Tropical Health. This device uses a chain functioning as a gear mechanism to scoop out the sludge. This equipment is not recommended for dry and compact sludge but for slurry.

A Nibbler

Source: Investigation into Methods of Pit lLatrine Emptying (O Riodon, 2009)

2.2 Fecal Sludge Treatment Mechanism

The anaerobic decomposition of excreta which takes place in on-site sanitation systems depends on several factors. These factors include the ambient temperature, the retention period, and the presence of inhibiting substances. Fecal Sludge (FS) treatment options that are practiced around the world comprise batch operated settling-thickening units; non-aerated stabilization pond; combined composting with municipal organic refuse and extended aeration followed by pond polishing.

Variability, caused by the anaerobic degradation process occurring in on-site sanitation systems, is dependent on several factors, such as ambient temperature, retention period and the presence of inhibiting substances. Dewaterability is also a varying parameter dependent on the degree of biochemical degradation of the sludge. Fresh, undigested sludge as collected from public toilets does not lend itself to dewatering.[11]

Since fecal sludge is a highly variable material, the design of a treatment has to be case specific. Physical, biological and chemical mechanisms are employed for the treatment of fecal sludge.

Physical Mechanism: The treatment methods separating solids from the liquid are as follows.

- Gravity Separation: This method is based on the principle of gravity, where the particles that are heavier than water settle down.
- Filtration: The process uses filter media to capture the substrate on the surface and lets the liquid infiltrate into the ground. Mostly planted and unplanted drying beds are used for the process of filtration. Drying beds consist of coarse layers. The parameters that have the greatest impact on slow filtration efficiency are the characteristics of the influent, the type of filtration media, and the filter

[11] Strauss et al. (2002)

loading rate.[12] Fecal sludge drying beds are usually designed by decreasing the coarseness of the filter media from sand at the top to gravel at the bottom.

- Evaporation and Evapotranspiration: In drying beds, along with the method of filtration, dewatering occurs through evaporation. Additionally, when plants are present in the drying bed, water transpires through evapotranspiration. For both these processes to occur, the air should be bereft of moisture.
- Centrifugation: The concept of centrifugation is applied by placing the sludge inside the centrifuge which rotates in high speed and pushes the solid outwards onto the centrifuge walls.
- Heat Drying: Heat drying process is used when the separation is required to go beyond the passive systems that rely on solar energy. External heat is supplied for the separation of the solid and liquid constituents.
- Screening: The mechanism of this separation is the same as that of filtration where large solids are restricted and the filtrate is allowed to pass.

Biological Mechanism: Biological treatment harnesses the metabolism and growth rate of microorganisms in naturally occurring processes and employs them in controlled situations to optimize the desired outcomes. Treatment systems usually rely on complex populations of microorganisms. As the microbes grow, they dynamically alter the system by modifying forms of organic matter and releasing and binding up nutrients. They also release gases and other by-products that can affect the environment.

- Metabolism: Energy is required for the growth of microorganisms. Essential nutrients for growth include nitrogen, phosphorus, sulfur, potassium, magnesium, iron and calcium.[13]
- Temperature: Temperature has a crucial impact on the growth of microorganisms.
- Types of Microorganisms: In FSM, the eukaryotes of greatest importance for treatment mechanisms are protozoa, fungi and algae, while pathogenic protozoa and helminthes determine pathogenic risk. Protozoa are unicellular, eukaryotic organisms.
- Aerobic Treatment: In this process, the treatment takes place in the presence of oxygen. Theses microorganisms require oxygen for respiration.
- Anaerobic Treatment: In this process, the treatment takes place in the absence of oxygen. Anaerobic digestion results in the formation of biogas.
- Nitrogen Cycling: Nitrogen and ammonia content is high in fecal sludge. Inorganic forms of nitrogen present in fecal sludge are used by microorganisms for their growth.

Chemical Mechanism: Chemicals can be mixed with fecal sludge to catalyze the performance of physical mechanisms.

- Alkaline Stabilization: Alkaline additives such as lime can be added to the fecal sludge either before or after desludging. The addition of lime prevents odor by killing the pathogens.
- Ammonia Treatment: Ammonia disinfection has been shown to be effective in urine (Vinnerås et al., 2008), sewage sludge (Pecson et al., 2007), and compost (Adamtey et al., 2009), but applications for FS are still in the research phase of development.[14]

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[12] Metcalf and Eddy (2003)

13 Fecal Sludge Management: Systems Approach for Implementation and Operation, Edited by Linda Strande, Mariska Ronteltap and Damir Brdjanovic.

- Conditioning: Coagulation and Flocculation by common additives such as lime, ferric chloride, alum and organic polymers are used to increase the performance of the fecal sludge prior to dewatering.

2.3 Fecal Sludge Treatment Technologies

In most cities, where a FSM plan is absent, the sludge extricated from sanitation facilities is indiscriminately discharged in water bodies or in landfills. Due to the limited capacity of on-site sanitation systems, the sludge needs to be removed periodically and then is to be treated further in order to decimate the remaining pathogens. Some of the sludge treatment facilities are discussed below.

Planted Drying Beds: Planted sludge drying beds use filtration, evaporation and evapotranspiration method for the treatment of fecal sludge. The system consists of plants/reeds, sand and soil. The fecal sludge is dewatered by filtration, wherein the filtrate percolates through the soil and is collected at the bottom. The advantage of this method over unplanted beds is that the filters don't need to be desludged after every feeding cycle. The fresh sludge can be directly applied to the previous layer as the roots of the plants maintain the porosity of the filter. The ratio between drained and evaporated liquid is dependent on the type of sludge, weather conditions and operating characteristics of the particular drying bed. In planted drying beds, this ratio is likely to be much lower. The sludge can be removed after a couple of years and can be directly applied in fields as compost. Drying beds require relatively low capital and operational costs but are space intensive.

Planted Drying Beds

Source: Fecal Sludge Management: Systems Approach for Implementation and Operation, Edited by Linda Strande, Mariska Ronteltap and Damir Brdjanovic.

Unplanted Drying Beds: In unplanted drying beds, gravity percolation and evaporation are responsible for sludge dewatering. This unit consists of sand, gravel and a drain at the bottom to collect all the filtrate. The solid aggregate on the surface can be used as a fertilizer. Where dried sludge is used in agriculture, helminthic (nematode) egg counts should be the decisive quality criterion in areas where helminthic infections are endemic. A maximum nematode (roundworm) egg count of 3-8 eggs/g TS. [15]

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[15] Xanthoulis and Strauss (1991)

Evaporation causes the mud to crack and result in improved evaporative water losses and enhanced drainage of the sludge liquid and rainwater.[16]

Unplanted Drying Bed

Source: Drying Beds at Niayes Fecal Sludge Treatment Plant, Dakar, Senegal (Photo: Linda Strande). Fecal Sludge Management-Systems approach for Implemmentation and Operation

Latrine Dehydration and Pasteurization (LaDePa): Latrine Dehydration and Pasteurization or LaDePa developed by Ethwinki is the process of conversion of fecal sludge into pathogen free pellets that can be directly used as manure in the agricultural fields. This process works on thermal and mechanical principles. This is an energy intensive process. The end product consists of pellets that can be used as fuel or as soil amendment.

Sedimentation/Thickening Tanks: Sedimentation/Thickening Tanks are employed to separate the solid and liquid constituents of fecal matter and work on the same lines as the septic tank. The heavier particles of the fecal sludge settle at the bottom of the tank by the action of gravity and the liquid matter float on the top of the tank. The liquid is drained out from the tank by an outlet pipe. Since the treatment in these tanks is only partial, the sludge, which settles at the bottom, is usually transported to drying beds. In urban areas, where the space is limited, this is an intermediary step that could reduce the required area of subsequent steps.

Circular Primary Settling Tank at Haran Treatment Plant

Source: Effluent reuse from constructed wetland system Haran (Al-Awamied, Syria Elisabeth v. Münch and Rahul Ingle, Abir Mohamed)

Co-composting: Co-composting of fecal sludge with organic solid waste is practiced worldwide. In this process, the biodegradable material is converted to compost by microorganisms under controlled aerobic and thermophilic conditions. Prior to the process of co-composting, the solid and liquid content needs to be separated. There are two

[16] Strauss et al.(2002)

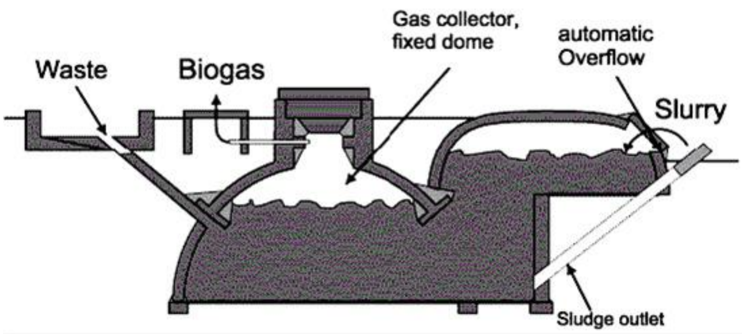
types of co-composting systems, namely, open and closed systems. In an open system, the raw solid fecal matter and the organic solid waste are piled up into heaps for aerobic decomposition. Similarly, when the raw organic material is enclosed in a container considered to be a closed system, the aerobic and thermal conditions can be controlled.

Co-compost of Fecal Sludge and Municipal Waste by Sanergy in Nairobi, Kenya

Source: Photo: Linda Strande, Fecal Sludge Management-Systems Approach for Implemmentation and Operation

Anaerobic Digestion: In this process, the organic matter is converted to biogas. In many developing countries, biogas plants processing fecal sludge mixed with cattle dung are generally operated as small, decentralized schemes serving one or several households or institutions.[17] The biogas produced is used as cooking gas in the households. Although energy recovery and conversion of untreated sludge to compost is observed in this process, the relatively high capital costs to install this setup may be an impediment to the wide applicability of this treatment.

Figure 4: Biogas Plant



Source: TBW GmbH, Frankfurt- Fecal Sludge Management (Sandec Training Tool 1.0- Module 5)

Vermi-composting: In this process, the earthworms act as sludge digesters by feeding on the pathogens and metals, decomposing the organic matter and mineralizing the nutrients. The role of earthworms in the stabilization of sewage sludge is greatly linked to sludge age and nutrient content, aerobic conditions, moisture content,

[17] Strauss et al. (2002)- From EAWAG Sandec (2008) Module 5, FSM Lecture

temperature, ash content and the loading rate.[18] The compost, which is produced by the action of the earthworms, can be directly used in agriculture.

Heap of Co-compost

Source: Sandec

Non-aerated Waste Stabilization Ponds (WSPs): This system comprises a series of treatment processes, where the solid and liquid, is separated in the first step followed by its treatment in aerobic ponds and then finally, at a facultative pond. The effluent, which is generated by this process, is discharged into surface waters but the solid matter is to be further treated due to its salinity.

2.4 Fecal Sludge Reuse Practices

Historically, feces have been used as organic fertilizer as it is rich in plant nutrients and organic matter. Current practices, which involve anaerobic treatment of fecal sludge, produce biogas, which is used as fuel and the remaining sludge is used as soil conditioner.

Dried fecal sludge has also been used in the manufacture of cement, bricks and clay based products. Dried wastewater sludge and FS has been shown to have similar qualities to other traditional raw building materials such as limestone and clay materials.[19]

Fecal sludge has shown positive results in the agroforestry. The sludge from pits has shown enhanced growth and improved health of trees. In the United States of America, the sludge is treated in deep row entrenchments followed by planting of trees.

