SMALL COMMUNITY AND RURAL SANITATION SYSTEMS

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Summary

Safe and appropriate disposal of human wastes is a basic requirement for sanitation and public health protection. For proper sanitation, effective treatment methods to ensure complete destruction of pathogens in excreta prior to disposal and reuse is a must. Conventional wastewater collection system, as found in modern cities, is often not feasible to be operated in small and rural communities, because of its prohibitively high cost. In developing countries, where poor water supply conditions exist, conventional system is technically not feasible. Typically, the cost of a conventional sanitation system, requires about one-fourth of the average annual income of these low-income communities. On-site sanitation technologies, with lower costs of installation, and low water supply requirements offer the advantages that are critical under such circumstances. Design of an effective on-site waste disposal system also needs, among other things, an adequate understanding of the relationship between excreta and health. The type and level of advancements in on-site technologies greatly vary among developed and developing countries. The variation depends mainly on affordability, local social customs and practices, and regulatory requirements for disposal.

1. History of Sanitation

Proper sanitation has been a concern for human beings since their early efforts to organize as communities. Ever since, sanitation has been a major focus of all development. Historic evidences indicate that systems existed around 2000 BC in ancient India and on the Island of Crete that drained water away from buildings. Open sewers were used as early as 6^{th} century BC in Rome that carried city wastes to the nearby River Tiber. With the industrial revolution during the mid-18^{th} century came urbanization and with expanding urban populations came sanitation problems. The first flush toilet developed by Sir John Harrington in 1596 for Queen Elizabeth I's Richmond Palace has never become commercial. Alexander Cumming developed a water-flushed toilet in 1775 and it was Joseph Bramah, a cabinetmaker in England who patented the first practical toilet in 1778. But these systems did not have devices to prevent water from continually flowing into the toilet. In 1872, Thomas Crapper and Co. first manufactured water-efficient flush toilets for commercial availability.

The toilet wastes were first collected in a privy vault-cesspool system. The privy vault-cesspool is essentially a simple pit often lined with stone located close to the residences or in the cellars. This system allowed solids to settle and the liquid to seep into the ground. The solids from these arrangements were spread on agricultural land. The adoption of flushing toilets and the resulting discharge of large quantities of fecally polluted water into the privy vault-cesspool systems often resulted in overflows, causing health hazards. The relationship between human wastes and diseases was first established by a pioneering epidemiological study by John Snow, a physician, who traced the recurrence of cholera epidemic in London, to a public tap that was being contaminated by the close-by cesspools. It was then theorized that the rotting human wastes result in the emergence of noxious vapors that cause diseases ('filth theory' or 'miasmatic theory' of diseases). Public health concerns due to the accumulation of human wastes close to the dwelling area resulted in the conveyance of all wastes towards watercourses. Water in huge quantity began to be used to move the wastes from households and the resulting sewage was transported through open sewers. These open sewers were eventually directed to the stormwater collection drains, leading the authorities to adopt a “combined water carriage sewer system” and later a “separate or sanitary sewer system” that excludes stormwater. These conventional sewer systems, with steep gradients that use water as the flushing agent were then installed to swiftly remove human excreta before it started to putrify. With the invention of the microscope in 1872, the “filth theory of diseases” gave way to the “pathogenic theory” that identified distinct groups of microorganisms as the ones causing diseases. Unfortunately, the conventional sanitary sewer systems retain much of their old engineering design criteria and hence high costs.

2. Issues in Adoption of Conventional Sanitation Technologies

In modern cities and other densely populated human settlements, development authorities and users alike view conventional sewerage as an absolutely essential part in managing household sewage. Though conventional sewer systems offer convenience and public health benefits to the users, it is often not feasible to operate these systems in rural and sparsely populated areas because of the following reasons:

- wastewater collection network in sparsely populated areas becomes expensive;
- capital and operation costs of treatment systems for such areas become prohibitively high because of the smaller scale of operation.

