Sanitation Logistics in India

Dissertation Submitted in the partial Fulfillment of

MBA (Logistics & Supply Chain Management) Degree

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DECLARATION

This is to certify that the dissertation report titled **"Sanitation Logistics in India"** submitted to the University of Petroleum & Energy Studies, Dehradun, Uttrakhand, by **Mr. Sushant Tendulkar,** in partial fulfillment of MBA (Logistics & Supply Chain Management) course, is bonafide work carried out by him under my guidance and supervision. To the best of my knowledge this particular work has not been submitted anywhere else for any other Degree. She has made an earnest and dedicated effort to accomplish this dissertation work.

I wish her all the best for her future endeavors.

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ACKNOWLEDGMENT

We think if any of us honestly reflects on who we are, how we got here, what we think we might do well, and so forth, we discover a debt to others that spans written history. The work of some unknown person makes our lives easier every day. We believe it’s appropriate to acknowledge all of these unknown persons; however it is also necessary to acknowledge those people, we know who have directly shaped our lives and our work.

I would like to take this opportunity to express my sincerest appreciation to **Dr. Neeraj Anand,** my mentor for guiding me in constructing and completing this report. It was really a wonderful opportunity to work with her. Her guidance through the discussions and suggestions activated my thought processes and generated a great deal of interest in dissertation.

I have no words to express a deep sense of gratitude to **University of Petroleum And Energy Studies** for giving me an opportunity to pursue my dissertation.

I would also like to thank **Mr. Aman Dua** course coordinator and faculty & staff for helping me prepare for a life after graduation.

Last but not of least importance, I take this opportunity to thank my **parents and friends** who have been with me and offered emotional and moral support.

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EXECUTIVE SUMMARY

Sanitation brings the single greatest return on investment of any development intervention– for every $1 spent on sanitation at least $9 is saved in health, education and economic development. Despite this well well-known fact, in India this sector has remained neglected for most of its post-Independence history. Even today, millions of Indians are subjected to grave ill health, increasing threats to safety, lower spending on education and nutrition, reduced productivity and lower income earning potential resulting into a deepening cycle of poverty – all for want of a basic sanitation facility.

This is especially true for urban India. Growing slum population and lack of acceptable hygiene force over 50 million men, women and children to defecate in the open every day. The poor bear the worst consequences of inadequate sanitation in the form of ailing children, uneducated girls and unproductive people, making these populations even more susceptible and costing India 6.4% of it's GDP.

The fact that even nations with lower per capita income such as Bangladesh and Pakistan are scoring far better than India on various sanitation indicators serves as a wakeup call. The need for improved urban hygiene in India is pressing and warrants public and philanthropic investment. Increasing levels of urbanization, rising masses of slums and historical lack of attention to urban hygiene only make this need more urgent.

Inadequate sanitation is much more than just tiresomeness - In India, 1,600 children die every day before 1 2 reaching their fifth birthday , 24% of girls drop out of school and more than 30% of sidelined women are violently assaulted 3 every year as the lack of basic hygiene forces them to travel long distances to meet their needs. Above all, lack of sanitation is not a symptom of poverty but a major contributing factor. Adequate cleanliness is a basic human right. Its lack is related to, and exacerbates, other burdens of inequity experienced by marginalized urban households, deepening the cycle of poverty. The lack of sanitation increases living costs, drops spend on education and nutrition, lowers income earning potential, and threatens safety and welfare. This is especially true for urban India.

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INTRODUCTION

The quality of drinking water and hygiene facilities are related to good health and sound environment. In wealthier communities this connection is taken for granted, but in the developing world poor water supply and sanitation remains one of the leading causes of illness and death. According to the WHo/UNICEF (2000), every year about 2.2 million people die from diarrhoea, mostly children. Intestinal worms infect about 10% of the population of the developing world. This causes malnutrition, anemia and retarded growth, depending upon the severity of the infection. 200 million people in the world are infected with schistosomiasis, of which 20 million suffer severe consequences. Improving hygiene, water supply and sanitation could control this enormous disease burden. one of the primary causes of contamination of water is the inadequate or improper disposal of human (and animal) excreta. According to the WHo sanitation guide sanitation refers ***to the means of collecting and disposing of excreta and community liquid waste in a hygienic way so as not to endanger the health of individuals or the community as a whole.***

Conservative forms of wastewater management and sanitation fall either under the category of water-borne systems (systems in which water is used as a medium to transport wastes, e.g. sewers) or pit latrines. The design of these technologies is based on the premise that excreta are a waste and that waste is only suitable for disposal. It also assumes that the environment can assimilate this waste.

The technologies are very high in investment, maintenance and operation costs. This has led to wastewater and excreta being discharged worldwide either poorly treated or not treated at all.

Currently more than 90% of wastewater and excreta worldwide are either only poorly treated or not treated at all at discharge. The conservative sanitation system in developing countries is the pit latrine (the excreta are accumulated in a large hole in the ground), because the costs of water-borne systems are too high and water for flushing is not (widely) available. Although the pit latrine and similar systems are simple and relatively low in costs, they are difficult to use or not useable in crowded areas, on rocky grounds, high groundwater level areas or areas that periodically get flooded. Furthermore, the design of the pit latrine (and of most other on-plot systems (systems where treatment of the excreta takes place at the same location where defecation takes place) aims at retaining only the solids and at infiltrating as much of the liquids in the surrounding soil as possible to reduce the frequency of emptying or having to make a new pit. However, the liquids infiltrated into the soil contain pathogens, viruses and bacteria, because they have been in contact with excreta, and thereby contaminate the groundwater.