When sludge is properly treated, is of good quality and used on land, it is now known widely as 'biosolids' to distinguish it in public acceptance terms from other sludge. The nutrients in excreta are beneficial for the growth of plants. Biosolids use displaces the need for some chemical fertilizer, especially those providing nitrogen and phosphorus. Biosolids contain biogenic carbon- carbon that is part of the pool of carbon constantly cycling through the biosphere and atmosphere. Carbon dioxide is a primary greenhouse gas emitted through human activities. So, if the amount of carbon can be curtailed from forming carbon dioxide, it can be counted as a reduction in human centred greenhouse gas emission. Application of biosolids in agriculture sequesters some of the carbon from forming carbon dioxide.

[18] Dominguez et al. (2000), Masciandaro et al. (2000)
[19] Jordán et al., 2005; Lin et al., 2012

Additionally, recycling biosolids in agriculture completes the nutrient cycle. In the recent times, the amount of carbon present in the soil has reduced significantly. Hence, returning carbon in the form of biosolids, while reducing the amount of carbon in the atmosphere will improve the soil quality.

3. Situational Assessment, Wadhwan

In Wadhwan, excreta are disposed of in facilities located on the housing plot itself. Whether these facilities are septic tanks, soak pit communal toilets or other types, they all accumulate fecal sludge, which needs to be removed periodically. The owners are little concerned about the problems with FS removal and management. FSM is usually limited to a de-sludging service that is provided by municipal agencies or the private scavengers, but proper sludge disposal and subsequent treatment or management are generally lacking. To arrive at a comprehensive solution, a detailed status of the situation needed to be ascertained and this was done as part of the study.

3.1 Prevalent Types of Sanitation Practices

As the underground sewage system is not in place in the city, currently, on-site sanitation facilities are being used by the residents in the city. The prevalent sanitation facilities of the city are septic tank, single and double pit latrines. Systems where the sewage is directly let out into the gutter channels are also found. Open defecation is practiced in majority of slums.

Although on-site sanitation is the most prevalent system, the Municipality in collaboration with GUDM has proposed an underground sewerage network, whose construction is underway. The land for the STP has been allotted but the proposal of the STP is on hold.

Table 5: Current Sanitation Facilities

No.	Type of Facility	Percentage
1	Single soak pit	65
2	Double soak pit	7.4
3	Septic tank	19.3
4	Directly connected to channel	3.1
5	No access to toilet	4.7

Source: Extrapolation based on field work (primary survey) 2015

Figure 5: Map Showing Extent of Underground Sewerage Network Recently Laid and Work in Progress

Source: Based on discussions with Chief Officer at Wadhwan

3.2 Prevalent Practices of Emptying

The sludge removal/emptying facilities at Wadhwan are of two types, removal by the Municipality using a vacuum pump and removal by manual scavengers. These operators normally dispose the sludge on the banks of the Bhogao River and at times, when the fringe of the city is closer than the River, the sludge is discharged indiscriminately in these sporadic locations.

3.2.1 Manual Emptying: Almost in all cities with manual emptying practice, it is practiced by a particular community. In the case of Wadhwan, it is Valmiki community. Most of them are employed by the Municipality as sweepers. They provide emptying services to earn additional income. As the equipment and practice of manual scavenging is very rudimentary, they carry out this work in an intoxicated state as it is an undignified and a repulsive task. When their services are needed, the citizens call upon them through the street sweepers, who are from the same community. There are about 40 households of this community staying at Wadhwan and almost all the families are engaged in this service. The manual scavengers operate at night due to the foul odor that is emitted when the sludge is maneuvered manually amid the unsightly conditions of its removal and conveyance. Additionally, as this process can take up to a few hours depending on the size of the sanitation facility, the streets get blocked for that duration. Hence, the night time, which is devoid of traffic on the roads, is designated for this activity. Two to three people are employed to remove the sludge of a household. Many citizens are averse to the operating of manual scavengers since they deploy open lorries to convey the sludge to the disposal site.

3.2.2 Mechanical Emptying: The Municipality uses a vacuum pump to siphon out the sludge, and a closed truck for its conveyance to the disposal site. Opening of the pit in order to remove the sludge is the responsibility of the household. In some of the areas, due to the narrow streets, the vacuum pump and truck of the municipal operator are inaccessible.

3.3 Methodology of Calculating Fecal Sludge Generation

Discussions with the officers at the Municipality and residents helped us divide the city into seven zones according to the most prevalent type of sanitation facility. It was observed that the variation in sanitation facilities had a co-relation with the age of the zone, income group residing in that area and geology. These zones are broadly classified shown in Table 6.

Table 6: Classification of Zones in Wadhwan based on the Prevalent Type of Sanitation Facility

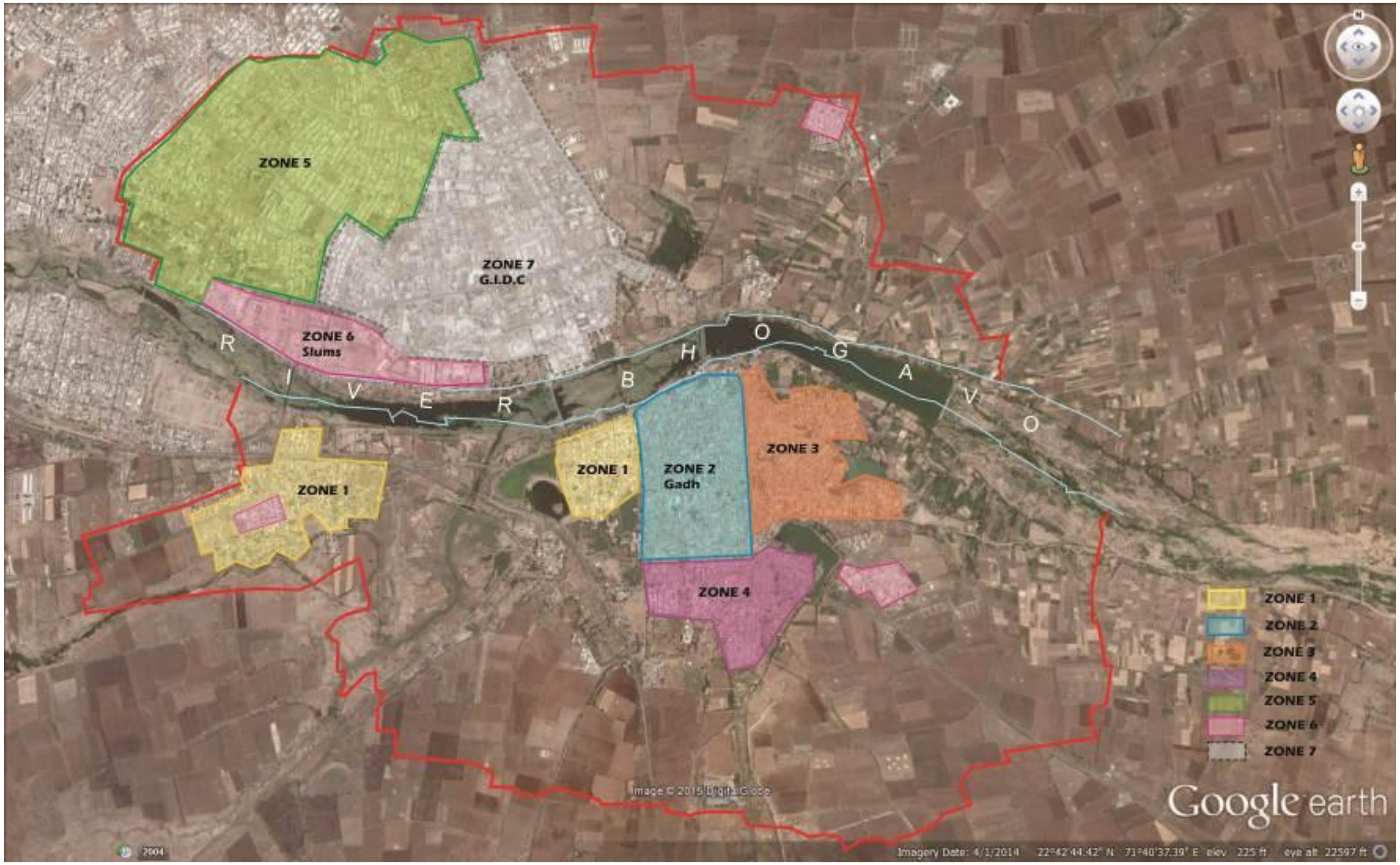
Zone	Prevalent Sanitation Facility	Income Group	Geology	Age
1	Single Soak Pit	Middle	Sandy	40
2	Single Soak Pit	Middle	Sandy	100
3	Smaller single soak pit 4’(l)x3’ (b) x 5’ (d)	Predominantly economically weaker and middle	Sandy	60
4	Septic Tank	Middle	Hard Rock	40
5	Large Single Soak Pit 10’(l)x10’ (b) x 10’ (d)	High	Sandy	20
6	Slums-Prevalence of open defecation	Economically weaker	Sandy	20
7	Gujarat Industrial Development Corporation (GIDC)-Not much fecal sludge generation occasional use and soak pit		Sandy	20

Two surveys were conducted in the city, one a detailed household survey and the other was the rapid household survey.

3.3.1 Detailed Household Survey: In order to get an idea of the various types of sanitation facilities prevailing in the city of Wadhwan, a household survey was conducted. 50 detailed household surveys were conducted in all the seven zones. The objective of this survey was to capture the types of sanitation facilities throughout the city. Information regarding the technical details such as the size, construction material of the sanitation facility, presence of a vent pipe was obtained from this survey. Socio-economic information about the households in terms of their perception of cleanliness and willingness to pay was covered. Other parameters such as the year of toilet construction, the medium by which the toilet is cleaned, diseases encountered due to water contamination and factors contributing to the contamination like proximity to water table were incorporated. (Refer Annexure 1 for Detailed Household Survey Form).

3.3.2 Rapid Household Survey: A rapid household survey was also conducted in all the zones. The primary objective of this survey was to obtain the volume of the sanitation facilities and the frequency of their emptying with a significant sample representing the typology of sanitation practices of the city. The sample size of the rapid survey was derived from the 12 wards in the city. A total of 400 samples were surveyed in all the zones. (Refer Annexure 2 for the Rapid Household Survey Form).

Figure 6: Map Showing the Seven Zones



Source: Satellite Image from Google Earth Accessed on 16 June, 2015

3.3.3 Transect Walk along the Town Boundary: A transect walk along the town boundary was undertaken with the Engineer, Mr. Harshad Acharya from the Municipality. This was to ascertain the limits of the city and ward boundaries so that these points could be marked on the satellite image sourced from Google Earth.

3.3.4 Mapping of City for FSM Plan: The city was mapped in the context of prevalent practices of sanitation. Zones as mentioned above were marked using Global Positioning System (GPS). Other important locations like existing solid waste disposal site, open defecation sites, Illegal dumping sites and farms using sludge as manure were also marked.

The results of the rapid household survey in terms of the number of households using a particular type of sanitation facility and the average volume of that facility were categorized ward-wise. Information about the total number of households in each of the twelve wards was obtained from the Municipality.

Drawing on the total number of samples collected in a ward, the total number of households using a particular facility within that sample and total number of households in that ward, the number of households using that facility was extrapolated.