Low-income urban communities, such as those found in the cities of developing countries require alternative wastewater management systems for sanitation, as conventional capital intensive systems can not be installed due to financial constraints. Typically, the cost of conventional sewerage is excessive, sometimes requiring a total annual expenditure in the order of a quarter of average household earnings in these countries. Non-affordability by the low-income communities in developing countries is one of the major reasons for lack of sanitation in these countries. Also, conventional systems can not be operated in these communities due to poor water supply conditions. As a result, more than 2.8 billion people in these countries are not served with any kind of sanitation (Table 1).

	Population (in millions)							
	Total		**Served**		**Unserved**		**% coverage**	
	’90	**’94**	**’90**	**’94**	**’90**	**’94**	**’90**	**’94**
Urban sanitation	1389	1594	936	1005	453	589	67	63
Rural sanitation	2682	2789	505	536	2177	2253	20	18

Source: World Health Organisation, Geneva, 1996

Table 1. Sanitation coverage in developing countries

3. On-site Sanitation Technologies

On-site sanitation technologies, with their lower costs of installation and low water supply requirements, offer the advantages that are critical under such circumstances. The concept of on-site wastewater management involves treatment (either fully or partially) of household wastewater at the point of generation, i.e., within the household premises. As history shows, like in the case of the privy vault-cesspool systems, on-site sanitation systems should not be considered merely as a cheap and easy alternative to a conventional sewer system, because poorly planned and poorly maintained on-site systems can increase the potential for health hazards due to increased exposure to pathogens. They can also cause diffuse source pollution of water ways, groundwater and adjoining land.

In both the developed and developing countries, on-site sanitation technologies offer alternatives to the conventional sewerage for rural and sparsely populated human settlements. However, the type and level of advancements in on-site technologies greatly vary among these countries. The variations depend mainly on affordability criteria and also on the local social customs and practices. Therefore, it will be appropriate to discuss on-site sanitation technologies in the context of developing countries separately from those adopted in developed countries.

4. On-site Technologies for Developing Countries

A variety of technologies are available for on-site sanitation. Not all of them are suitable for all geographic locations and circumstances. One should carefully consider the selection of any of these systems taking into account various factors such as local customs and beliefs about personal hygiene, ease of maintenance, public health risks, groundwater pollution, etc., that may affect or that may be affected by selected arrangement. A list of probable on-site sanitation alternatives suitable in on-site sanitation technologies is given below:

(a) ventilated improved pit (VIP) latrine;
(b) Reed’s odorless earth closet;
(c) batch-composting toilet;
(d) continuous composting toilet;
(e) aquaprivy with soakaway;
(f) pour-flush (PF) latrine with soakaway;
(g) pour-flush latrine, septic tank and soakaway.

4.7. Ventilated Improved Pit (VIP) Latrines

Conventional pit latrines, the most common sanitation facility in many developing countries, is nothing but a hole in the ground with a squatting plate covering the hole and a temporary superstructure for privacy. The major disadvantages of these arrangements are the malodorous conditions and the breeding of flies and mosquitoes. In permeable soils, the liquid part of the excreta together with water used for latrine and personal cleansing, percolates into the surrounding soil.

