Handbook on

Technical Options for on-Site Sanitation

Ministry of Drinking Water and Sanitation

Government of India

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Preface

Provision of adequate sanitation to all communities has been a major challenge in India. This is also due to the fact such communities have full spectrum of variations in socio-cultural and economic conditions. It is said that in India near stone -age civilization co-exists with atomic –age civilization. On one hand, there are Primitive Tribal Groups for whom sanitation is still not a felt need problem at all, on the other; there are communities whose sanitation condition is comparable to any community of a developed country. The Ministry of Drinking Water and Sanitation is committed to help all such communities in rural areas in improving sanitation through its national flagship scheme of Total Sanitation Campaign.

In addition, there is a wide range of hydro- geological conditions in different states in India. Selection of on-site sanitation technology should be as per the geological condition of the targeted area, to avoid ground water pollution risk out of on-site sanitation. It has been observed that due to lack of information many communities implement prototype technology of household sanitation even it may not suit the soil and hydrological conditions of the area.

The objective of the technology providers, particularly in rural areas should be to find out what the people are doing and help them to do better. The Handbook has tried to provide sustainable technological options for on-site sanitation for different hydro-geological conditions. Hardware by itself can not improve health very much; what matters is the way in which it is used and the way in which it may promote changes in hygiene related behaviors.

I am pleased to note that the book has been compiled by the Consultant (Sanitation and Waste Management) National Resource Centre of the Ministry, with needs of many stakeholders of sanitation programmes. It will prove useful for public health engineers, sanitarians in the field, different NGOs, CBOs and communities involved in implementing sanitation programmes and also for administrators, health personnel, planners and many others who are concerned with improving sanitation in rural community in India.

(Vilasini Ramachandran)

Chapter- 1

Introduction

Sanitation is a broad term which includes safe disposal of human wastes, waste water management, solid wastes management, water supply, control of vectors of diseases, domestic and personal hygiene, food, housing, etc. Sanitation and environmental sanitation have the convergence in many aspects, environmental sanitation is largely viewed as "the control of all those factors in man's physical environment which exercise a deleterious effect on his physical environment, health, alleviating poverty, enhancing quality of life and raising productivity- all of which are essential for sustainable development''(WHO 1992).

Feachem et al. (1983) gave a rough guide to the relative importance of different aspects of sanitation as follows: Excreta disposal- 25; Excreta treatment- 15; Personal and domestic cleanliness-18; Water quality- 11; Water availability-18; Drainage and silage disposal-6 and Food hygiene- 17 points.

Sanitary household toilet is the most important aspect of sanitation. Besides, restoration of dignity, privacy, safety and social status, sanitation has strong bearings on child mortality, maternal health, water quality, primary education, gender equity, reduction of hunger and food security, environmental sustainability, global partnerships and ultimately poverty alleviation & improvement of overall quality of life. Open defecation is still in practice in many rural areas resulting in serious social, health, economic and environmental problems. Openly left human waste helps in breeding and transmission of pathogens, which carry diseases and infections. The problem is most acute for children, women and young girls. Children, especially those under 5 are most prone to diarrhoea and sometimes even lose their lives. Loss of number of school days is another problem in times of illness. In case of women, lack of sanitation facilities often forces them to restrict themselves by reducing and controlling their diet, which leads to nutritional and health impacts. Women, especially adolescent girls, face higher risks of sexual assault due to lack of household toilets.

Impacts of good sanitation: Good sanitation has the following impacts on individuals and on community:

- Improves health

- Decrease in morbidity and mortality
- Improves man-days
- Improves productivity
- Poverty alleviation
- Improves water quality
- Minimizes incidence of drop-out in school particularly girl students

It is an accepted fact that poor pays directly and indirectly more due to bad sanitation. Most of them who earn on daily wages basis lose out in case of illness due to bad sanitation. Further, other members of the family who look after the sick member also lose their daily earnings or schooling (in the case of children). In most of the rural areas health facility is rarely available forcing people to take the advice of private doctor or quacks who charge very high leading to more economic loss.

Open defecation has been a deep-rooted age old socially inherited behaviour in rural India. Provision of adequate sanitation coverage in rural India has been a major challenge due to its heterogeneous socio-economic conditions. Hence, even with advent of technology in rural India, substantive proportion of the rural poor still prefer to purchase a "mobile phone", rather than on investing for sanitary toilets, since sanitation is neither a felt need nor open defecation is a socio-cultural taboo. The most important challenge for effective implementation of sanitation program in rural areas is that most rural population being poorly informed or not overtly conscious of the linkage between sanitation and health. Due to inadequate knowledge and lack of, awareness they mostly believe that good or bad health lies due to reasons other than improved or bad sanitation. Another important barrier for sanitation is that there is no concept of community health and hygiene in rural areas. Wherever, there is awareness, it is limited only to personal sanitation and hygiene, not at community level. Effect of sanitation can be gauzed only when facility and practices are adopted at community level.