Calculation of Total Number of Soak Pits

The total number of soak pits was calculated by dividing the total number of samples using a particular facility by the total number of samples collected in that ward. The quotient obtained was multiplied with the total number of households in the ward, thereby, producing the total number of households using that particular facility. This method was employed to calculate the total number of households using each sanitation facility in all zones.

For example, 35 surveys were conducted in Ward 1.The samples obtained for each ward were categorized into the following: single soak pit, double soak pit, septic tank, open defecation or toilets directly connected to channels. For example in Ward 1, out of the samples collected , households using single soak pit were 26, households using double soak pit was 1, households using septic tank were 8, households practicing open defection were 0 and households having toilets directly connected to channels were 0.

The total number of households in each ward was obtained from the Municipality.

The total number of households using a particular sanitation facility was calculated by dividing the number of samples using that facility by the total number of samples collected for that ward. The quotient was multiplied by the total number of households in that ward to get the total number of households using that facility. Taking the example of Ward 1 (total number of households 1,599) and the sanitation facility as soak pit:

Total number of households using Soak Pits in Ward 1= 26/35 x 1,599 = 1,189.

The average volume of each sanitation facility was calculated ward-wise. For the calculation of septic tank, the volume of the tank was halved as approximately half the tank volume constitutes wastewater and scum.

In order to calculate the weighted mean volume of a sanitation facility for the whole city, the average volume of that facility in each ward was multiplied with the total number of households using that facility in that ward. This was done for all the wards and the product obtained for each ward was added. The sum was divided by the total number of households using that sanitation facility in the whole city. Thus, the weighted mean volume of each sanitation facility was calculated.

The total volume of fecal sludge generated in each of these sanitation facilities was calculated by multiplying the weighted mean volume of each facility with the corresponding number of households using that facility in the whole city. The average frequency of emptying of each facility was obtained from the rapid household survey. The total volume of fecal sludge generated per year was computed by dividing the weighted volume by the frequency of emptying for each facility followed by adding all their quotients. For septic tank, the weighted volume was divided by three, as it is proposed to ensure that the septic tank must be emptied every three years.

Figure 7: Map Showing the Coverage of the Rapid Household Surveys and Detailed Household Surveys of Slums

Source: Satellite Image from Google Earth Accessed on 16 June, 2015

3.4 Socio-Economic and Demographic Characteristics of Respondents

The average household size is seven. On an average, a family consists of four adults and three children. The water supply in most prosperous households was augmented with borewells. The willingness to pay for a regulated desludging service to be provided every three years, by having to pay a yearly sanitation tax to the Municipality was received with a mixed bag of feelings. A lot of respondents complained about the incompetence of the Municipality and feared that this venture would not be successful.

A few of the enterprising and economically well-off communities had laid their own stormwater drainage channels along the streets. There were cases where households had constructed soak pits just for the collection of the grey water.

There was no inhibition towards the construction of the sanitation facility within the premises of a house. Most of the sanitation facilities were within the premises and when the area of land was less, they were constructed under the roads.

Water tax payment is only 50 per cent due to the lax regulatory framework of the Municipality and the delinquency of the residents. Under these circumstances, if the residents are expected to pay an additional sum for sanitation, they are bound to default.

3.5 Current Service Providers in Wadhwan

The two service providers of fecal sludge extraction, transportation and disposal services are the public sector (Municipality) and the private sector (manual operators).

3.5.1 Manual Operators:

The fecal sludge emptying service in Wadhwan is dominated by the manual operators. They belong to the lowest social rung of the caste system. All the residents of Valmiki Vas, a community, which comprises 500 households, are engaged in the manual emptying of fecal sludge. In addition to this community, two families that perform this service more frequently reside at Samsan. Each family at Valmiki Vas gets summoned once a year, whereas the two families at Samsan are called four to five times a month. The manual operators at Samsan are called more frequently during the winter, which goes as much as 15 to 20 times a month.

Fecal sludge emptying is a part-time job for all these operators. Majority of them are employed full-time at the Municipality for sweeping and cleaning jobs. Given the social stigma, unsightly conditions, foul odor and long duration for the completion of the task, fecal sludge emptying is always carried out in the night.

Not only is manual emptying performed in areas where the municipal truck is inaccessible but also in areas where truck accessibility is not an issue. Usually, it takes a minimum of four people and a maximum of six people to empty, convey and discharge the sludge. The number varies according to the size of the sanitation facility. The operators try to complete the work in one night but when the size of the sanitation facility is large or the stratum at the bottom is unyielding, the work spills over to the consecutive night. The fee levied for the service ranges from Rs. 2,000/- to Rs. 6,000/- depending on the size of the sanitation facility.

Manual fecal sludge emptying is a strictly a male's profession. Most of the families have been engaged in this work for over 40 years. Some of them can get through the work only under the influence of alcohol. Due to the exposure to highly concentrated gases in the sanitation facilities, a few of them have been reported to be suffering from cholera, gastric and throat problems. The first timers are afflicted by high fever which persists for weeks. No precautionary gear is worn during the whole operation. In spite of trying their best to increase their service charges yearly, the charges have remained stagnant for a long time due to the reluctance of the customers to pay more. None of the manual operators were aware of the Prohibition of Employment as Manual Scavengers and their Rehabilitation Act, 2013.

3.5.2 Mechanical Operator:

The Municipality is the sole operator for mechanical emptying and transport services. One person is designated to maneuver a vacuum pump, hose pipe and a closed truck. This service at the Municipality has been functional for ten years. In the Gadh locality and all the slum areas in the city, due to the narrow width of the streets, the accessibility of the trucks is restricted. All the bulk generators such as hospitals, apartments, factories, hostels, schools and hotels utilize the services of the mechanical operator.

The Municipality levies a fee of Rs. 750/- for each trip from the sanitation facility site to the disposal site.

The breakdown of the expenses incurred by the Municipality is as follows:

- Operator charges: Rs. 6,000/- per month.
- Diesel: 15 l/two day.

3.6 Cleaning, Transport and Disposal of Fecal Sludge

The entire activity of desludging a sanitation facility by either of the two services consists of the removal of sludge, its transportation and disposal without treating it.

Despite the Municipality having allocated a site for the disposal, none of the operators discharge the sludge there. The long haulage duration to the designated disposal site renders it uneconomical. Therefore, the operators expel the sludge as per their convenience in order to save time and cost. The minimum distance between the periphery of the city and the site is approximately three km. The solid waste generated by the whole city is discharged here. A vermi-compost plant consisting of three shaded vermi-compost pits for the treatment of solid waste is located on the site. This plant has been defunct for a couple of years due to the inability of the private contractor to accrue the costs for its maintenance.

3.6.1 Manual operators: When their service is required, the households whose sanitation facilities are to be emptied either call them up or approach them at their homes. They don't keep a log book entry of the households serviced by them. Most of the on-site systems are located in the courtyard or under the roads.

The equipment used by the manual operators for the complete operation, from removal to disposal is a bucket, rope, blue drum, push cart, shovel and hoe. In Valmiki Vas, a sole entrepreneur owns four sets of push-carts, which he leases out to the manual operators at a charge of Rs. 400 per trip. The two families at Samsan own one set of equipment.

Equipment for Manual Emptying

Source: Photo taken at Wadhwan 26 June, 2015

Once the lid of the sanitation facility is heaved, the operators wait for about an hour for the gases to escape. First, the liquid and the scum, which floats on it, are extracted with the help of a bucket and a rope. The effluent is poured in the blue drum which has a capacity of 200 l. Once it is full, it is conveyed to the disposal site on the push cart. The disposal site is either the River or the periphery of the town. The selection of either depends on the proximity of the sanitation facility to these two disposal sites.

On having extracted the liquid constituent of the sludge, the operators descend into the sanitation facility to rake out the solid stratum. The hardened excreta are hauled out of the facility using a bucket. For small sanitation facilities, the blue drum is used to carry the sludge, but when the volume of the fecal matter to be emptied is large, a chakra (a type of local vehicle) is rented. The rent for the chakra, which is Rs. 1,000/-, is borne by the household. The site for the disposal of the fecal sludge is the same, the River or the peripheral areas of the town.

3.6.2 Mechanical Operator: The Municipality provides the service through an application form. Whenever a household wants to avail this service, they fill out an application form, which is submitted at the Municipality.

The mechanical suction unit is an assembly of a vacuum suction pump, hose and a vehicular mounted closed tanker. This unit is manufactured by the company, Industrial Plants and Waste Treatment Corporation. The capacity of this tanker is 2,000 l. An indicator on the tanker shows the volume of sludge siphoned out.

Mechanical Vacuum Pump and Tanker

Source: Photo taken at Wadhwan on 29 June, 2015

Usually, the operator makes one to two trips per household with a maximum reaching up to four. The process begins with the removal of the lid by manual operators since this task does not fall into the Municipality's scope of work. The hose is then inserted into the sanitation facility and the sludge is siphoned out by the vacuum pump. Once the tanker is full, it is routed to the River or the peripheral areas for the sludge discharge.

The major drawback reported from both the respondents as well as the Municipality was the inefficiency of the vacuum pump to pull out the sludge which coagulates to a hard consistency at the bottom of the sanitation facility. As a result, two manual operators have to invariably descend into the sanitation facility in order to remove it. Night time is designated for this activity. After all the fecal sludge is removed, the lid is replaced by the manual operators.

3.7 Predominant Sizes of the Disposal facilities

The most predominant dimensions, range of the dimensions as well as the recommended sizes by SBM guideline of the sanitation facilities are enumerated below.

Table 7: SBM Guideline on the Sanitation Facilities

Sanitation Facility	Predominant Size	Range of Sizes	SBM Recommendations(for 5 users)	Ahmedabad Urban Development Authority's recommendation
Septic Tank	7'(l) x 5(b)' x 7(d)'	6'(l) x 4'(b) x 5'(d) (Smallest) to 8'(l) x 6'(b) x 10'(d)(Largest)	5'(l) x 2'6"(b) x 3'(d)	4'9"(l) x 2'4"(b) x 3'2" (d)
Single Soak Pit	6'(l) x 6'(b) x 8'(d)	4'(l) x 3'(b) x 5'(d) (Smallest) to 10'(l) x 10(l) x 10'(d)(Largest)	Not Recommended	-
Double Soak Pit	3'(dia) x 5'(d)	3' (dia) x 5'(d) (Smallest) to 7'(l) x 7'(b) x 8(d)(Largest)	3' dia x 3'6" (d)	-
Location of sub soil dispersion				>12 m to drinking water source

There is a lack of awareness amongst the people regarding proper septic tank and soak pit designs, operation and maintenance. The National Building Code and Bye-laws are not followed by households as the monitoring enforcement department is weak.