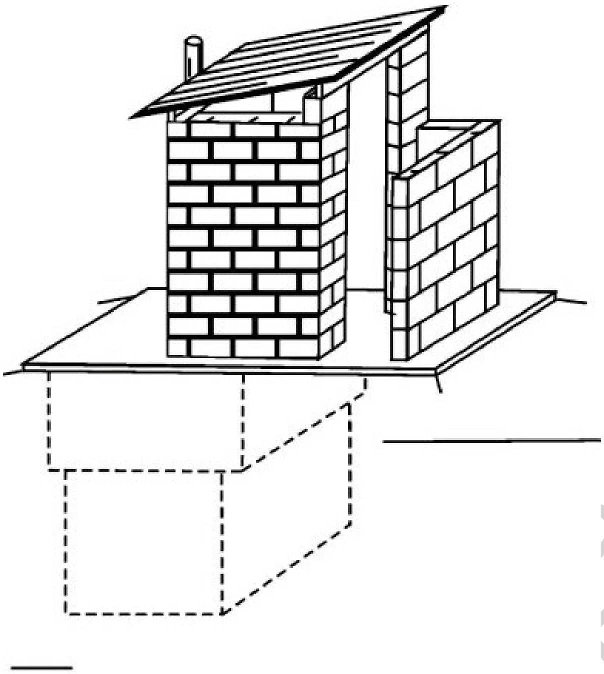

Figure 1. Isometric view of a VIP latrine

The solid fraction undergoes anaerobic digestion and gets reduced in volume. The VIP latrines are designed to overcome these disadvantages with simple modifications. They have four essential components: a pit, a vent-pipe attached to the pit, a squatting platform and the superstructure (Figure 1). The pit is approximately 1 m^2 in cross section, and its depth is calculated for the design period. Depth is normally in the range of 3 to 8 m. It must be of sufficient size that the need for shifting or cleaning/desludging the pit does not arise frequently, at least not more frequently than once in 12 months. The pit is slightly offset from the squatting platform so that a vent pipe can be attached to the pit for odor control. It is either unlined or partially lined just below the squatting platform. It is better to line the upper part of the pit to avoid collapse of pit and also to properly support the squatting platform. In order to avoid surface run-off from entering the pit, the area surrounding the pit has to be appropriately graded.

The minimum recommended size of vent pipe for maximum odor control is 150 mm. The vent pipe has to be painted black and located on the side where there is sunshine for most time of the year. This is to heat the air inside the pipe to create an up-draft. Any odor generated from the decomposition of pit contents will be expelled via the vent pipe. Covering the pipe with a gauze screen will prevent flies and other insects entering the toilet thus minimizing the health hazard from these insects. Both the vent pipe and the gauze screen must be made from corrosion resistant materials such as fiberglass or PVC.

Depending on the preference of the user, the superstructure for the VIP latrine can be permanent or removable. Under normal circumstances, when the pits are filled to about three-fourths of its capacity, the superstructure and the squatting platform are removed and the pit is filled up with soil from a new pit dug nearby. If the user prefers a permanent superstructure that can not be moved or where space is not available to move a VIP latrine, this system can be constructed with two pits.

This modification—ventilated improved double-pit (VIDP) latrine—will contain two pits dug side by side covered by the same superstructure. The pits will be used alternately and the squatting plate is moved from the full to empty pit as necessary. The pit, which is full, has to be covered with soil and should be emptied not less than twelve months after the last use. As a further improvement to VIDP latrines, each pit can be constructed with separate squatting platforms with a covered opening for desludging without disturbing either the superstructure or the platforms. Desludging can be done manually or mechanically. This must be done approximately when the second pit is also full.

4.8. Reed's Odorless Earth Closet (ROEC)

ROEC is an alternative design for a VIP latrine. The pit in this type of latrine is completely offset from the squatting platform and the excreta fall into the pit through a chute attached to the platform (Figure 2). Hence, the pit can be constructed for longer design period. Usually the design lifetime for this kind of sanitation arrangement is around fifteen to twenty years. It also has a vent pipe to control fly and odor nuisance.