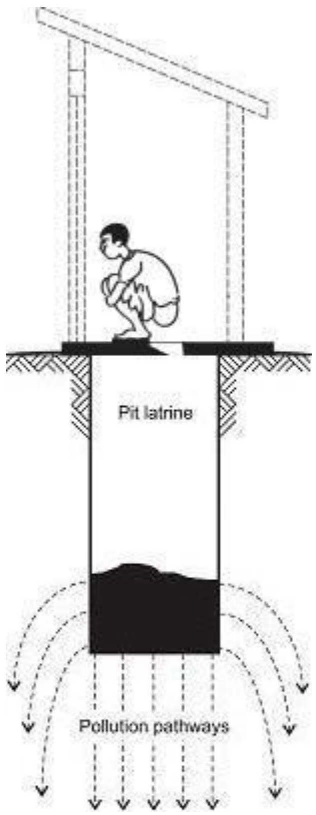

Figure 1 The simple pit latrine or "drop-and-store" Model (Picture: Adapted from Harvey (2002))

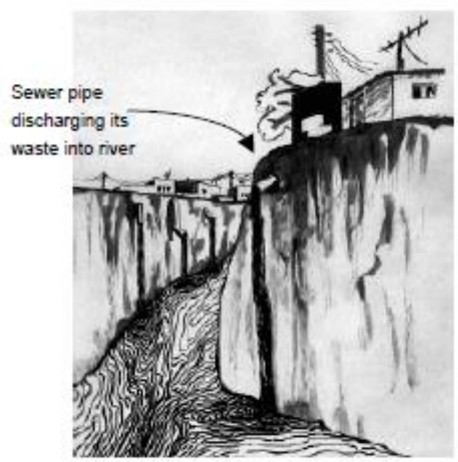

Figure 2 The waterborne sanitation system or "flush-and discharge" model - Most flush and discharge approaches shift the burden of disease and responsibility to communities downstream. (Pictures: Esrey (2001))

INDUSTRY PROFILE

The conservative systems do not provide an solution to wastewater management and sanitation, because the health of the individual and the community as a whole is still endangered as explained above. on top of this, there is a growing awareness and need to safeguard the limited resources in the world. This is particularly urgent with regard to fresh water and mineral resources. With the ongoing water scarcity the application of waterborne systems is becoming more difficult, because water is used for transportation of the waste. Clean water is too precious to be flushed down the toilet. Another problem is that the nutrients and trace elements that are present in excreta (through the food that is consumed by the people) are not channeled back into the agriculture fields. Mostly they end up (along with the waste water) in water bodies where they become unusable and polluting or the nutrients and trace elements remain concentrated and covered up in an hole in the ground. To restore soil fertility, chemical fertilizers are currently used to produce adequate amounts of food. During the "Green Revolution" nutrients were given the status of being limitless. The components in chemical fertilizer are scarce and are likely to become the subject of geopolitical conflicts given the highly skewed distribution in the world.

The economically extractable reserves for phosphorus are estimated to be exhausted within the next 130 years. Phosphorous cannot be substituted by alternative resources and is at the same time an essential nutrient for all forms of life (think of food production). Recycling from sanitation can be a partial remedy, because a significant percentage can be recovered by using sustainable agriculture and hygiene. However, mixing and diluting excreta with water, as is done in sewage systems, make recovery of the nutrients very costly. Therefore, changes in the conservative hygiene and wastewater systems and adaptation to more sustainable practices for sanitation are needed in order to make recycling economically viable. Ecological sanitation is an approach that regards human excreta and wastewater not as waste but as a resource that should be made available for reuse.

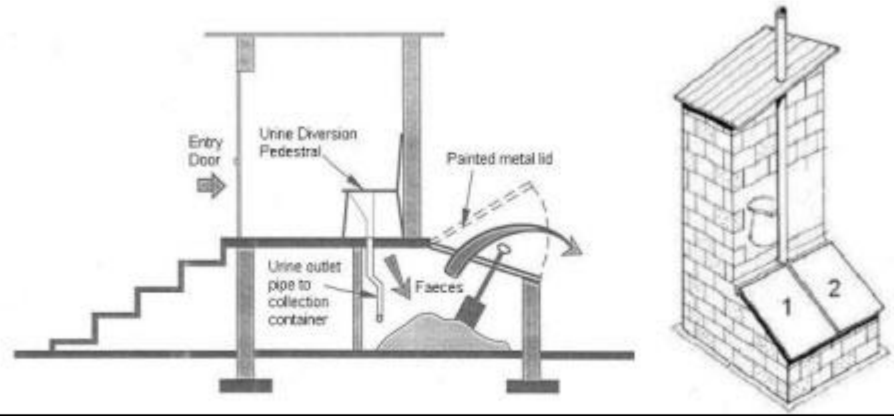

Figure 3. An example of Double vault system. Left image adopted from Austin(2002) and right image from Winblad(2004)

The basic principle of ecological sanitation (EcoSan for short) is to close the loop between sanitation and agriculture. In making organic matter, plant nutrients and trace elements available to agriculture, soil fertility is preserved and long-term food security is safeguarded. The main objectives are to:

· reduce the health risks related to hygiene, contaminated water and waste;

· prevent the pollution of surface and ground water;

· prevent the degradation of soil fertility;

· optimize the management of nutrients and water resources

EcoSan does not service a particular technology, but is rather a new viewpoint in handling substances that have so far been seen merely as a waste to be disposed of. Excreta can provide a fertilizer for farming and urban agriculture, also for those who currently cannot afford or use chemical fertilizers.

RESEARCH OBJECTIVES

- To assess the current status of water supply, sanitation (including on-site sanitation) and solid waste management in the metropolitan cities.
- To suggest the future use of ECOSAN and its advantages.

RESEARCH METHODOLOGY

Type of Research Design: Descriptive (Diagnostics)

Type of Data: Secondary

Methods of Data Collection:

- **Secondary:**
    - Research papers
    - Journals
    - News papers
    - Magazines etc.