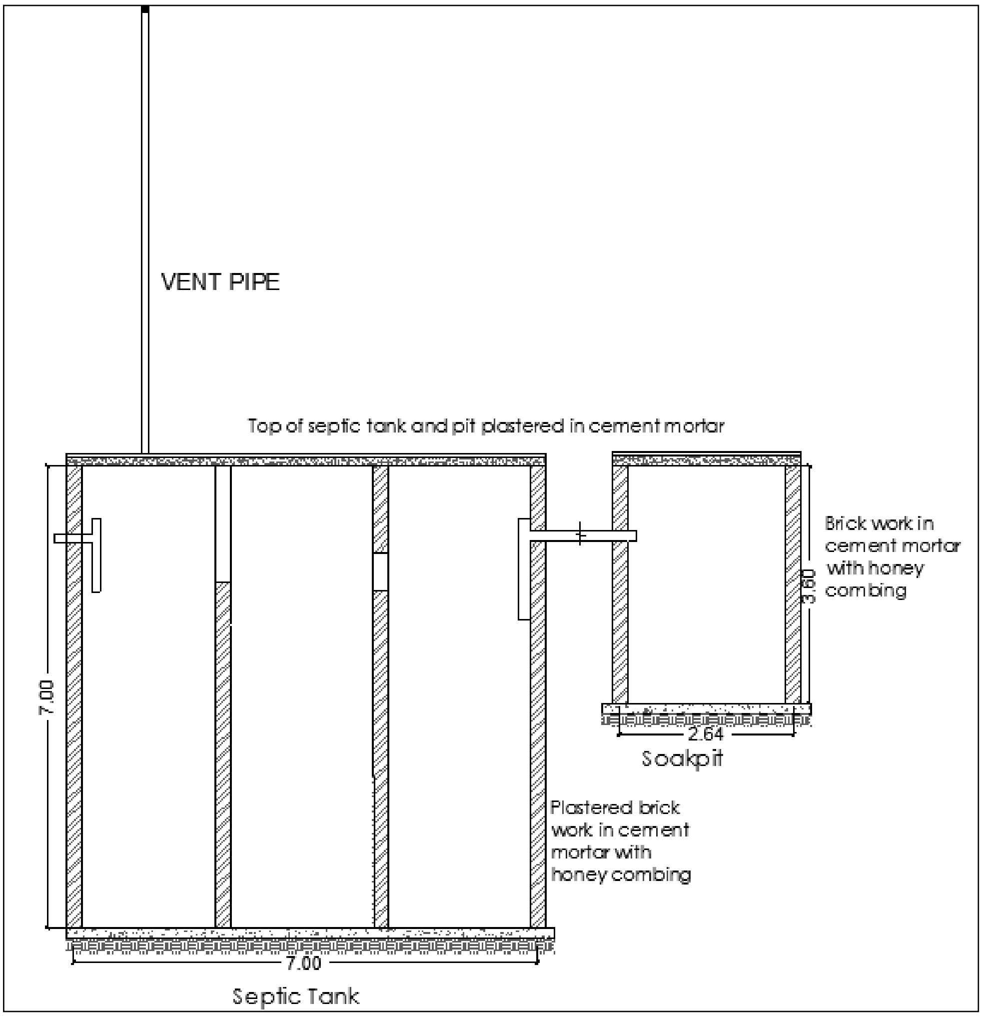
Septic Tank:

Septic tanks constitute 19.4 per cent of the sanitation facilities in Wadhwan. Majority of the septic tanks are constructed with bricks and cement mortar and the rest with stone and cement mortar. All the septic tanks are plastered with cement. Majority of them have three chambers. Circular septic tanks were not encountered in the surveys. In the hard rock terrain of Wadhwan, septic tanks with an outlet directly connected to the gutter line were observed. Due to the impervious hard rock, the percolation capacity of the ground is limited. These typologies where the soak pits are absent constitute 1.7 per cent of the total number of septic tanks.

Septic Tank at Wadhwan

Source: Photo taken of a septic tank at an apartment on 29 June, 2015

Figure 8: Schematic Section of a Typical Septic Tank



Source: Drawing prepared by information inferred from field surveys

According to CPEEHO guidelines, the ventilation shaft should extend at least 2 m above the top of the highest building within a radius of 20 m. A few of these ventilation pipes barely managed to rise above the height of the building.

Inadequate Height of Vent Pipes

Source: Photo taken at Wadhwan on 29 June, 2015

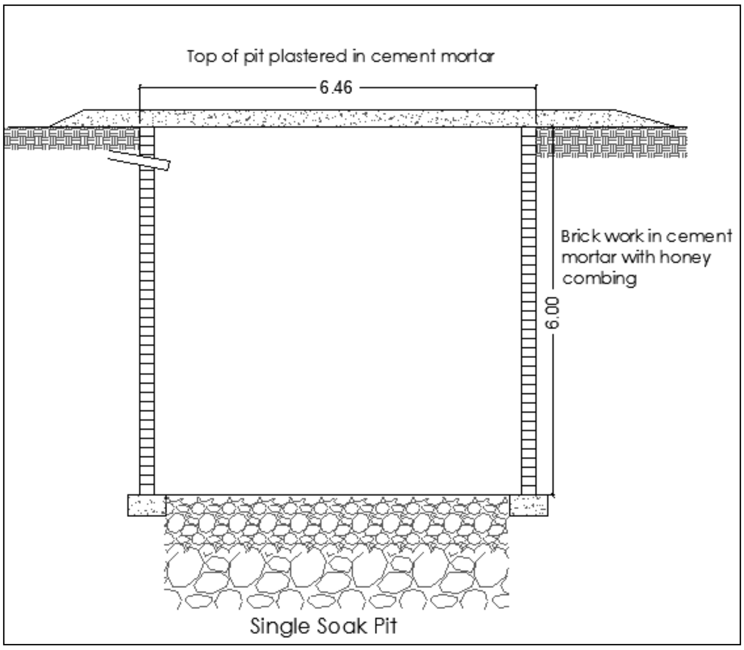
Single Soak Pits:

Single soak pits are the most prevenient sanitation facilities in Wadhwan. They constitute 65.3 per cent of the sanitation facilities. The study found that 3.5 per cent of the households had soak pits, which were circular in plan while 96.5 per cent of the households had soak pits, which were rectangular or square in plan. These pits were either constructed with stone or with brick and all of them were perforated along the sides and left open at the bottom of the pit. Majority of these pits had a vent pipe. Although a vent pipe is not necessary in this sort of arrangement as the gases produced infiltrates into the soil through the perforations, most of the households, which had single soak pits, had constructed a vent pipe. A water seal trap was noted in all the toilets.

Inaccessible Location of Soak Pit without Provisions of Opening

Source: Photo taken in Hudco Colony, Wadhwan on June 25, 2015

Figure 9: Schematic Section of a Typical Single Soak Pit



Source: Drawing prepared by information inferred from field surveys

Double Soak Pit:

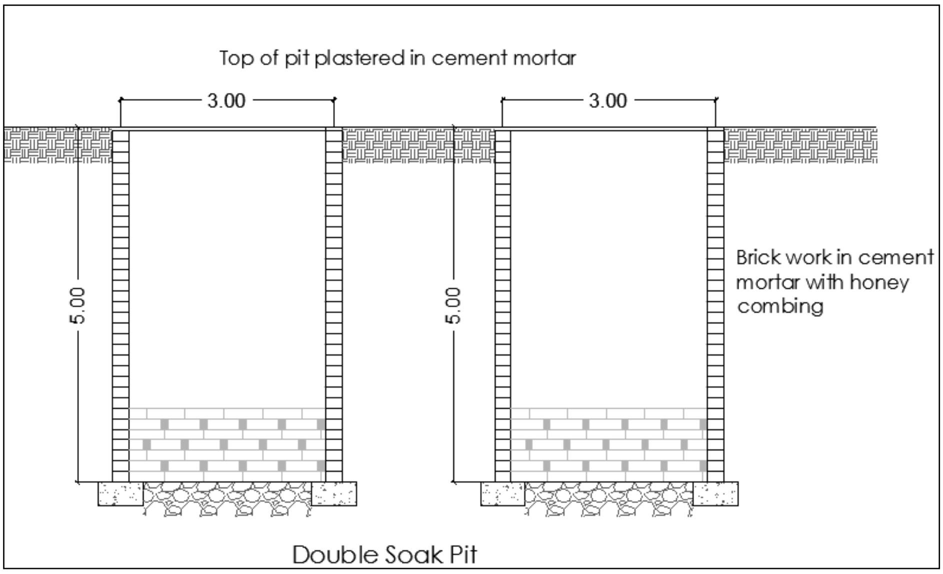
Double soak pits comprise 7.5 per cent of the total sanitation facilities in Wadhwan. The study found that 24 per cent of the double soak pits were circular in plan while 76 per cent were rectangular or square in plan. The double pits are constructed with brick or stone, are perforated and left open at the bottom of both pits. In the Gadh area of the city, the World Bank scheme of twin pit latrines was implemented. Around 950 twin-pit latrines were constructed by the end of 1986.[20] The location of these twin-pits was mostly under the streets. A household had to dole out Rs. 2,000 for the construction, after receiving a subsidy of Rs. 300.

Double Soak Pit with Provision for Opening

Source: Photo taken in Gadh Area, Wadhwan on 28 June, 2015

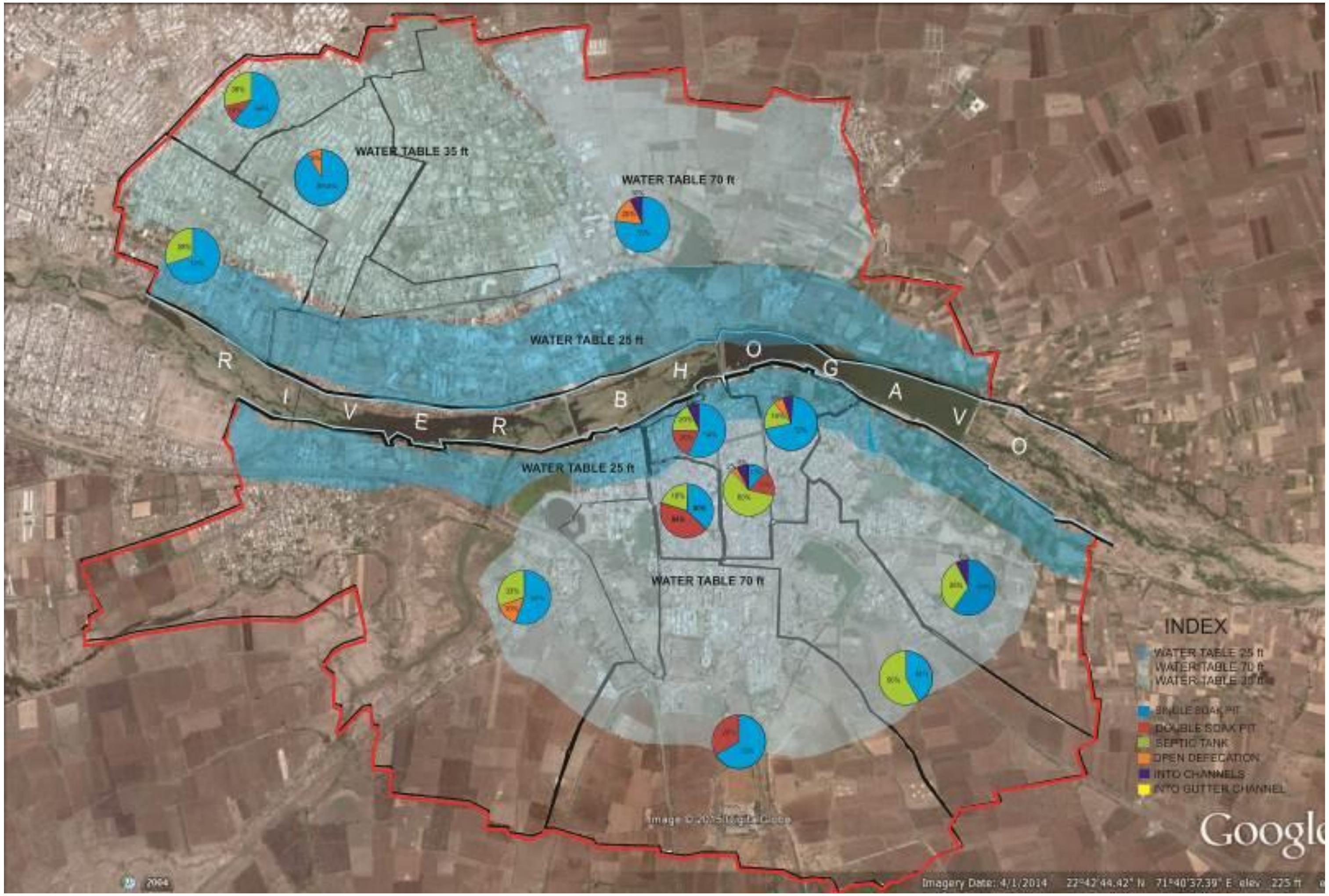
[20]World Bank Document, Gujarat Water Supply and Sewerage Project

Figure 10: Schematic Section of a Typical Double Soak Pit



Source: Drawing prepared by information inferred from field surveys

Figure 11: Map Showing the Distribution of Sanitation Facilities in Each Ward



Source: Pie charts derived from field survey data overlaid on map sourced from Google earth on June 25, 2015

3.8 Volume Generated

Currently, the total volume of fecal sludge generated in a year is 6,433 cubic meters (cu. m). Single soak pits, which generate 84 per cent of the total sludge, comprise the major share of the volume. Septic tanks generate 12 per cent sludge followed by double soak pits, which generate 4 per cent sludge.