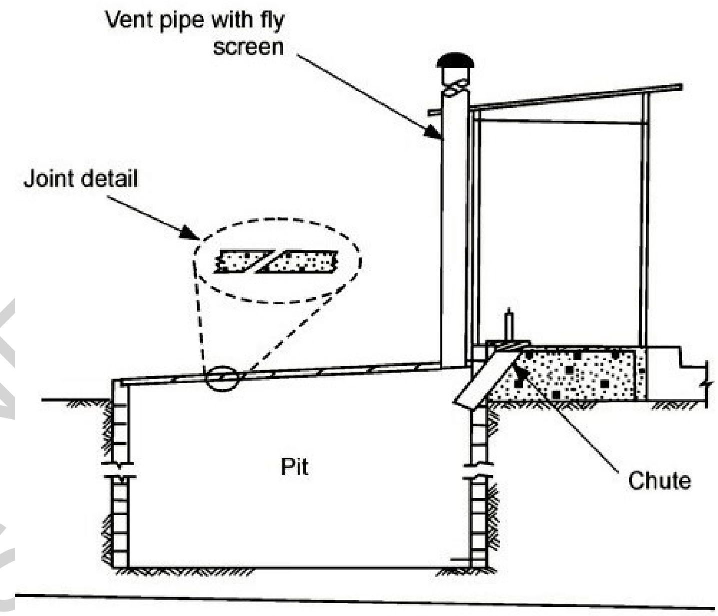

Figure 2. Reed's odorless earth closet

A disadvantage with ROEC is that in the absence of flushing or cleaning, the chute gets easily fouled with excreta. In spite of this disadvantage, it is preferable to the VIP latrines for the following reasons:

- It can be designed for longer life period;
- Since the pit is completely offset, there is no fear of collapse of the pit and possible danger to the users;

- The pit contents will be invisible, and emptying the pit will be easy and hence can be constructed with permanent superstructure

4.9. Batch Composting Toilets

There are two basic types of composting toilets, namely the batch and composting types, depending upon how it is operated. These toilet systems rely upon the natural process of anaerobic composting to degrade the human waste. Double-vault composting (DVC) toilets are the most common types of batch composting toilets. They include two adjacent pits used alternately for every four to six months. Once a pit becomes half to three-fourths full, it is filled with ash, grass and other household organic refuse such as kitchen wastes, food wastes, paper wastes, etc. to absorb excess moisture in the pit and then covered with soil.

The anaerobic composting process that occurs in these pits require several months to complete. Vault ventilation reduces odor and fly nuisance. By keeping the squatting plate clean, DVC toilets can be made so as not to pose any significant health risks. After a period of five to six months necessary for the die-off of a majority of pathogens, the compost can be removed and can be used as a fertilizer or as a soil conditioner. DVC toilets are suitable where:

- users take sufficient care in the maintenance of the toilet;
- sufficient organic filling materials such as ash, saw dust, grass or vegetable wastes are available;
- users are not averse to handling the composted material;
- there is opportunity for local use for the humus produced.

4.10. Continuous Composting Toilets

In continuous composting toilets or the “multrum” toilets (after the Swedish design), the composting pit, which is immediately below the squatting plate, has a sloping floor with inverted U- or V-shaped channels suspended above it to promote aerobic conditions in the chamber. Household organic wastes such as kitchen wastes, cardboard, grass etc., also can be added to the pit to obtain necessary carbon-nitrogen ratios for better composting.

Moisture requires to be carefully controlled at around 40 to 60%. In some designs, arrangements are provided for entry of outside air to promote aerobic conditions inside the composting chamber. Use of bulky materials such as straw or grass also help to this end. The composting material slowly moves down the sloping floor to a humus vault kept at the end for collection. The compost needs to be removed regularly for disposal.

4.11. Aquaprivy with Soakaway

An aquaprivy consists essentially of a squatting platform that is situated directly on a fully lined tank that discharges the liquid fraction to an adjacent soakaway (Figure 3).