LITERATURE REVIEW

Author	Year	Context	Parameters
Marieke Slob	2005	Logistic Aspects of Ecological Sanitation in Urban Areas	Focuses on various transportation techniques of human waste
Christoph Lüthi, Jennifer McConville	2009	Rethinking Sustainable Sanitation For The Urban Environment	Discusses about the infrastructure, reuse and recycling.
Prof.C.A.Srinivasamurthy, Mr M.Subburaman,	2011	Ecological Sanitation Practitioner's Handbook	Discusses the various Ecological sanitation designs and technological options
F.Tettenborn, I.Kaneva, J.Grünauer, M.Winker, R.Otterpohl	2007	Transport and Logistics basics in the context of new sanitation concepts	Addresses the new distribution system in sanitation transportation

FINDINGS AND ANALYSIS

Current status and structure

India is a country with one of the lowest coverage levels of sanitation in the world. The United Nations Statistics Division points out only 15% of the rural population and 61% of the urban population had access to improved sanitation1 in 2000. Faced with growing pollution problems, Indian cities are not able to provide services that are adequate, neither quantitatively nor qualitatively. of the 4000 towns and cities in India, 300 have a sewerage system and only 70 of them have treatment facilities. This means an lot of untreated, raw sewage finds its way to low-lying areas and natural watercourses such as the river Yamuna flowing through Delhi. The result is that many water bodies have become open sewers polluting not only their surroundings, but also causing serious health and environmental problems to towns and cities downstream. However, sanitation falls under the direct responsibility of the MCD indicating the lack of coordination that can and is occurring.

Conservative Sanitation Systems: Drawback & Limitations:

Conservative sanitation systems adopted for disposal of human excreta are primarily based on either "flush or discharge" or "drop and store" principles. These methods, developed at early stages of evolution of sanitation concepts, aim to dispose human excreta rather than viewing it as a resource and treating at source. Conservative sanitation can be termed as

"Linear sanitation approach" also termed as "end of pipe" technology, leads to disposal of enormous quantities of nutrients present in human excreta unproductively into water bodies causing pollution, apart from wastage of precious fresh water. Some of the limitations of conservative sanitation technologies are as follows:

1. Massive infrastructure needed and high to go through a complex treatment processes.
2. Elimination of organic matter and nutrients at sewage treatment plants requires enormous amounts of energy and chemicals.

3. Use of freshwater to transport human excreta in sewers results in high drinking water demand. In water-scarce regions, additional pressure is put on limited freshwater resources.
4. Drop and store method of treating human excreta onsite has limitations too. Groundwater especially in coastal areas and areas with shallow water table get contaminated by disease causing pathogens and nitrate present in human excreta.

General idea of main logistic systems

on a high level basic logistic systems can be distinguished depending on how the collection and transport takes place and is organized. The first division can be made between direct transport and transport with transfer operations. Transfer becomes a necessity when haul distances increase to such a distance that direct transport is no longer economically possible or when the destination can only be reached with a different means of transport. It is cheaper to haul a large volume of waste in large increments over an long distance than it is to haul a large volume of waste in small increments over an long distance. Depending on the size of the collection vehicles transfer might be cheaper.

The second division that can be made is the means of transport. With regard to the secondary collection or transport basic differences can be made between transport by road, rail, water, air or pipes. In this research only road transport is relevant. Transport by rail, water or air is not relevant due to the limited distance that has to be bridged, ± 10-20 km; the destination (farmers or a treatment facility) is located near the rim of the city. Concerning a pipe system, large-scale pipe infrastructures lie outside the scope of this research. This leaves only transport by road for secondary collection.

With regard to the primary collection, transport by road and small-scale pipe systems are possibilities. Basic distinctions can be made in who does the primary collection and the means of collection.

Main Transportation system

There are many different existing transport systems potentials. In order not to disappear in all the possible options this chapter will focus on the identification of a few main systems. These main systems can be seen as basic systems in which there has not been a choice yet for the particular handling and transport equipment. This can be filled in more concretely in a later design stage together with the assessment of different (equipment) options. The concepts are identified in the first section and the second section determines the appropriateness of each concept for urine and faeces transport. Based on this, one main system is chosen which will be worked out in detail further in this research. The parameters of design will give information on the variations and choices that have to be made within the main system.

Main logistic system	Operator of primary collection	Means of collection	Analogy with existing collection systems
Public toilets	Household-member	Inside the body of household member.	Communal collection (households discharge their waste at predetermined locations. Refuse-collection vehicles visit these sites at frequent intervals to remove waste (secondary collection))
Household member brings urine and/or faeces to a collection point	Household-member	Household containers	
Collection vehicles collect urine and/or faeces at each household	Collection service	Household container is switched for empty container or household container is emptied into collection vehicle	Door-to-door collection service
Piping system on street/block level	Automatic (collection service)	Small diameter pipes from households to a large collection tank	Small bore sewerage (small diameter sewers laid at shallow gradients to convey sewage)

Suitability of systems for urine and faeces collection

The suitability of the different systems for urine and faeces collection is considered for each system.

Community toilets

Community toilets provide less convenience for the household members than an individual toilet. It takes more time to go to a public toilet, because it is further away and there can be queues. Furthermore, public toilets tend to be dirty and women often do not feel safe visiting the toilets, especially when it is dark.

Household member brings urine and/or faeces to a collection point

People who do not have the profession of excreta removal do not want to be engaged in the handling of excreta. Although this system could mean the household members can bring the urine and/or faeces free of charge or even receive some money for it at the collection point instead of having to pay a collection fee to a collector. Even though urine is technically clean, it is associated with excreta/faeces and not perceived as something that they could be seen with from an social point of view.

However, when the system is in operation for a certain amount of time and people see what a urine diverting toilet and urine collection is about and see what faeces look like when it has undergone primary treatment, people might start to change their opposition to handling the excreta themselves and feel comfortable to bring it to a collection point if this saves money. They could also start to use it for own purposes as fertilizer if they start a small garden on their roofs.