Note:

1. In the calculation of fecal sludge, only 20 per cent of the volume of soak pits was considered for the total amount of fecal sludge generated annually. The rationale for doing this is as follows:

The current situation of fecal sludge transportation by manual operators is a blue drum which has a capacity of 200 l. From the surveys, 300 cubic feet (cu. ft) (8,495 l) is taken as the average volume of a soak pit. Considering two blue drums are used, in an ideal situation the number of trips an operator will have to make is 8,495/400, or 21. Clearly, there is a discrepancy as from interviews with the manual operators, it was noted they make a maximum of four trips to clean a facility. So, in reality the actual volume of fecal sludge that is removed from the facility is only 1,600 l, which is approximately 20 per cent of the total volume of the soak pit.

Table 8: Volume of Fecal Sludge Generated

		Number of Samples Collected					Number of Households using a Typology					Average Volume			Average Volume Ward-wise
Ward	House holds in Ward	Soak Pit	Double Soak Pit	Septic Tank	Open defecation	Into Channel	Soak Pit	Double Soak Pit	Septic Tank	Open defecation	Into Channel	Soak Pit	Double Soak Pit	Septic Tank	
1	1,599	26	1	8			1,188.00	46	365	0	0	310	360	100	4,21,222
2	2,211	60			1		2,175.00	0	0	36	0	310	-	-	6,74,174
3	1,052	21		1			1,004.18	0	48	0	0	324	-	100	3,30,137
4	1,588	32			10	6	1,058.67	0	0	331	198	268	-	-	2,84,104
5	1,145	10		6		1	673.53	0	404	0	67	359	-	149	3,02,307
6	1,031	53		13	4	4	738.42	0	181	56	56	335	-	125	2,70,079
7	1,178	12	15	54	2	7	157.07	196	707	26	92	324	331	165	2,32,337
8	1,118	6	3	3		1	516.00	258	258	0	86	334	-	142	2,09,282
9	1,114	5	8	2			371.33	594	148	0	0	52	95	81	87,975
10	1,523	6		3	2		830.73	0	415	277	0	190	-	213	2,46,173
11	1,200	13	1				1,114.29	86	0	0	0	430	210	-	4,97,509
12	1,070	9		10	1		481.50		535	0	0	420	-	152	2,83,550
		Total Number of Households Using each Facility Ward-wise					10,307	1,180	3,062	726	499				

Weighted Volumes

Single Soak Pit	Double Soak Pit	Septic Tank
312 cu. Ft	132 cu. ft	150 cu. ft

Total Volume generated in a year:

= Weighted volume x Number of Households/Frequency of Emptying

Single Soak Pit	Double Soak Pit	Septic Tank
312 x 10,308/9 = 3,58,205	132 x 15,610/10 = 15,610	150 x 3,062/3 = 1,52,695
20% of Total Volume =20/100 x 3,58,205 = 71,641	20% of Total Volume = 20/100 x 15,610 = 3,122	
Total volume generated	2,27,728 cu. ft or 6,433 cu. m	

4. Results and Analysis of FSM Practice

Using the situation status information of the last chapter, analysis and synthesis is carried out so that strength and limitation of different facilities is understood. The preferences of different stakeholders are also analyzed along with their perceptions.

4.1 Economic Status and Choice of Sanitation Facility

There was a direct correlation between the prosperity of a household and the size of their sanitation facility. Although the choice of the sanitation facility itself did not vary with respect to the economic status of the household, there was a variation in the sizes. The prosperous households that had opted for the construction of single soak pits had built much larger soak pits, with dimensions of 10' x 10' x 10'. The households whose site area exceeded 1,000 sq. ft. opted for the construction of septic tanks.

4.2 Situation in Slums

In the six slums of Wadhwan, the Municipality is engaged in the construction of the residents' toilets as well as their sanitation facilities. The Municipality has taken up the construction of only single soak pits. The SBM guideline prescribes construction of the soak pit with 3' diameter and 3'6" depth. However, on the site, it was observed that the pits built are of the size 2'x2'x3' only. On interacting with the respondents, it was learned that the sizes of the soak pits were inadequate at 2' x 2' x 3' and in most cases, the beneficiaries invested their own money to make the pits bigger. In spite of having a functional toilet with a sanitation facility, open defecation was preferred due to the erratic and inadequate supply of water as mentioned by most respondents. The toilets were availed only during the rainy season. The location of the slums fosters the practice of open defecation as the slums are along the River, near a water body or on the fringe of the city, thereby, enhancing accessibility. Case specific situations where the toilet is directly connected to the gutter channels were encountered in a few slum areas.

4.3 Limitation and Risks of Existing On-site Sanitation Facilities

Single pit:

1. Once it is full, the house owner may abandon the use of toilet completely.
2. When a large single pit is constructed with the view of not having to empty it frequently, the sludge hardens at the bottom, thereby, impeding its extraction. In addition, the effective volume of the pit gets recurrently reduced as there is a constant slew of incoming sludge which hardens over time.

Septic Tank:

1. The construction of a septic tank is more expensive than that of a soak pit.
2. A septic tank requires regular maintenance. If the tank is not regularly maintained, then the solid sludge gets into the soak pit, thereby, undermining its performance.
3. Larger space is required for the construction of a septic tank.
4. For soak pits to function, the soil conditions should be suitable for the infiltration of effluent from tank, unless it is connected to a settled sewer.

Double Soak Pit:

1. Unless the household is explained about the operation and maintenance requirement of the double soak pits, there is a propensity of making a mistake in the utilization of this system. If not informed, households may not use the pit alternately or they may not wait a year for its removal. A year being the stipulated duration essential for the sludge to degrade and become innocuous.
2. In areas where the soak pit is in close proximity with the groundwater, the effluent in the soak pit may percolate though the ground and contaminate the groundwater.

4.4 Perception and Preferences of Residents Using Emptying Services

Call for Services: The channel through which the household owners get in touch with the manual operators is random and is mainly subject to the availability of the operator. Since there are 500 such families engaged in this activity, the market for sanitation services is competitive. There is no single manual operator dominant enough to influence the fee charged for emptying services. Although the services are unorganized, there was no dissatisfaction in the way the services had to be sought. In case of the mechanical services, they have to make the bookings with the Municipality and usually, it takes a day or two for the job to be done.

Mechanical Vs Manual Emptying Preferences: All the respondents were satisfied with the services of the manual operators although their major flak was the long duration of the activity. On the other hand, almost all respondents, who had employed the Municipality for the sanitation service, reported the inefficiency of the vacuum tanker to extract the hardened fecal sludge. After the scum and liquid constituent are removed, two manual operators have to be invariably deployed for its removal. Predominantly, the households having septic tanks call the Municipality for emptying their tanks, when they are full. One of the reasons for availing the Municipality service is the less time consumption for the service and the fact that it is much more sanitized as compared to the manual operation.

Awareness about Dumping Site: Residents had strong reservations against the sludge being dumped along the River bank. In fact, the residents of Ambavadi, a locality near the River bank, where the sludge discharge was rampant, until a few months ago, staged a series of protests demanding them to stop the disposal. They complained of bad odors which would incessantly drift through their locality, unhygienic living conditions and so on. The Municipality took note of these protests and since then has ensured that the sludge is not discharged near Ambavadi anymore.

The respondents were not aware of the designated site for the disposal of fecal sludge earmarked by the Municipality. From the focused group discussions, it was inferred that all the suggestions to improve the FSM practice at Wadhwan by the residents clamored for timely cleaning of sludge and use of efficient technology to remove the hardened sludge.

Willingness to Pay for Underground Sewerage Network: Majority of the citizens expressed inhibition at the prospect of having to shell out extra money to get a connection to the proposed underground sewerage network. They opposed the idea as they have already invested money to build their on-site sanitation facility which doesn't require any maintenance for nine years. As the recovery rate of the water supply tax is only 50 per cent, one can assume the sanitation tax recovery rate would be around the same if not less.

4.5 Potential Reuse by Farmers

There is a clandestine farmer market and the farmers applying fecal sludge as manure in agriculture refused to come to fore and accept this practice. Although none of the farmers admitted to indulging in this practice, interaction with a family of manual operators that converts the fecal sludge into manure and sells it, was sufficient enough evidence to substantiate the use of fecal sludge as manure.

The fecal sludge collected by the operator is dumped in a pit and then covered by a layer of sand. Within a month, the fecal sludge transforms into manure. The manual operator sells it to the farmers during the winters. On an average, he manages to sell only two trucks per month with each truck worth Rs. 1,000/-. Due to the availability of fecal sludge free of cost from the river banks, the purchase of the same from manual operators is hindered as the farmers pick it up directly from the river banks.

As there is an existing market for the manure obtained from fecal sludge, formalizing of this activity is paramount to the FSM plan.

Manure out of Fecal Sludge


Source: Photo taken at Wadhwan on June 28, 2015

5. Way Forward

There is an urgent need for Wadhwan city to take cognizance of the current situation of FSM practices and design appropriate changes that can address many gaps in the cycle of FSM. Existing relevant practices of FSM in the developing countries for Wadhwan are described in Chapter 2 earlier. These practices are in three distinct steps viz. safe evacuation and transport, treatment and reuse practices.

The recommendation for FSM in Wadhwan has above three steps. In addition to that it is proposed to include transfer pits as described below. Private service providers will do the emptying and transport till the transfer pits whereas transport and subsequent treatment from transfer pits to the treatment center, will be responsibility of the municipality. Municipality would be able to generate some revenue by selling treated sludge for agriculture usage.

5.1 Emptying and Transport Equipment

Wadhwan city has distinct parts, viz. walled city, other city and the part of industry and new resident development across the river. The core city is quite old and has very narrow lanes. The evacuation and transport in these area is very difficult, hence, appropriate emptying equipment is required. Manual scavengers currently engaged in this work may be incentivized to buy the mechanical equipment and carry out emptying and transport safely.