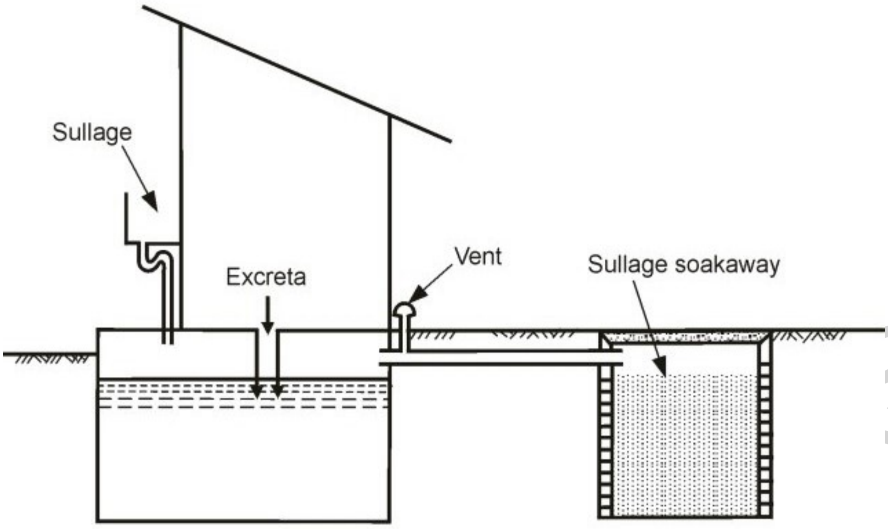

Figure 3. Aquaprivy with soakaway.

The squatting plate is attached with a drop pipe of 100 or 150 mm diameter and the bottom end of this pipe is kept about 10 to 15 cm. below the water level in the collection tank. This creates a simple water seal between the squatting platform and the contents of the tank. It also prevents nuisance due to flies and odor. A small vent pipe also is incorporated in the design to expel gases produced in the tank. It is important that the tank be completely watertight so that the water seal is not tampered due to leakage of water outside the tank. The excreta are directly deposited into the tank and undergo anaerobic decomposition. The collection tanks are designed normally for two to three years, after which the tank needs to be desludged. The liquid fraction that overflows from the tank needs to be discharged through a soak pit or soak drain.

Maintenance of the water seal has always been a problem in aquaprivies, when insufficient water is used to balance the water losses from the tank. A simple modification of the conventional aquaprivy, in which the household sullage also can be added to the tank can overcome this disadvantage. The sullage helps to readily maintain the water seal. This will obviously increase the quantity of discharge from the tank requiring a larger soakaway capacity to absorb excess flows. This modified version is called a "self-topping aquaprivy."

Major advantages of the "self- topping aquaprivies" are:

- they can be located inside the house;
- they are odor and fly free;
- health risks are minimal.

The main disadvantages are:
- they are relatively costlier than the previously described systems;

- high level of skill requirement for construction;
- pits are to be emptied regularly which may require municipal involvement;
- significant amount of water is required for maintenance of the system.

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Biographical Sketches

T. Viraraghavan graduated in civil engineering from the University of Madras in 1955 from the College of Engineering, Guindy, Madras, India. He worked for the Government of Tamil Nadu (Madras) for 10 years as Assistant Public Health Engineer and later for 5 years for the Government of India as Assistant Adviser in Public Health Engineering for the Ministry of Works and Housing. During 1962–63, he completed an M.Sc. in Public Health Engineering. He attended the University of Ottawa, Canada, during 1970–75 and obtained a doctorate in Civil Engineering in 1975. He worked as a senior environmental engineer with ADI Limited, Consulting Engineers, Fredericton, N.B., Canada, during 1975–82. Dr. Viraraghavan joined the Faculty of Engineering, University of Regina, Regina, Saskatchewan in 1982;

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S. Vigneswaran is currently a Professor and a Head of Environmental Engineering Group in Faculty of Engineering, University of Technology, Sydney, Australia. He has been working on water and wastewater research since 1976. He has published over 175 technical papers and authored two books (both through CRC press, USA). He has established research links with the leading laboratories in France, Korea, Thailand and the USA. Also, he has been involved in number of consulting activities in this field in Australia, Indonesia, France, Korea and Thailand through various national and international agencies. Presently, Dr. Vigneswaran is coordinating the university key research strengths on “water and waste management in small communities”, one of the six key research centers funded by the university on competitive basis. His research in solid liquid separation processes in water and wastewater treatment namely filtration, adsorption is recognized internationally and widely referred.