Collection vehicles collect urine and/or faeces at each household

It is acceptable for people to hire a person who collects the urine and faeces. There is no cultural opposition against this and therefore this system is likely to be acceptable for the community members.

Piping system on street/block level

In this case a distinction has to be made between urine and faeces collection. A piping system for faeces is not considered appropriate, because it needs water to transport the faeces through the pipes. This is against the principle of EcoSan of using/polluting no or very little water. Furthermore, the faeces have to be collected untreated in this case. This is against the principle of providing safe sanitation, because of inevitable leakages in the pipes and the invisibility of the leakages under the ground, which lowers chance of repairs.

Factors to consider when selecting a collection and transportation vehicle

The selection of a specific type of collection and transportation vehicle is a very important decision. Waste collection vehicles might be very efficient and effective in one part of town or for transport of a certain type of waste, but might be totally unsuitable to work under different conditions. Waste collection vehicles designed to operate in low-density urban areas with well-paved roads might be totally unsuitable to handle high-density areas with poor access, although the two areas might be in the same city.

Ecological Sanitation Systems: Advantages & Novel Features

Ecological sanitation systems render human excreta safe, preventing pollution rather than attempting to control it after pollution takes place and proposes to use the safe products of sanitized human excreta for agricultural purposes. Therefore it can be categorized as a “closed loop” sanitation system which treats human excreta as a resource. Human excreta are processed until they are completely free of disease organisms. Nutrients obtained in the form of compost and urine is recycled by using them in agriculture. As ecological sanitation systems adopt treatment processes that closely mimic the cycles of nature, it is sustainable and has no negative impact on the environment.

Some of the advantages in the use of ecological sanitation systems are:

1. Ecological sanitation systems lead to saving enormous quantities of fresh water since urine diverting dry toilets and waterless urinals do not require water for flushing.

2. Faeces and urine which require different treatment processes can be handled easily when separated at source. Studies show that the segregated treatment approaches are both energy efficient and cost effective.
3. Separation of faeces, which has high pathogen levels, from urine and absence of water used for flushing, significantly reduces the volume of waste fraction to be treated.
4. By using ecological sanitation approach pollution of water sources and the risks posed by diarrhoeal diseases due to unsafe disposal of human excreta can be mitigated.
5. Ecological systems facilitate decentralized and sustainable treatment options for safe disposal of human excreta.
6. Compost obtained from ecological sanitation toilets is a good soil conditioner and increases soil fertility.
7. Urine, which is usually sterile, is rich in nitrogen, phosphorous and potassium can be directly applied to crops or further processed as crystal fertilizer.
8. Recovery of nutrients from human excreta using ecological sanitation systems can effectively substitute mineral fertilizers which are non-renewable whose prices have increased multifold due to depletion of oil and phosphate rock reserves.

Linking sanitation and agriculture using ecological sanitation approaches can play a major role in ensuring health security as well as food security of economically weaker sections of society.

Nutrient Rotation

Nutrients such as nitrogen, phosphorous and potassium play an important role in the growth of plants. In general, nitrogen and potassium make up about 80 percent of the total mineral nutrients in plants; phosphorous, Sulphur, calcium and magnesium together constitute 19 percent, while all the micronutrients together constitute less than 1 percent. Nitrogen is responsible for the dark green color of stem and leaves, vigorous growth, branching / tailoring, leaf production, size enlargement, and yield formation. Phosphorous is essential for growth, cell division, root lengthening, seed and fruit development, and early ripening. Potassium increases resistance of plants to disease, creates winter hardiness and drought resistance, and produces stiff stalks and stems to reduce water logging. It also increases grain plumpness as well as growth of fruit and root vegetables.

Nutrients present in soils are consumed by crops to produce food and other products for the benefit of human beings and animals. Crop products are often consumed faraway from the production sites, sometimes thousands of kilometers away in another country. When crop products are moved, the nutrients contained in them are also transported. This implies movement of nutrients from the production area to the area where they are finally utilized. If nutrients excreted as a waste after consumption are not recovered and simply discharged into water bodies, it causes a break in the natural nutrient rotation and leads to depletion of nutrients in the soil. As a result, these misplaced nutrients have to be substituted by chemical fertilizers produced from finite mineral and oil reserves. Providing nutrients to soil solely through fertilizers is often unaffordable by many poor and marginal farmers leading to food insecurity and poverty. Use of chemical fertilizers also leads to environmental pollution and degradation of soil health in the long run.

Elements (g / ppd)	Urine	Faeces	Urine + Faeces
Nitrogen	11.0	1.5	12.5
Phosphorous	1.0	0.5	1.5
Potassium	2.5	1.0	3.5
Organic carbon	6.6	21.4	30
Wet weight	1,200	70 - 140	1,200 - 1,400
Dry weight	60	35	95

Table 1. Major elements present in human excreta (Source: Esrey et al.

Nutrients	Nutrients in 500 litres of Urine	Nutrients in 50 litres of Faeces	Total	Fertilizer needed to grow 250 kgs of cereal
Nitrogen	5.6 kg	0.09 kg	5.7 kg	5.6 kg
Phosphorus	0.4 kg	0.19 kg	0.6 kg	0.7 kg
Potassium	1.0 kg	0.17 kg	1.2 kg	1.2 kg

Table 2. Major nutrients in human excreta and quality of nutrients required to grow 250 kg cereals (Source: WEDC)

Nutrients in Human Excreta

Urine and faeces excreted by human beings are rich source of nutrients like nitrogen, phosphorous and potassium. on an average, every human being excretes 500 liters of urine and 50 liters of faeces in a year. These values vary giving to age and dietary habits of an individual. Urine contains noteworthy portion of nutrients excreted by the human beings. Studies suggest that around 80% of nitrogen, 66% phosphorous and 80% of potassium are present in urine. Faeces are rich in organic carbon with over 80%.