The Equipment: Considering the available emptying and transport equipment in Annexure III, a Vacutug II is recommended for the extraction and transportation of fecal sludge. The manufacture recommended fluidization in the following way: the pump should be first set to vacuum, then after sucking, some sludge to set the pump to pressure and then blow back into the pit.

Calculation of number of Vacutugs required:

Since the proposal enforces the removal of fecal sludge every three years for a septic tank, the total amount of fecal sludge generated in a year would be 16,012 cu. m. The following is the calculation of the number of Vacutugs required.

Calculation of number of Vacutugs required:

Table 9: Calculation of Number of Vacutugs for Single and Double Soak Pits

Total number of households using soak pits	11,487
Total number of households to be emptied in a year	11,487/9 = 1,276
Total number of households to be emptied in a week	1,276/52 = 24.54
Assuming that a Vacutug empties two soak pits in a day and works six days a week , the number of households it services in a week	2x6 = 12
Total number of Vacutugs required to service 24 households	24/12 = 2

Table 10: Calculation of Number of Vacutugs for Septic Tanks

Total number of households using septic tanks	3,062
Total number of households to be emptied in a year	3,062/3 = 1020
Total number of households to be emptied in a week	1,020/52 = 19
Assuming that a Vacutug empties two septic tanks in a day, and works five days a week, the number of households it services in a week	2x5 = 10
Total number of Vacutugs required to service 19 households	24/12 = 2

Therefore, the total number of Vacutugs required to service the whole city is 2+ 2= 4.

The capital cost of each Vacutug is around Rs. 10 lakhs (shipping cost not included).

8 vacutugs are required, therefore, 4 x Rs. 10 lakhs = Rs. 40 lakhs.

Financing for Entrepreneur: The National Safai Karmacharis Finance & Development Corporation (NSKDC) can play a vital role in arranging soft loans for the manual operators to buy equipment for emptying and transport of fecal sludge. NSKFDC extends low-cost finances through state level channelizing agencies. Four types of loans that are extended include i) term loan ii) bridge loan iii) working capital loan and iv) micro-credit. The interest rates are subsidized and range from 3 to 6 per cent per annum and the loan period can go up to 10 years. The loan for sanitation related vehicles is up to Rs. 15 lakhs with a 4 per cent rate and a repayment period of 10 years.

5.2. Transfer Pits

The solid waste transfer system comprises decentralized trailers interspersed at various locations in the city. When the capacity of these trailers reaches its limit, they are towed away by trucks to a centralized solid waste disposal site. Taking a clue from the solid waste treatment transport, FSM transport can also be designed.

It is recommended that sludge from narrow lanes of the Wadhwan city may be collected to these transfer points interspersed within the city and then is transported to a centralized treatment plant. Transfer points could offer a potential point of transfer of responsibilities from the private operators that provide the household cleaning and disposal to transfer pits to the public sector operators, who are responsible for the disposal from the pits to the treatment plant. This plan was shared with the Municipality and four such prospective transfer points were identified with the help of Mr. Harshad Acharya, Engineer, Wadhwan Municipality. These transfer pits would have a significant impact on the costs of waste transport. Further, instead of the haphazard illegal dumping along the River and peripheral areas, these designated spots would be expedient and ensure a safe disposal practice.

In hard rock areas due to the permeability, septic tanks are not connected to soak pits and instead their outlet pipe is connected to grey water channels. In this scenario, it is recommended to cover these channels or replace them with pipes. In order for the functioning of the system, it should be ensured that none of the solid enters this network. The effluent gathered may be released into a common soak pit at an appropriate location where the permeability is good. Such a soak pit may be constructed near the transfer pits.

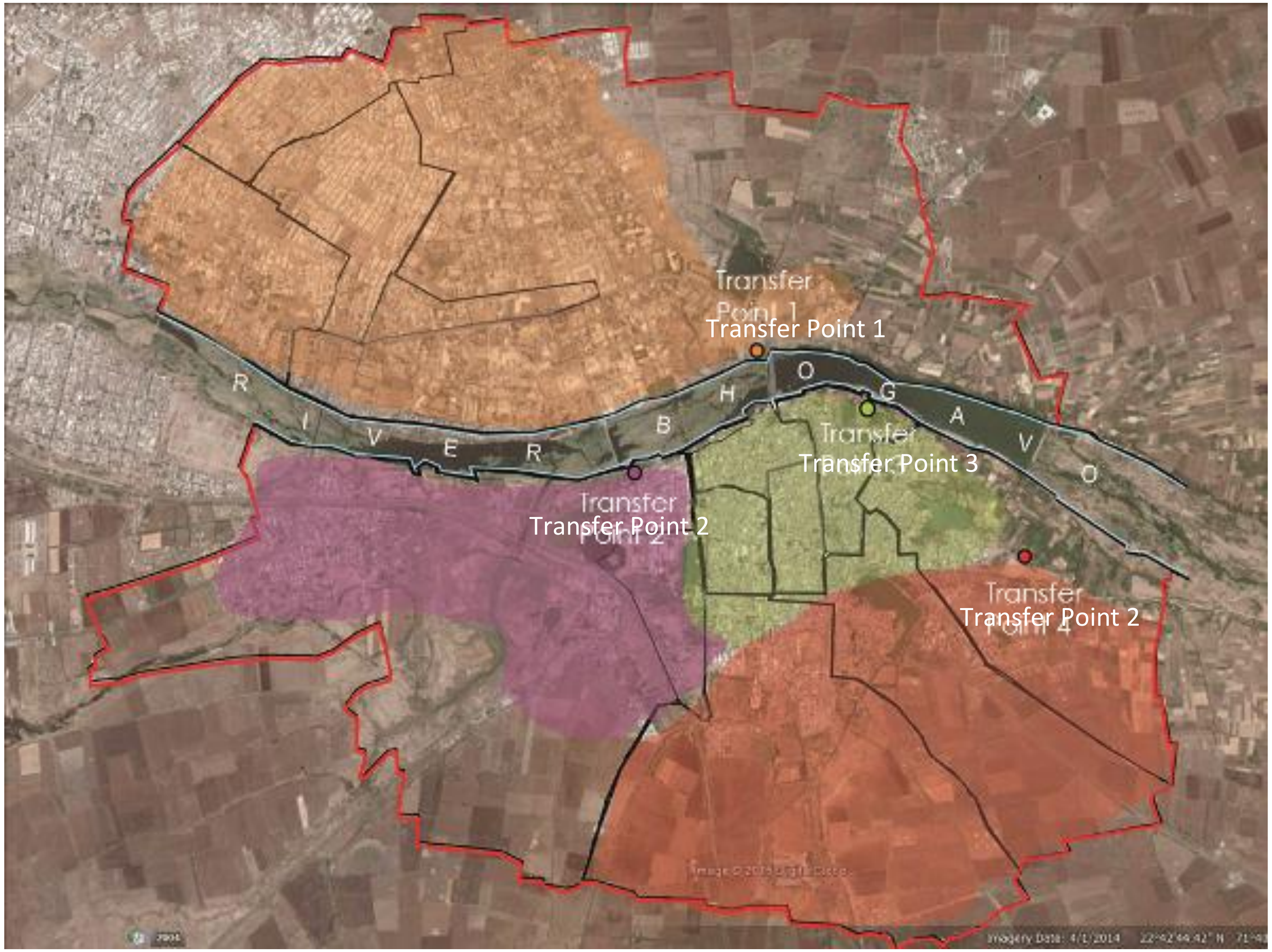
Table 11: Size of Transfer Pit

Number of transfer points	4
Since the fecal sludge is applied once a week to the drying beds, emptying of each transfer point	Once in a month
Total amount of fecal sludge generated in a year	6,433 cum
Total volume of fecal sludge generated in a month	6,433 cum/12 = 536 cu. m
Volume of each transfer point	536/4 = 134 cu. m.
Instead of one transfer pit at a location, four water tight chambers are considered. The reason for having four chambers at one transfer point is due to the monthly cycle of desludging one transfer pit/location. Since there are four weeks in month, the four chambers are delineated for each week. The volume of each chamber-Volume of each transfer point/Number of transfer points	134/4 = 33.5 cu. m
The approximate dimensions of a chamber	2.5m x 4m x 3m
Assuming that the cost of construction is Rs. 2000/- per cu. m, the total cost of construction of all the chambers	33.5 x 16 x 2000 = Rs. 10,72,000

Table 12: Number of Vehicles Required to Clean the Transfer Pit

The volume of fecal sludge generated in a week	134 cu. m
Since the capacity of a tanker is 2000 l, number of trips required in a week	1,34,000/2,000 = 67
Assuming that a tanker will make five trips in a day, number of trips in a week	7 X 5 = 35
Total number of 2000 l tankers required	67/35 = 2 (approx.)

Figure 12: Proposed Transfer Point Locations in Wadhwan



Source: Satellite Image from Google Earth Accessed on 16 June, 2015

5.3 Treatment Plant

The fecal sludge that is aggregated needs to be treated so as to make it pathogen free and safe for reuse. For this treatment, it is necessary that the site for treatment should be away from the city habitation.

The current vermi-compost site designated for the disposal of fecal sludge and solid waste would be an ideal location for the treatment plant. This site is located at an approximate distance of 3 km from the city. All the land between the vermi-composting site and the closest city boundary falls under the flood plain region. Hence, this is the closest safely located site.

Table 13: Proposed Design for Unplanted Sludge Drying Beds

Total volume of fecal sludge generated in a year	6,433 cu. m
Total volume of fecal sludge generated in a day	6,433 cu. m/ 365 days = 17.6 cu. m
The sludge is applied in a batch mode about once per week intervals in layers of no more than 20 to 30 cm.[21] Taking 30 cm as maximum depth, area per bed= volume per bed/depth	17.6 cu. m/ 0.3 m = 58 square meters (sq. m)
Since the sludge is applied once per week, 7 such facilities for daily loading will be needed. Each facility should have an area of 58 sq. m. As this is too large to handle as a single bed, this area is further divided into two beds. Area of each bed/2	58/2 = 29 sq. m
Total number of such beds	7x2 = 14

The design and cost of the sludge bed is Annexure V and Annexure VI

[21] http://www.sswm.info/category/implementation-tools/wastewater-treatment/hardware/sludge-treatment/unplanted-drying-beds

5.4 Calculation of Sanitation Tax for Operation and Maintenance

For the purpose of calculation, of the total costs incurred by the Municipality for the O&M of the treatment plant and the transfer of sludge from transfer pits to the treatment plant, 80 per cent be borne by the households using soak pits and 20 per cent to be borne by those having septic tanks or newly constructed sanitation facilities.