Best option for improved sanitation is by construction and proper use of a latrine by the household, which is owned and maintained for its own use and benefit. Such individual toilets can be built through various technological options to suit the household's affordability.

Total Sanitation Campaign and its Key Provisions

In 1986, the Rural Development Department initiated India's first national programme on rural sanitation, the Central Rural Sanitation Programme (CRSP). The CRSP interpreted sanitation as construction of household toilets, and focused on the promotion of pour-flush toilets through hardware subsidies to generate demand. The key issue of motivating behaviour change to end open defecation and use of toilets was not addressed. As a result the programme in the supply driven mode had limited intervention in improving rural sanitation coverage. As a result there was only just 1 percent annually growth of sanitation coverage throughout the 1990s.

In light of the relatively limited intervention of the CRSP in improving the rural sanitation coverage, the Government of India restructured the programme, leading to the launch of the Total Sanitation Campaign (TSC) in the year 1999. Total Sanitation Campaign (TSC) is a flagship scheme of the Government of India administered by the Ministry of Drinking Water and Sanitation. TSC supports village communities to end open defecation in their areas and achieve total sanitation, to improve social dignity, privacy and ensure hygienic and healthy living environment. Creation of demand for sanitation from people through Behavior Change Communication (BCC) and supporting them with information on a menu of technological options to construct and use safe sanitation facilities is the prime objective of the TSC.

Under the TSC, financial support in the form of an incentive is given to households living Below the Poverty Line (BPL) for construction and use of toilets. However, the main focus of the program is to create sustainable awareness and behavior change among the people, through capacity building and motivation to build individual household latrines (IHHLs) to own and maintain.

The key challenge in achieving total sanitation in villages is to provide sustainable technology affordable even for poor families in different geographical conditions and also bring about a change in the knowledge, attitudes and age–old practices of the villagers towards open defecation. To end this state, providing easy access to a toilet and motivating people to use them is an important challenge

Chapter -2

Linkage of sanitation, health and toilet

Sanitation has a direct linkage with health of any community**.** The most important challenge for effective implementation of any sanitation program in rural areas is that most of the rural population is unaware of the linkage between sanitation and health; and health and productivity. Due to inadequate knowledge and awareness, they believe that good or bad health and poor productivity is due to reasons other than sanitation. For such communities, social status/ dignity and privacy are only benefits of toilets. The TSC program aims to highlight such social benefits of sanitation leading to demand driven approach, making the program successful in rural areas.

i. Human waste and disease transmission

Human excreta contain a full spectrum of pathogens that transmit from diseased persons to healthy ones through various direct and indirect routes, causing infections and superimposed infections. In rural areas it is estimated that about 80% diseases are water borne diseases-directly or indirectly linked with human wastes. Different infections from human wastes enter into human body through fluids, fingers, flies, food and fields. Such transmissions from different sources can be depicted through the following diagrams (Fig. 1 and Fig 2). It is obvious that most of the transmission of infections can be avoided through use of proper toilet and hand washing before eating and after defecation.