Urine is usually sterile; unless it is cross contaminated with faeces, while it is important to inactivate pathogens present in human excreta before it is applied to agricultural lands. Treatment procedures which can be adopted to render human excreta safe are discussed in the coming sections.

The basic steps implemented to render safe handling and recycling of human excreta is listed below:

- **Source Separation:** Source separation of faeces, urine and wash water and ensuring that no water be used for flushing would reduce the volume of pathogenic material. only the faecal fraction needs to be paid great attention.

- **Isolation:** The pathogenic material should be isolated until it is safe for recycling and this eliminates the risks of contamination.

- **Volume Reduction:** The volume and weight of pathogenic material is reduced by dehydration and/or decomposition to facilitate storage, transport and further treatment.

- **Sanitization:** Reducing pathogens to a harmless state, by sanitization: primary treatment on-site (dehydration / decomposition, retention), secondary treatment on / off site (further dehydration, high temperature composting, changes in pH by the addition of lime), and, if necessary, tertiary treatment (incineration).

Recycling Nutrients present in Excreta

Urine and faeces can be safely recycled back to soil after treatment. Suitable treatment options can be introduced through ecological sanitation systems appropriate to the situation.

Urine can be subjected to various treatment processes like storage, volume reduction, hygienisation, struvite recovery and evaporation. Direct application of urine to crops after a short storage period is the most preferred option being adopted in rural areas presently. However, direct application of urine over a sustained period may lead to increase in soil salinity of agricultural lands requiring periodical monitoring and mitigation measures. Collection of urine from urban areas and institutions like schools and public places, transportation of large volume of urine increases the cost of application. Therefore, methods like struvite recovery, volume reduction and evaporation are being explored. Urine has proved to be a quick acting multicomponent fertilizer which has very low heavy metal content. Better plant yield, taste and plant characteristics have been observed among plants fertilized with urine.

Dehydration or decomposition processes are applied to eliminate pathogens present in faeces. Aeration, increased temperature, high pH due to addition of ash and lime and microbial activities are some factors responsible for inactivation of pathogens in faeces. Compost obtained from the process is rich in carbon and a very good soil conditioner. Some benefits exhibited by compost are improved soil structure and water holding capacity, good microbial activities, prevention of pests and disease, moderation of temperature, slow release of nutrients and binding of heavy metals.

Ecological Sanitation Systems

Any sanitation system that sanitizes waste materials and facilitates recovery of useful substances can be termed as an ecological sanitation system. However, it is quite difficult and a challenging task to classify the numerous methods which can be utilized to achieve this purpose. Single or a range of systems in combination can be employed to achieve this objective. The following schematic representation shows various ecological sanitation systems which can be employed to address major waste streams.

In this section, a few important cost effective and decentralized ecosanitation systems which can be employed in rural areas to treat human excreta are discussed. However, ecosan is not limited to these technologies alone; other technologies which are capable of meeting these objectives would also be considered as ecological sanitation systems.

Ecosan Toilets (UDDT)

Urine diverting dehydrating toilets which are commonly termed as "ecosan toilets" are widely being adopted across many parts of the world due to their versatile application and operational ease. Unlike other systems, ecosan toilets utilize dehydration process which is less complex and best suited to most places. Faeces, urine and wash water, especially in places like India, where people follow ablution after defecation, need to be separated using a specially designed toilet 3-hole seat The faeces and additive of soil, wood ash or dry leaves added after every use are collected in a chamber or removable bin placed directly below the toilet seat. By maintaining dry conditions inside the chamber and by enhancing air circulation through vent pipes provided to the chamber, dehydration of faecal matter is achieved. Due to factors such as increase in pH, higher temperature, aeration and dehydration, the mixture is sanitized and desiccated into a fine power-like substance after isolation period of 9-12 months. This dry residue or compost collected from the vault is a good soil conditioner which can be applied to agricultural lands.

Urine diverted to a storage tank can be applied to crops as a nitrogen rich fertilizer containing both phosphorous and potassium. Urine which is usually sterile does not require treatment unless cross contamination with faeces occurs. Wash water containing pathogens is diverted safely to a soak pit or a plant bed provided outside the toilet.

Ecosan toilets help in saving water, preventing contamination of ground water and recycling nutrients excreted by human beings to agriculture. It is suited for construction in all types of regions including dry, cold, hilly and plain areas.

Design Features

Ecosan toilets can be constructed in various designs based on factors such as climate, temperature, availability of space, convenience and features desired by the users. Variation in design is achieved through modification of the faeces collection chamber and toilet seats installed.

Ecosan toilets are usually designed based on collection capacity of 500 liters of urine and 50 liters of faeces excreted by a person in a year. However, the usage pattern varies between households, schools and public places.

For designing ecosan toilet chambers, parameters such as ultimate volume of desiccated faeces and additives added, quantity of urine and wash water generated by a person per use must be taken into account. The ultimate volume of desiccated faeces and additives vary depending on the volume of faeces and additives added after every use.

Cost Estimate

The cost of a household ecosan toilet depends on factors like quality and type of material used, number of chambers opted (one or two), thickness of walls, finishing of the toilet unit, urine diverting pan opted and other amenities such as like doors and ventilators. The cost of a household ecosan toilets built based on these factors is expected to range between Rs 10,000 to Rs 20,000 given the current market price of the materials and labor across India.

Reduction in the cost of a household ecosan toilet can be achieved by constructing the superstructure with locally available materials such as thatch, bamboo, and waste wood and gunny bags while the substructure of the toilet is constructed using proper masonry. Some of the options explored in a project funded jointly by the cost of a household ecosan toilet worked out based on the standard materials and current cost of materials and labor is about Rs 16,915.

Community Ecosan Toilets

Ecosan toilets can also be constructed at community level in densely populated areas where space for promoting household ecosan toilets is a constraint. Either a large scale community ecosan toilet complex or a decentralized row type ecosan toilet unit can be promoted in such scenarios. Row type units have an advantage as these can be easily maintained by few families (3-4 numbers) who would use the toilet. A large community complex would require a very systematic maintenance routine.