Table 14: Costs Incurred by the Municipality

Number of people employed to maintain treatment plant	3
Salary per month	Rs. 6,000/person
Total annual salary of all three employees	Rs. 6,000x3x12 = Rs. 2,16,000
Number of people employed to transfer the fecal sludge from transfer pit to sludge drying bed	4
Salary per month	Rs. 6,000/person
Total annual salary of all four employees	Rs. 6,000x4x12 = Rs. 2,88,000
Total annual expenditure on salary of seven employees	Rs. 5,04,000

Table 15: Expenditure for Soak Pit Users

80% of total annual expenditure of seven employees to be borne by households having Soak Pits	80% of 5,0,4000 = Rs. 4,03,200
Amount each household has to pay annually (80% of total households)	4,03,200/11,487 = Rs. 35

Table 16: Expenditure for Septic Tank Users

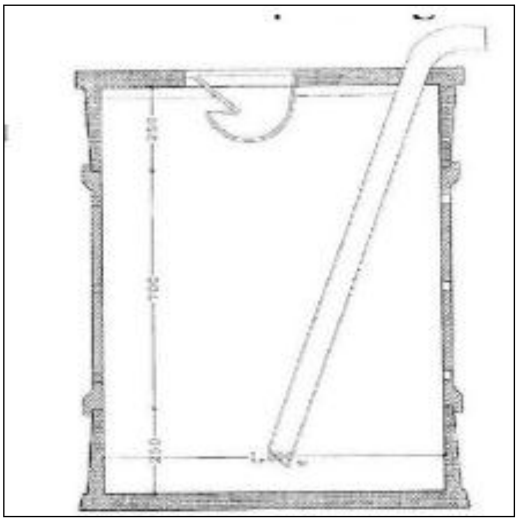
A person is employed by the Municipality who sends out notifications to each household for the fecal sludge removal from septic tanks, every three years. Salary of the employee:	Rs 6,000/- month.
Annual Salary of employee	Rs 6,000X12 = Rs. 72,000
20 per cent of the total costs incurred by Municipality for operation and maintenance of treatment plant and transfer pits:	20% of Rs. 5,04,000 = Rs. 1,00,800
Total sum	Rs. 72,000 + Rs. 1,00,800 = Rs. 1,72,800.
Amount each household has to pay annually	172800/3062 = Rs. 56

5.5 Recommendations for the Building Bye-laws

Since Surendranagar and Wadhwan are forming a joint urban development authority, the building guidelines could incorporate the following guidelines:

1. Non-sewered areas should have provision for at least two pits, one for black water and the other for grey water. They should have a built-in suction/blowing pipe that leads to the base of the pit which will enable dense sludge to be removed and for a pit to be emptied from outside the superstructure without spillage.[22]

Figure 13: Built-in Suction/Blowing Pipe



Source: Top view, side view of UN-HABITAT Proposed Pre-cast Concrete Pit Design (1) - Investigation into Methods of Pit Latrine Emptying (O Riodon, 2009)

2. For the accessibility of manual suction machines, the pit should be located somewhere in the front or on the side of the building. The location of the pit at the backyard should be prohibited for it hinders the accessibility of the mechanical suction system.
3. The pits should be located within the site of the building and not below the streets.
4. The discharge from the sanitation facilities should not be allowed in public drains in view of public safety, health and hygiene.

5.6 Recommendations for the Municipality

For the sanitation service plan, the following guidelines can be adopted by the Municipality:

1. A census/audit of the number of toilets connected to various types of on-site sanitation facilities should be done.
2. A database of the last date of emptying of the sanitation facility for each household should be maintained.

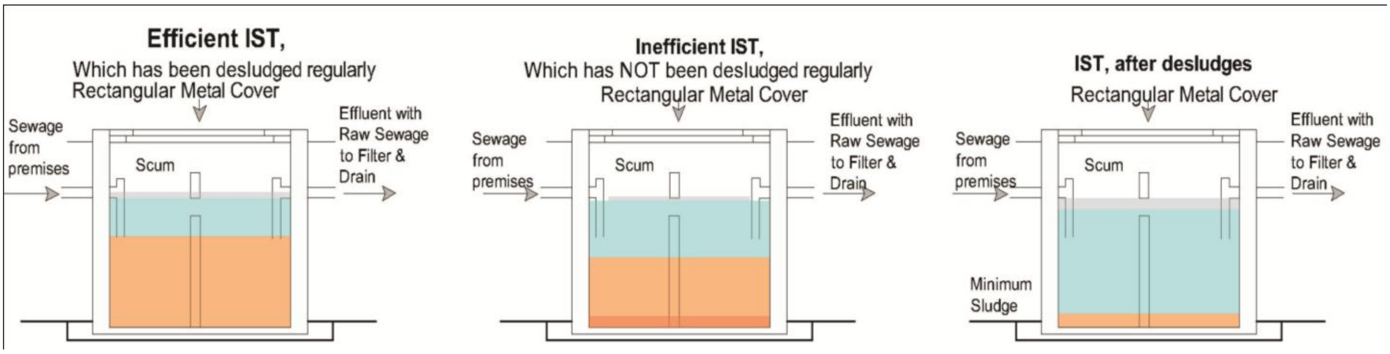
[22] Cambridge University

3. Design an alert system, where the user is notified about the emptying of their sanitation facility. Based on the user's response, the service of a mechanized emptying system would be made available to the user. This was recommended by the chief officer of Wadhwan.
4. Dissemination on the appropriate sizes, location and construction of sanitation facilities should be taken up by the Municipality. This could be achieved through campaigns, posters etc.
5. The Municipality should ensure that the persons engaged in the mechanized emptying, transport and disposal of fecal sludge should have safe and protective gear.
6. It is the mandate of the Municipality to ensure that the building bye-laws are complied with. This requires it to not only approve the drawings on paper but to check its actual construction on the site.
7. Retrofitting of existing on-site sanitation facilities by cutting out a hole in their lids for a polyvinyl chloride (PVC) pipe in order to ease the insertion of a hose during the time of emptying.

5.7 Emptying Regulations

In the city of Wadhvan, there are a range of sanitation facilities that may be broadly categorized as septic tank like and the soak pit like. These two broad categories are based on the type of fecal sludge that is extracted from them. From soak pits, the fecal sludge would contain much lesser water, whereas from septic tank, water would be significant constitute of the fecal matter. As demonstrated in the following figure, it is necessary to empty the septic tank at least once in three years.

Figure 14: Septic Tank Emptying



Source: Self-drawn

Newer soak pits constructed under SBM are of smaller capacity so they would also need emptying once in three years as prescribed in the guidelines. On the other hand, the existing soak pits (80 per cent of existing sanitation facilities) have large capacities and do not need emptying as frequently. Our survey has brought out that the frequency of emptying is once in nine years for such facilities. It is argued that soak pits also should be emptied once in three years so that the fecal matter does not harden at the bottom, reducing the capacity of the soak pit. However, our interactions with the officials and communities informed us that it would be prudent not to impose emptying the soak pit periodically as such enforcements do not lead to desired outcomes. House owners may be made aware of benefits of doing so and can continue to empty it when they feel the need.

Looking at the narrow lanes, prevailing practice of private service providers and the capacity of Municipality, it is suggested that the fecal sludge emptying and transport may be a combination of formal and informal arrangement. Informal markets may do the task of emptying the soak pit and bringing it to transfer points. The advantages of it are

- It allows users (households) to supplement government services especially in cases where the services are not reaching to certain localities or certain group of individuals.
- It can help in the development of an effective interface between private service providers and user by creating a mechanism for interaction and feedback that allows the reformulation of policy design and implementation to meet the particular needs and expectations of users.
- It fosters an economy that is market based and hence sustainable.

The Municipality would be responsible to send the alert every three years to users having septic tanks and would empanel service providers for it. They would in turn report to Municipality once the service is provided. Such a formal arrangement would ensure that the septic tanks are vacated every three years.

5.8 Limitations of FSM

The FSM plan in the above section deals with the fecal matter collected in disposal system of toiles across the city. However, in addition to that it has grey matter and effluent. This plan does not consider the wastewater described below.

The grey water from kitchens is disposed in soak pits, closed channels and mostly, open channels that run along the streets. The outlet of all the open channels terminates in the Bhogao River. In addition, effluent from 30 ties and die units in the Gadh area is conveyed to the River through these open drains. Untreated effluents from the 400 factories in the GIDC area also find their way to the River.

Bhogao River

Source: Photo taken at Wadhwan on June 25, 2015

Effluent from Tie and Die Units

Source: Photo taken at Wadhwan on June 25, 2015

Grey Water Disposed into Open Drains

Source: Photo taken at Wadhwan on June 25, 2015

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ANNEXURES

Annexure I Detailed Household Survey

1.	1.1 Name:	1.2 Contact (phone) 1.3 Address			
2.	Size of Family:	2.1 No. of Adults	2.2 No. of Children		
3.	Presence of Toilet	Yes No			
4.	Type of toilet	4.1 Sitting 4.2 Squating 4.3 Pouring 4.4 Flushing			
5.	If no toilet, what practice	5.1 Public Toilet	5.2 Open defecation		
6.	No of HH using Public Toilet				
7.	Type of Sanitation Facility Mention 'Other' in last cell, if none of the mentioned	7.1Single Pit Latrine	7.4 Septic Tank w/o Soak Pit		
		7.2Double Pit Latrine	7.5 Septic tank with Soak Pit		
		7.3Tanki	7.6 Septic tank, into channels	7.7 Closing the pit	
8.	When did you construct toilet?				
9.	Vent pipe in disposal system	Yes No			
10.	How do they clean the toilet	Acid Phenyl Soap Water			
11.	How often do you clean the toilet	Daily Twice a week Weekly Mention			
12.	Size of the disposal facility				
13.	Above ground/ Belowground?	Above Below			
14.	How is the sanitation facility designed?	Material of the walls/ perforated? Yes No Is it sealed at the bottom? Yes No			
15.	Is there a water connection to the toilet? Yes No				
16.	Source of water - domestic use?				
17.	Payment of water tax	Regular Irregular Pending Never			
18.	Where does grey water go?	Pit	Open Channel	On street	Underground sewer
19.	How often pit is emptied				
20.	Do tenants get pit emptied?				
21.	Are there seasonal variations?				
22.	Back flow of water in toilet?	Yes No	22.2 Which season?		
23.	Who do you call to empty the pit? How soon they arrive?	23.1 Manual Scavengers 23.2 Municipal vacuum pump	23.3		
24.	How much do they charge? How many people in manually?	24.1 Manual Scavengers 24.2 No of People- 24.3 Municipality			
25.	How do you find out that the pit needs emptying?				
26.	If not, for how long have you not emptied the pit?				
27.	Problems faced? If yes, what kind?				
28.	Perception of cleanliness				
29.	Willingness to pay for a regulated service from municipality				
30.	Do you have hand pumps	Yes No	Distance from disposal in meters 30.1 Horizontal 30.2 vertical		
31.	Disease	Diarrhea	Dysentery	Typhoid	Cholera
32.	Plot Size				
33.	Based on Observation – High Income Middle Income Economically Weaker				
34. Remark/ Suggestions					

Annexure II Rapid Household Survey

1.	Name		3. Address
2.	Contact		
3.	Type of disposal system		
	3.1 Single Pit		3.5 Septic Tank outlet into channels
	3.2 Double Pit		3.6 Tanki Type
	3.3 Septic Tank+Soak Pit combined		3.7 Open Defecation
	3.4 Septic Tank and Soak Pit seperate		3.8 Direct connection of latrine to stream
3.9	Number of Chambers in Septic Tank		
4.	4.1 Size of disposal system Soak Pit Length Width OR Diameter And Height		4.2 Size of disposal system Septic Tank Length Width OR Diameter And Height
5.	5.1 Frequency of emptying soak pit		
	5.2 Frequency of emptying septic tank		
6.	6.1 When was the last time you emptied soak pit?		
	6.2 When was the last time you emptied septic tank?		
7.	How was emptying done?	Manually	Mechanically