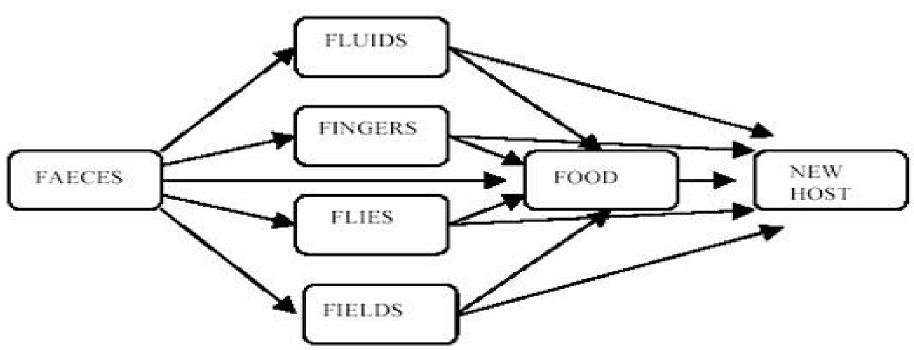


Figure 1. The F-diagram

Source: Wagner & Lanoix 1958

Primary prevention and routes of possible transmission of diseases from faeces

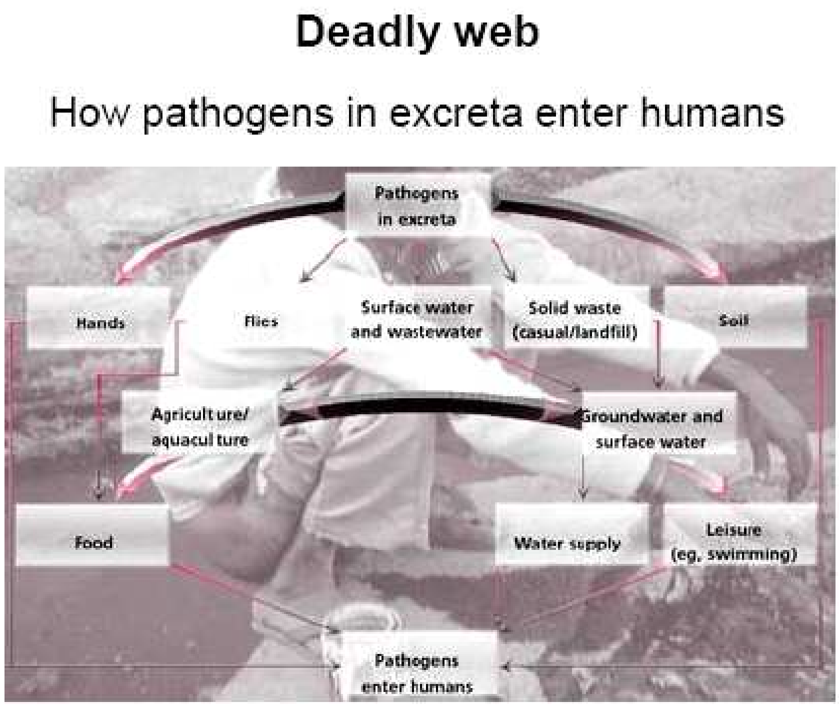


Fig 2

ii. Pathogens in human excreta

There are several bacterial pathogens in human wastes causing diseases. Some of the commonly found bacterial and helminthic pathogens are as described below (table 1 and 2).

(Table 1) Bacterial Pathogens in Human Excreta

Bacteria	Diseases	Reservoir
Escherichia coli	Diarrhoea	Human
Salmonella typhii	Typhoid fever	Human
S. paratyphii	Paratyphoid fever	Human
Other salmonellae	Food poisoning and other salmoellioses	Human
Shigella spp	Bacilliary dysentry	Human
Vibrio cholera	Cholera	Human
Other vibrions	Diarrhoea	Human
Campylobactor fetus	Diarrhoea	Human , Animals
Yarsinia enterocolitica	Diarrhoea and septicimia	Human, Animals

(Table 2.) Helminthic Pathogens in human excreta with mode of transmission

Helminthis	Common name	Diseases	Transmission
Ancyclostoma duodenale	Hookworm	Hookworm	Human-soil-human
Ascaris lumbricoides	Roundworm	Ascariasis	Human-Human-soil
Taenia saginata	Beef worm	Taeniasis	Human-Cow-Human
T. solium	Pork Tapeworm	Taeniasis	Human-Pig -Human
Trichuris trichura	Whiworm	Trichuriasis	Human –Soil-Human

Health aspects of sanitation require some understanding of the types of diseases involved, their transmission, and how sanitation hardware and hygiene promotion influence them. The classification of different infections and likely effects of interventions and control measures as suggested by Faechem (1983) and Cairn Cross & Faechem (1993) is presented below (Table 3) which clearly indicates that provision of toilet is the most important aspect of control of most of the infections.