Community ecosan toilet complex also must be made accessible to people with special needs. Therefore, provisions like ramp and toilets which can accommodate wheel chair must be provided. other provisions like incinerator in women's toilet can be provided.

A community ecosan toilet complex for a village with a population of 500 has been considered in this section. A row ecosan toilet with four toilet units has been designed for the use by 12 families (i.e. one toilet for three families) with a total of 50 members.

i) Capacity

- Community Complex - one ecosan toilet for 20 persons.
- Row Toilets - one ecosan toilet for 3 families

ii) Volume of Chamber

- For designing the storage volume of faeces collection chamber, an ultimate volume of desiccated faeces and additive mixture of 0.20 to 0.30 liters per person per day can be considered depending upon the local condition and usage pattern.

iii) Type of Chambers

- A twin chamber ecosan toilet is most ideal which requires very minimal maintenance compared to others.
- Single chamber ecosan toilets will be difficult to maintain in a community set-up.

iv) Retention Period

- A minimum retention period of 10 months for pathogen inactivation of faeces and additive mixture in the faeces collection chamber must be considered in the design.

- Urine can be collected in a tank of 500-2000 liters capacity can be installed based on the number of users. Provision should be made for transporting urine for agricultural applications.

v) Floor Space and Level

- In a large community ecosan complex, at least one ecosan toilet for people with special needs with a minimum size of 1750 mm x 2100 mm should be provided separately in toilet units meant for men and women.

- Specially designed chairs with washing arrangements and strong handles for offering support to children with special needs must be provided in ecosan toilets designated for their use. other ecosan toilets with two chambers must be at least 1,200 mm x 1,500 mm in size.

- In the design of community ecosan toilet complex, features like ramp and one ecosan toilet for people with special needs exclusively in men's and women's toilet units, hand washing facility, raised basement for free access, RCC roof cover and ceramic tiling on walls and floors for easy maintenance have been considered.

- In the row ecosan toilet, features like standard finish with RCC roof, urine diverting pan, urine collection tank and wide steps for accessing the toilets are provided. Where necessary, these units also can be made friendly to people with special needs by incorporating a ramp and specially designed ecosan toilet chair.

The cost of community ecosan toilet unit (capacity 500 persons) and the row ecosan toilet unit (capacity 50 persons) works out to Rs 10,57,322 and Rs 1,43,464 respectively.

Waterless Urinals

Waterless urinals look very much like conservative urinals in design and these can be used in the same manner. However, waterless urinals do not consume water for flushing and thus result in saving anything between 56,800 liters to 1, 70,000 liters of water per urinal per year.

on an average, a person urinates about 1.5 liters a day. Urine, which is usually sterile and contains mostly water, does not require additional water for flushing to make it flow into drainage lines. Therefore, installing waterless urinals will reduce the quantity of fresh water used for flushing urine and also substantially reduce the volume of sewage generated.

Waterless urinals reduce cost as they do not require plumbing accessories required for water flush urinals. Importantly, the dry operation of waterless urinals and touch free processes reduces significantly the spread of communicable diseases. odour trap instruments using sealant liquid, microbial control, membrane and curtain valve fitted to waterless urinals assist in preventing odour settled inside the drainage lines connected to urinals. Therefore, installing waterless urinals at homes, organizations and public places can offer several advantages.

However, waterless urinal models developed so far largely caters only to the need of men. Few attempts were made to develop female urinals in the past; however these have not been replicated very widely due to very low levels of success. Therefore, this section primarily deals with waterless urinal options developed for the use by men's or boys in schools. However, the proposed option for collecting urine from the present urinal design of girl's urinals has been discussed in detail as well.

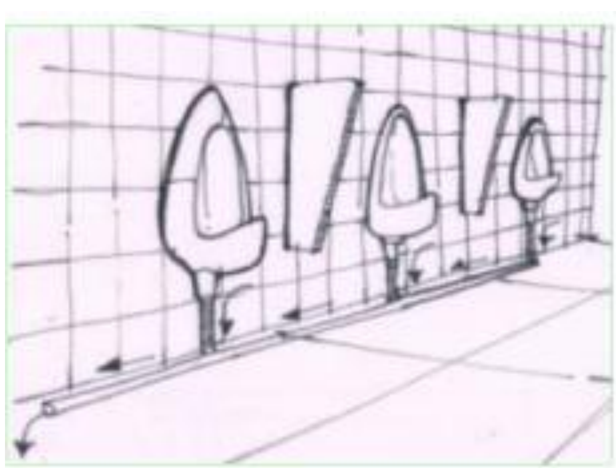

Figure 5.1 Schematic view of waterless urinals installation in a public place

Handling

The ecosan toilets should be designed to retain the mixture of faeces and additives for a period of 9-12 months to effect dehydration and / or composting process. The maturation period should be counted after faeces collection process has been stopped in a faeces collection chamber or removable bin. Therefore, after an ecosan toilet chamber / bin are full, it should not be used further and no water or urine should be allowed to enter it. The maturation process should be carried out preferably within the ecosan toilets, and if necessary it can be carried out outside the system.

When the secondary process of composting is carried outside the system, the materials must be handled with extreme care. The materials subjected to secondary processing must be isolated and stored safely to prevent contact with insects, animals and the outside environment. Persons handling these materials must wear shoes and gloves for safety. Also, the tools used must be cleaned and disinfected after every use.

Application Procedure

Compost is rich in macro and micro nutrients as well as organic matter, which increases the water-holding and ion-buffering capacity of the soil, serves as food for the micro-organisms and is important for improving soil structure. The compost harvested can be applied to crops as a fertilizer and to improve soil properties. Faecal matter is especially rich in phosphorous, potassium and organic matter. Both organic matter and ash, which are often added to the faeces, increase the buffering capacity and the pH of the soil, especially important on soils with low pH. organic matter also improves the structure and the water-holding capacity of the soil.