Annexure III Comparison of Mechanical Equipment

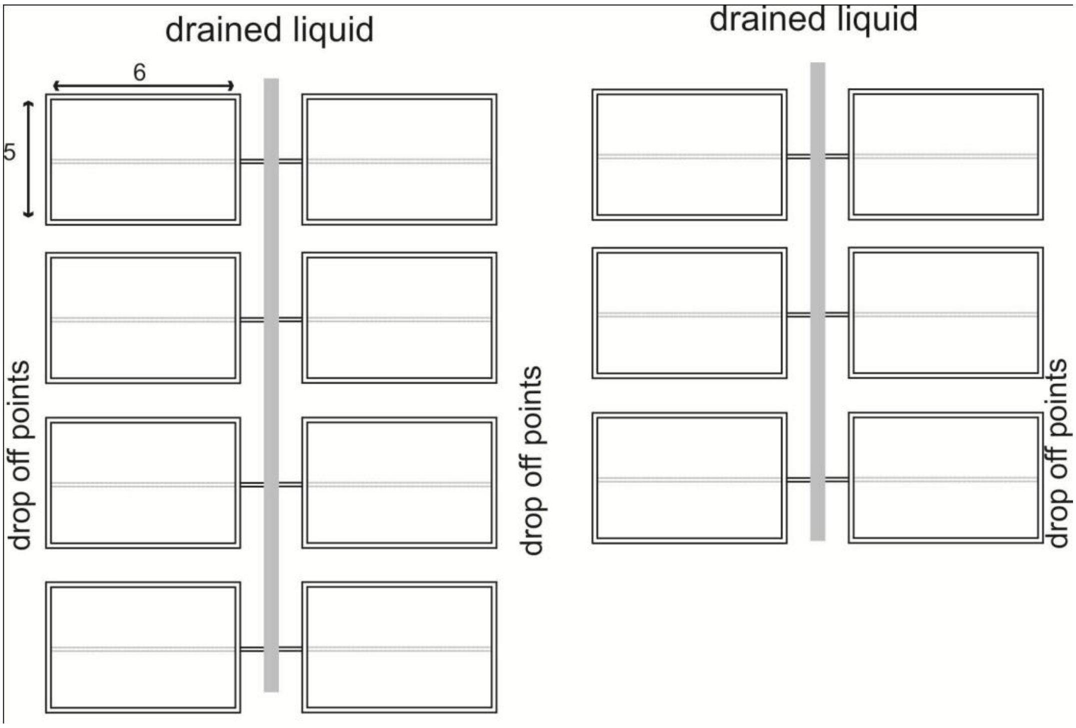
Mechanical Equipment	Disadvantages	Advantages	In the Context of Wadhwan
Conventional Vacuum Tanker	- Cannot access narrow roads - High capital costs - High O&M costs	- Less contact with sludge - Fast emptying services	- Not recommended as the Municipality already owns one such tanker with a capacity of 2,000 l. Calculations to determine the number of tankers required are in Annexure IV
Vacutug	- High capital cost - High O&M costs - Lack of spare parts, usually the Vacuum pump which is nominally an imported part - Very hard to move in uneven alleyways when full	- Low odor technology - Faster emptying than manual methods - Less contact with sludge	- Recommended. Although this system has its fair share of flaws, it has had maximum applicability worldwide and is continuously improving. Since Wadhwan has a fairly plain/stable terrain, its locomotion will not be an issue. Fluidization of hard and dense sludge is viable in this model and has been tried and tested
Dung beetle	- Unable to remove sludge from single pit latrines - Limited physical application of this model, hence, its efficiency is not fully explored	- Low odor technology - Faster emptying than manual methods - Less contact with sludge	- Not recommended due to its limited physical application
Mapet	- Difficult to transport sludge over large distances	- Cheaper than motorized equipment	- Not recommended as from previous experience in Tanznia, it was noted that the service providers were unable to recover transportation and maintenance costs from emptying fees
Gulper	- Can't extract sludge beyond one meter from ground level - No means of sludge disposal off-site	- Can access most locations - Cheap - Can be produced locally	- Not recommended as the depth of most on-site sanitation facilities exceeds one meter

Annexure IV Comparison of Treatment Facilities

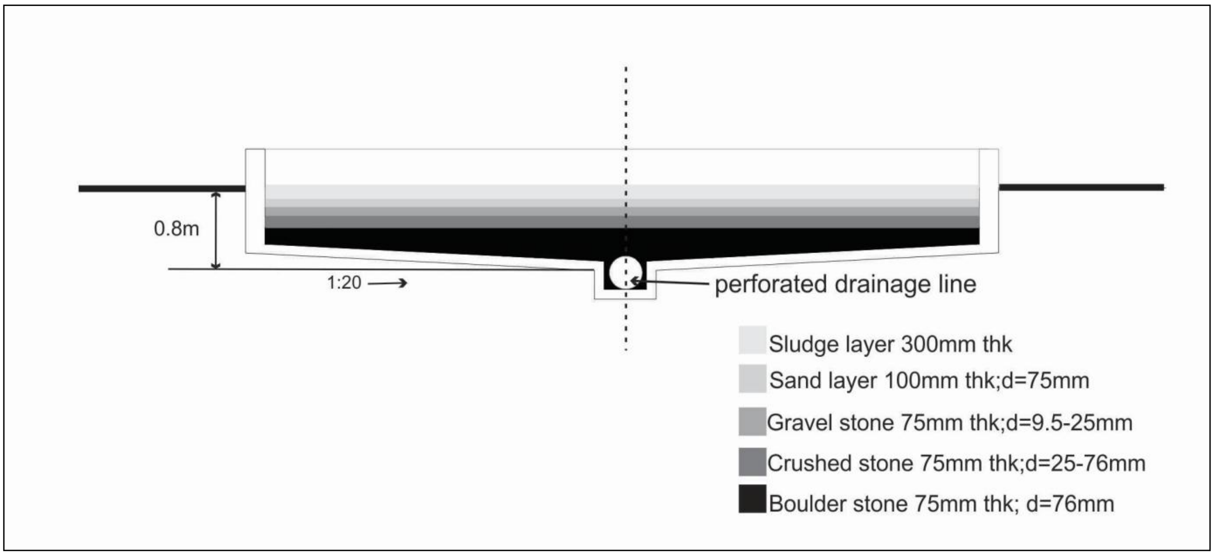
Treatment Facility	Disadvantages	Advantages	In the Context of Wadhwan
Planted Drying Beds	- Large area of land required - Causes bad odor - Desludging is laborious	- No external energy required - Low capital cost - Low operator skill - Low O&M cost - Species that are planted can be income generating	- The main advantages of planted drying beds over unplanted drying beds is that desludging is required only once in 5 to 10 years, whereas in the case of unplanted drying beds desludging has to be done more frequently. Frequent desludging is favorable in the context of Wadhwan since a business model for manure is anticipated - Due to the harsh summers in Wadhwan, the plants need to be tended to
Unplanted Drying Beds	- Large area of land required - Causes bad odor - Desludging is laborious	- No external energy required - Low O&M cost - Species that are planted can be income generating	- Unplanted drying beds are suitable for the context of Wadhwan as this treatment facility has minimal O&M costs
Latrine Dehydration and Pasteurization	- High O&M costs - Electrical Energy is required	- Instant production of manure that can be directly applied in the fields	- This treatment is unsuitable for the context of Wadhwan as this process is highly energy extensive
Sedimentation/Thickening Tanks	- Requires expert design and construction - Causes bad odor - Large area of land required - Effluent and sludge require further treatment	- No electrical energy is required	- This is not recommended as the effluent and sludge require further treatment
Co-composting	- Operation by skilled person - Labor intensive	- No electrical energy is required	- For the functioning of this treatment, the solid waste has to be segregated into bio-degradable and non-biodegradable categories. Since Wadhwan has no such practice in place, this method is unfavorable

Treatment Facility	Disadvantages	Advantages	In the Context of Wadhwan
Anaerobic Digestion	- High technical and construction expertise - Process is slow - High capital costs.	- Generation of renewable energy - The remaining sludge could be used as manure - Low space requirements - No electrical energy is required	- The limited applicability of this treatment is due to its high capital costs with concurrent low affordability. Hence, it is not recommended for Wadhwan
Vermi-composting	- Regular watering - Slow process - Moderately high O&M costs	- Odor free process - Earthworms remove toxic and heavy metals from end product	- As this process requires regular watering, the operation and costs are relatively high. Hence, this would not be the best solution for Wadhwan

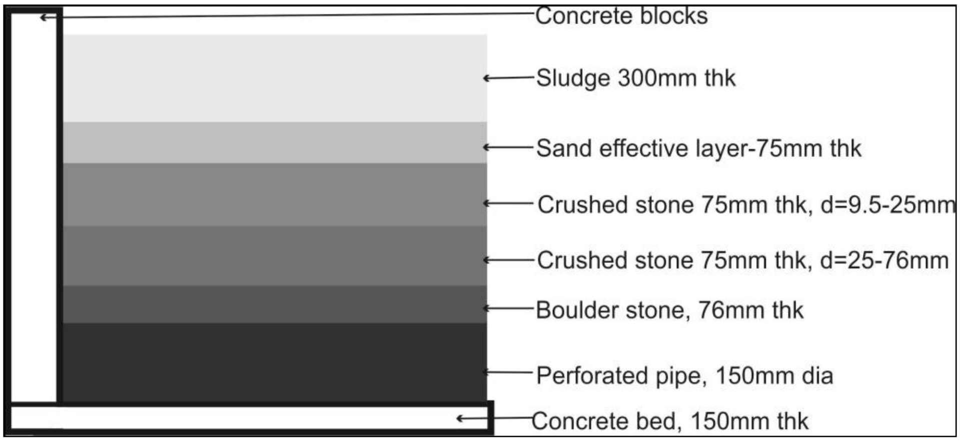
Annexure V Design and Cost Estimation of Treatment Plant



Plan of 28 Sludge Drying beds



Section of an individual sludge drying bed



Detailed section of the filter media

Annexure VI: Proposed Design for Unplanted Sludge Drying Beds

Sr.no.	Description	Number	Length	Breadth	Depth	Volume			Unit/Rate		Cost
			m	m	m	cu. m.		Unit			Rs.
	Volume of pit		7.4	3.7	0.8	21.90					
1	Sand effective layer	28	7.4	3.7	0.75	574.98	204.18	brass	1200	/brass	2,45,010.5
2	Gravel stone	28	7.4	3.7	0.75	574.98	204.18	brass	1200	/brass	2,45,010.5
3	Crushed stone	28	7.4	3.7	0.75	574.98	204.18	brass	1800	/brass	3,67,515.7
4	Boulders	28	7.4	3.7	0.2	153.33	54.4	brass	1800	/brass	98,004.19
5	Concrete bed	28	7.4	3.7	0.15	115.00	-	-	-	-	97,755.56
	Material			Unit	Cost	Total cost					
	Cement		8	Bags	300	2400					
	Sand		0.19	Brass	1200	225.78					
	Aggregate		0.38	Brass	2300	865.49					
	Total cost for one concrete bed					3491.27					
6	Concrete Blocks	28	-	-	-	-	182.5	No.	20	/unit	1,02,218.7
	Volume of walls	1	7.4	3.7	0.2	5.476					
	Volume of one concrete block					0.03					
	Number of blocks required					182.5333					
	Total cost for unplanted sludge drying beds										**11,55,515**