Table 3. **Sanitation related diseases and the likely effects of interventions**

	Category	**Examples**	**Prominent transmission mechanism**	**Likely effect of sanitation hardware alone**	**Likely effect of hygiene promotion alone**	**Major control of infections**
1	Faecal–oral (non-bacterial)	Hepatitis A, Amoebic dysentery, Rotavirus giadiasis	Person to person contact, Domestic contamination	Negligible	Moderate	Domestic water supply, health education, Improved housing, **Provision of toilets**
2	Faecal oral (bacterial)	Cholera, salmonellosis, Shigellosis	Person to person contact, domestic contamination, water contamination, crop contamination.	Slight to moderate	Moderate	Domestic water supply, health education, Improved housing, **Provision of toilets,** treatment of excreta prior to discharge or reuse
3	Soil Transmitted Helminthes	Hookworm Roundworm Whipworm	Path/ compound contaminatior Communal defecation are Crop contamination	Great	Negligible	**Provision of toilets,** treatment of excreta prio to discharge or reuse
4	Tapeworms	Beef Tapeworm, Pork	Path / Compound contamination	Great	Negligible	**Provision of toilets,** treatment of excreta prior

		tapeworm	Fodder contamination Field contamination			to discharge or reuse
5	Water based helminths	Schistosomiasi	Water Contamination	Moderate	Negligible	**Provision of toilets,** treatment of excreta prior to discharge or reus
6	Excreta Related insect vectors	Filariasis, some faecal- oral diseases	Insects breed in sites of poor sanitation	Slight to moderate	Negligible	**Provision of toilets,** treatment of excreta prior to discharge or reuse

Chapter -3

Criteria for a sanitary toilet and sustainability of sanitation

I. Criteria for a sanitary toilet

There was a major breakthrough in the field of on- site sanitation when World Health Organisation, Geneva, published the book "Excreta Disposal for Rural Areas and Small Communities" by E.G. Wagner & J.N. Lanoix, in 1958. Another book of WHO on "A Guide to the Development of on-site Sanitation by Franceys, R. Pickford j. & Reed, R, published in 1992 provided useful information on on-site sanitation. The books gave details of different technological options for sanitation suitable for rural and small communities. Some technologies, like pit toilets, as mentioned in these books, are being implemented in rural as well as urban areas in different countries. The book describes simple technologies from pit latrines to chemical toilets. Wagner & Lanoix (1958) recommended the following seven basic criteria for a sanitary latrine.

i. The surface soil should not be contaminated.
ii. There should be no contamination of ground water
iii. There should be no contamination of surface water.
iv. Excreta should not be accessible to flies or animals.
v. There should be no handling of fresh excreta
vi. There should be freedom from odours or unsightly conditions.
vii. The method used should be simple, inexpensive in construction and operation.

II. WHO Guidelines for the safe use of waste water, excreta and grey water (2006)

The use of excreta and grey water in agriculture is increasingly considered a method combining water and nutrient recycling, increased household food security and improved nutrition for poor households. Recent interest in excreta and grey water use in agriculture has been driven by water scarcity, lack of availability of nutrients and concerns about health and environmental effects. The guidelines are based on the scientific evidence concerning pathogens, chemicals and other factors, including changes in population characteristics, changes in sanitation practices, better methods for evaluating risk, social/equity issues and socio-cultural practices. Recommendations of WHO for treatment, storage and use of human wastes is presented in table 4.

Table 4. Recommendations for storage, treatment of dry excreta and faecal sludge before use at the household and municipal levels.

Treatment	Criteria	Comment
Storage; ambient temperature 2-20°C	1.5-2 years	Will eliminate bacterial pathogens; regrowth of E.coli and Salmonella may need to be considered if rewetted; will reduce viruses and parasitic protozoa below risk levels. Some soil –borne ova may persist in low numbers
Storage ; ambient temperature > 20 -35°C	>1 year	Substantial to total inactivation of viruses, bacteria and protozoa; inactivation of schistosome eggs (< 1 month); inactivation of nematode (roundworm) eggs, e.g., hookworm (Ancyclostoma / Necator) and whipworm (Trichuris); survival of a certain percentage (10- 30%) of Ascaris eggs(≥4 months), whereas a more or less complete inactivation of Ascaris eggs will occur within 1 year.
Alkaline treatment	pH >9 during > 6 months	If temperature is > 35°C and moisture < 25%, lower pH and / or wetter material will prolong the time for absolute elimination

III. Sustainability of a sanitation technology

The primary objective of the sustainable development is to reduce the absolute poverty through providing lasting and secured livelihoods that minimize resource depletion and environmental degradation. In absolute term it is quite difficult to find out sustainable technology/ methodology for any development process, however, sustainability of sanitation can easily be viewed in absolute term – without any conflict with the development process. In fact it is always complementary to the development processes. To make the sustainability more specific, it should be adjudged in the following terms:

- **Socio-cultural aspects** - Social acceptance and adoption
- **Health and Economy**- There should be no or minimum health risk with the system. Further it should be affordable to common people with least operation and maintenance costs.
- **Technical function –** Ease to operate and maintain the system, in different climatic conditions.