Compost can be applied to crops as given below:

- Compost should be applied and mixed into the soil preferably before cultivation or showing to ensure availability of phosphate for proper plant growth.
- Local application in holes or furrows close to the plants can make the nutrients available to the plants.

- The application rate of compost can be based on the current recommendation for the use of phosphorous-based fertilizers.

It is better to apply compost supplemented with a source of nitrogen. Urine or urea fertilizer can be applied as a source of nitrogen.

Processing and Application of Urine

Urine harvested by installing ecosan toilets and waterless urinals can be utilized as a resource in agriculture. As urine contains macro nutrients such as nitrogen, phosphorus, potassium and Sulphur, among others, it can be termed as quick acting multi-component fertilizer. Also, urine has very low concentration of heavy metals than conservative chemical fertilizers.

Presence of pharmaceutical residues in urine and its effects on crops is an issue being debated. However, other factors like the risks posed by pesticide residues in agriculture, use of sewage and animal manure which also contain high level of pharmaceutical residues for agriculture and the release of these in water bodies are of much higher concerns to be noted.

Higher nutrient (NPK) uptake by plants from liquid urine than from solid mineral fertilizers was observed. Crop trials conducted in India and various parts of the world have shown that crops fertilized with urine produce higher yield and show better plant characteristics. Therefore, by using urine as a fertilizer, small and marginal farmer’s from rural areas can benefit by replacing it with the expensive chemical fertilizers.

Urine which is usually sterile may get cross contaminated with faeces in the ecosan toilets. However, pathogens present in urine can be disinfected by storing urine for longer period. Hydrolysis of urea in urine into ammonia helps in disinfecting the pathogens. The table provided below contains the Swedish guideline for storage of urine for pathogen elimination from urine. Direct use with short time storage is adequate for urine collected from small domestic systems. Higher ambient temperatures in countries like India results in disinfection within a short storage period of 3-7 days.

Storage and Handling

Loss of ammonia must be controlled during storage and application processes. By keeping the storage containers of urine covered and use of very thin aeration pipes or use of one way air admittance valves, loss of ammonia can be reduced. Persons involved in application of urine must take precautions like wearing of gloves, boots and face mask. Sufficient care must be taken when inspecting large urine collection tanks due to high ammonia levels present in it. Hand washing with soap after urine application is also important. Phosphate precipitates settling down in urine tanks due to spontaneous precipitation can be recycled as fertilizer to crops.

Selection of Technology

Selection of suitable technology plays an important role in the success of an ecological sanitation programme. Ecological sanitation system to be implemented in an area should be selected based on various factors such as climate, availability of materials, geography of the area, agricultural practices, social factors, economic conditions of the population and technical skills available. Some of these factors are explained as below:

Climate: The factors like temperature, humidity and precipitation should be considered while selecting appropriate type of ecological sanitation system.

Materials: The availability of materials determine the suitability an ecosan system in an area. Civil works can be designed according to the availability of materials.

Geography: Type of land, soil and water table should be considered while designing ecosan systems as well as reuse of urine and compost for agriculture. These factors are critical for areas which area prone to floods.

Agriculture: The characteristics of local agriculture and home gardening should be taken into account while planning recovery and application of nutrients.

Social Factors: The customs, beliefs, values and practices should be taken into account while planning the ecological sanitation systems. Especially promotion of source separation of urine and faeces, waterless urinals and recycling of nutrients in some communities require considerable amount of awareness and education.

Economic Condition: The systems designed must commensurate with the financial ability of communities to build. Identifying suitable options through participatory process help in overcoming this aspect.

Technical skills: The level of technology adopted should be based on the technical skills locally available or what can be created in an area.

Supply Chain Mechanism

Instituting effective supply chain mechanisms can play a very vital role in supporting the demand created for ecological sanitation through awareness and education programmes. Aspects related to both hardware and software is essential for assisting people who are willing to construct ecosan toilets. Ensuring hardware support towards making the construction materials such as pans, slabs, pipes and plumbing materials available locally is very important. Similarly, the software aspects such as ensuring the availability of skills and knowledge to construct ecosan toilets are equally essential.

Production Centers / Sanitary Marts: Production centers / sanitary marts can be established to make hardware components that are essential for the construction of ecosan toilets. Existing units which are already involved in the production of sanitary items can also start producing ecosan related components. These units can stock essential components such as ecosan toilet seats, pipes, plumbing items, jerry cans, prefabricated ventilators and doors and concrete slabs. Based on the local availability of bricks, sand and cement, a decision whether to stock these items can be taken up. Setting-up of local production centers / sanitary marts managed by SHGs or NGos can drastically reduce the cost of sanitary items as they can produce and sell these products at a reasonable price than private operators.

Local Entrepreneurs & Youth: Involving local entrepreneurs who are into construction activities can be beneficial. Also, local youth who are looking for employment can be trained in construction activities. Necessary training and incentives to take part in the programme should is devised considering the marketing sanitation approach. Creating a local workforce can enable availability of skills within the communities for scaling-up and sustainability of the initiatives. As members of the local community, these trained individuals will be in a better position to motivate people to adopt ecological sanitation components.

NGOs: Local NGOs having rapport with the communities should be involved in promoting ecological sanitation activities. Their close interactions with the communities place them in an advantageous position to promote a difficult development component like sanitation. These NGOs should be trained along with necessary programme support to carry out work related to ecological sanitation. The potential of establishing sanitation parks, production centers and experimental plots with the NGOs should be explored for long-term sustainability of the initiatives.

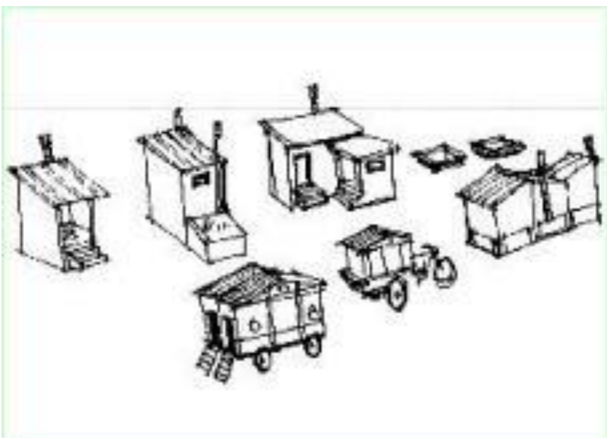

Figure 9.3 Demonstration of various technological options through sanitation parks

CONCLUSION

Combination of faeces, urine and solid waste collection services

Integration of the faeces, urine and solid waste collection services can be advantageous as economies of scale can be released e.g. at a low participation level the trolley purchased for urine collection stays unused most of the time. It is probably technically possible to easily remove the urine equipment in the trolley. In that case, the trolley can also be used for the faeces collection. As the faeces collection takes up only a few days per year in the beginning, it is suggested to also use the trolley as a transfer station for the solid waste collection. Currently the solid waste collectors have to go a long way to the nearest transfer location. When one needs to purchase a tricycle for the urine collection in case the tractor cannot access every house this could be employed for the solid waste collection as well.

For faeces collection it is advised to collect this within a few days by hiring a couple of daily laborers instead of regularly using the tricycles that are also used for solid waste collection. When the tractor trolley for urine collection is available this can be used for secondary transport, otherwise it can be hired somewhere. This is quick, easy and cheap.

Awareness and education should be integrated, as the purpose of all these services is the same: creating a healthy and clean environment. Tackling all three issues at the same time will make people more willing to participate. Supervision and payment organisation can also be combined for the different services as the operations have many similarities and the employment of the people and equipment can be divided among each of the services.

RECOMMENDATION

The following is recommended:

· *Start with hardware building for demonstration purposes*

After the initial introduction of EcoSan and awareness is rising but no material actions have followed yet. Until demonstration toilets are set up with the subsequent collection people will not start to consider whether they would adopt such a system, as it is very difficult to understand what the whole system will actually look like; they have never come into contact with it before. Note also that people are not easily motivated, as the EcoSan toilet requires a higher level of commitment from the user than the toilets they are currently using and they have to spend extra money to change their toilet. Demonstration will be essential for the people to believe what is being claimed. After identifying the families who are interested to install a demonstration urine-diverting toilet (the restructuring of the current pits to a double vault system can wait until the required research is finished) an engineer/plumber can start making a design for the specific houses and build it. The collection method has to be discussed with some collectors to see what is workable for them. The local farmers have already been waiting for a long time for urine to come to be able to start experimenting. Together with an agricultural expert a few farmers should start planning the set-up of field trials to determine what the best application rates and methods are. This plan should also include the set-up of storage in order for them to be ready when urine starts to arrive. Hardware building for the demonstration toilets, the first equipment required for collection and transport and the field trials should be included in the project as this is very important in enabling people to make an informed choice and has to start as soon as possible.

· *Teach people about water use*

The addition of flush water quickly increases total collection costs. Informing the participants about this is very important to be able to limit costs. Water reduction is also necessary for the double vault system.

· *Stimulate the connection of the individual urine containers*

Laying a small pipe between the participants in the same street should is stimulated. This is not only important to lower transportation costs, it is also important in the light of the bad road conditions. Collection becomes a lot easier when the vehicles can stay on the main streets and may be the only long-term solution. People might be easily motivated to do this, because the more houses are connected together, the smaller the household containers can be; a cost advantage for the households. It also means a reduction in vehicle movement in front of their house and in their area.

· *Integration with drain management and solid waste management*

The community might be more motivated when EcoSan is integrated with proper drain and solid waste management. Proper drain management has a higher priority for them and they see sanitation, solid waste and drain management as one issue. Tackling only one issue will not solve their problem i.e. living in an unhealthy and dirty environment. By also tackling drain management people might start to trust and be willing to make investments and changes sooner. Proper drain management is also beneficial to the collection service (solid waste and sanitation), as it will improve the road conditions.

· *Give training and targeted information to the collectors*

To avoid or minimize the consequences of handling the potentially hazardous faeces several technical and organizational measures can be taken and have been suggested. But most important is that workers are made aware of the nature of the health risks to which they are exposed and that they know how to protect themselves. Training and targeted information may be the most successful measure.

· *Include hygiene promotion*

Technology alone cannot break the cycle of disease transmission; poor domestic and personal hygiene diminish the positive impact of improved sanitation. Hygiene promotion should therefore receive a prominent and reoccurring place in the awareness and education programs.

· *Encourage and educate urban agriculture*

By growing food products on the rooftops the high incidence of malnutrition can be reduced. The food can be used for direct consumption and to generate income, improving food security as well. Furthermore, when people can use the urine and faeces for their own purpose, they will be much more motivated to adopt EcoSan and manage the system properly.

REFERENCES

- Christoph Lüthi (2009), “RETHINKING SUSTAINABLE SANITATION FOR THE URBAN ENVIRONMENT”,
- Prof V M Chariar and Er S Ramesh Sakthivel (2005), “Ecological Sanitation Practitioner’s Handbook”,
- Marieke Slob (2005), “Logistic Aspects of Ecological Sanitation in Urban Areas”,
- F. Tettenborn*, I. Kaneva, J. Grünauer, M. Winker, R. otterpohl (2007), “Transport and Logistics basics in the context of new sanitation concepts”,
- Prof. Usha P. Raghupathi (2005), “STATUS OF WATER SUPPLY, SANITATION AND SOLID WASTE MANAGEMENT IN URBAN AREAS”