- **Environmen**t - Help restore environment rather than disturbing the ecosystem.

The degree of importance of the above aspects varies widely depending on socio-cultural and economic aspects of the community and also with the nature and magnitude of the development works.

Socio-cultural aspects: For implementing any programme related to sanitation, social aspect is one of the most important issues to make it sustainable. Sanitation is mostly regarded as a socio-cultural issue rather than techno-economic. There are still many people in rural areas who due to lack of adequate knowledge, simply can not correlate between sanitation and health. This is evident also from the observation that there are many people having own vehicles, good houses and children enrolled in good public schools but without household toilets. This is simply due to lack of awareness on health and sanitation. However, there are other groups of people who really cannot afford to construct a toilet due to lack of required fund. Such families need financial support from other agencies to have their own household toilets.

In India most of the people use water for ablution. Therefore, pour flush or water borne toilet designs are socio-culturally more acceptable. However, there should be minimum requirement of water to flush human wastes to make it sustainable even in water scarce areas. Dry toilet or any other design of toilet where use of water is prohibited, is difficult to be adopted by many people. Such toilets are not sustainable in many rural areas.

Health and economy: Since sanitation is directly linked with the preventive measures to all the water borne diseases that account for over 80% sickness in rural areas, it is a sustainable means to improve health and consequently productivity of a family or community. So far as the sanitation in terms of household toilet is concerned; it is always a onetime expenditure with almost nil recurring cost. However, there are several people under BPL who really can’t afford to pay any amount for the construction of toilets. Same may be the case with some people of category who are APL, actually unable to bear the cost of a toilet. For them economical aspect is more important than social aspect. Design of toilets should also be adequately suitable to check any handling of waste resulting in possible infections.

Technical function: Sustainability of any design of toilet depends on its technical function, operation and maintenance. Any recurring expenditure on the maintenance of toilet is normally not acceptable for majority of the rural population. Safe disposal or reuse of human excreta should be considered as sustainable sanitation.

Environment: Improved sanitation with well planned solid and liquid waste management has always been a function leading to improved quality of life. In fact, sanitation is a major developmental activity, complementary to the sustainable environment.

Chapter-4

Technology options for on-site sanitation

There are several technologies for human waste disposal from household toilets. Most of the technologies are a refinement of already known and practiced methods, based on experience by different communities. It is too difficult to find any technology which is universally sustainable. Selection of technology should be based on socio-cultural and economical aspects of beneficiaries and hydro- geological conditions and soil type of the intended area. Based on the hydro-geological conditions of the areas and socio-cultural behavior of people, the technology options can be broadly grouped for the following two situations:

I. **For normal soil with low water table**

II. **For high water table areas and /rocky soil**

Every toilet has two major parts- (a) **Substructure and (b) Superstructure.** Substructure is technically important as it provides safe disposal or reuse of human wastes. All the technical options are meant for substructures only. Superstructure is basically meant to provide privacy of the toilet and major technical inputs are not required for this component. There may be a wide range of types of superstructures for the same type of sub structure, depending on the affordability of the beneficiaries. Both the aspects have been described separately in the following paragraphs

I. For normal soil with low water table

In most of the areas in India, people use water for ablution and type of soil is normal. Under such conditions on-site sanitation, through pit toilet is most suited option. Some of the pit toilet technologies used in India are as below:

A. Single off-site Pit Water Seal Toilet A ‘Single Offset Pit Water Seal Toilet’ consists of a pan, water seal / S trap, a squatting platform, a junction chamber, a temporary/ permanent superstructure and a single pit. The pit is constructed away from the squatting platform and connected to the same by a pipe or drain, through a junction chamber (Fig 4.1). The wall of the pit has honey combs that help percolate effluent from pit into soil. There is no vent pipe with pit latrine as gases produced in pits are diffused in soil.

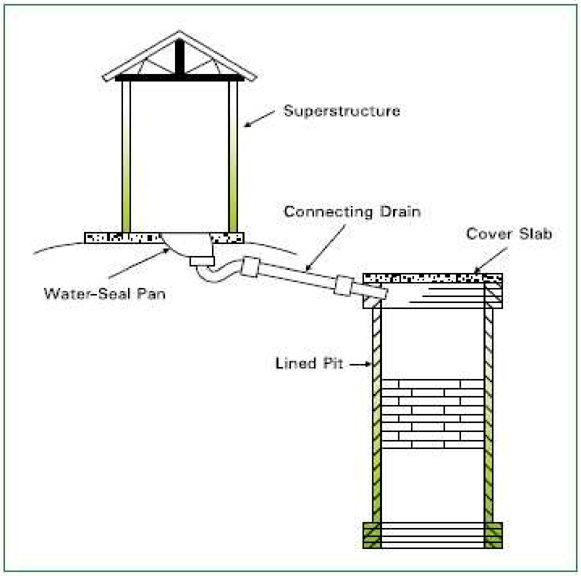


Fig. 4.1

Disadvantages:

Major disadvantage of the single pit is its operational unsustainability. After the pit is filled, it can't be emptied as it contains fresh as well semi degraded excreta. Mechanical devices are normally not readily available in rural India. Under such conditions, the only option left is to clean such pits manually by scavengers. Such manual scavenging is unsocial, unhealthy and against the Scavengers liberation Act of the Government of India and is a punishable offense. Therefore, single pit toilets create more problems than it solves.

B. Single pit toilet with provision of double pit.

In rural areas many times the villagers can't afford the cost of a double pit toilet at one time. Such beneficiaries opt for construction of a single pit, with the provision of second pit to be made later (Fig 4.2, 4.3). This second pit is constructed at later stage, before the first pit is filled. Advantage of having a second pit at later stage just is that one time initial expenditure for construction of toilet is reduced. These two pits are used alternately. Capacity of each pit is for about 3 years. After first pit is filled, human waste is diverted to the second pit. Two years after blocking of the first pit, its contents turn into solid, odour free manure, suitable for use in agriculture and horticulture purposes.

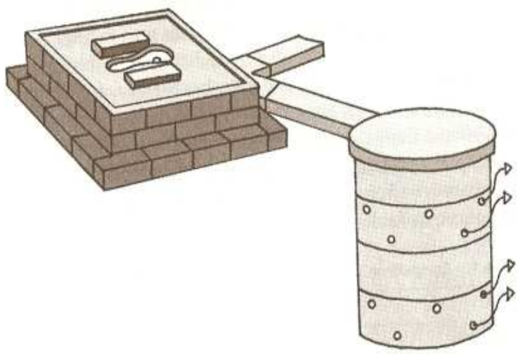


Fig 4.2 Single pit toilet with provision of a second pit Fig 4.3An open ring channel pit

Pits can be constructed with brick, cement or ferro- cement ring channels. Cost of ring channel is significantly lower than brick work.

C. Twin Pit Water Seal Toilet

The Twin Pit Water Seal Toilet is a complete on-site sanitation measure at household level which, on one hand fulfills all the sanitary requirements of a toilet and on the other hand, provides continuous use with minimal maintenance. The main components of such a toilet are the two pits used alternately, a pan, water seal / trap, squatting platform, junction chamber and a superstructure.

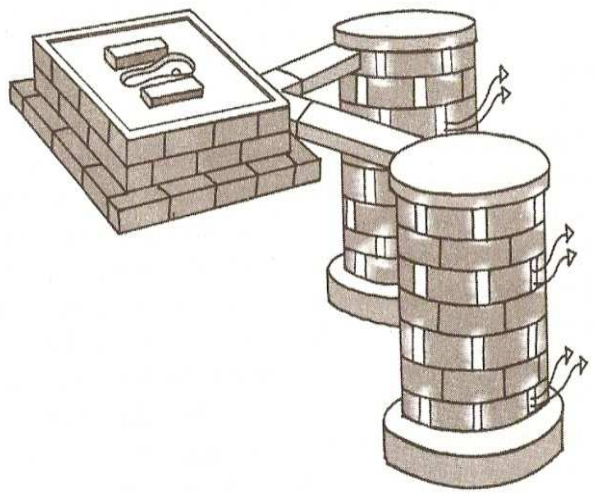


Fig. 4.4

Under the system, there are two pits which are used alternately (Fig 4.4) . Both the pits are connected with a junction chamber at one end. Pit walls have honeycombed structure. Bottom of the pit is not plastered and is earthen. Depending on the number of users of toilet, size of the pit varies. Capacity of each pit is normally kept for 3 years. First pit, after it gets filled up in about 3 years is blocked at the junction chamber and second pit is put in operation. Water part of excreta percolates in soil through honey combs. After 2 years of blocking of the first pit, its contents degrade completely and turn to solid, odourless, pathogen free manure. It is dug out by beneficiaries and used for agriculture and horticulture purposes. After the second pit is filled, it is similarly blocked and the first pit is put in use again. Thus, alternate use of both the pits continues. A plan and section of two pit toilet is as below (fig 4.5)

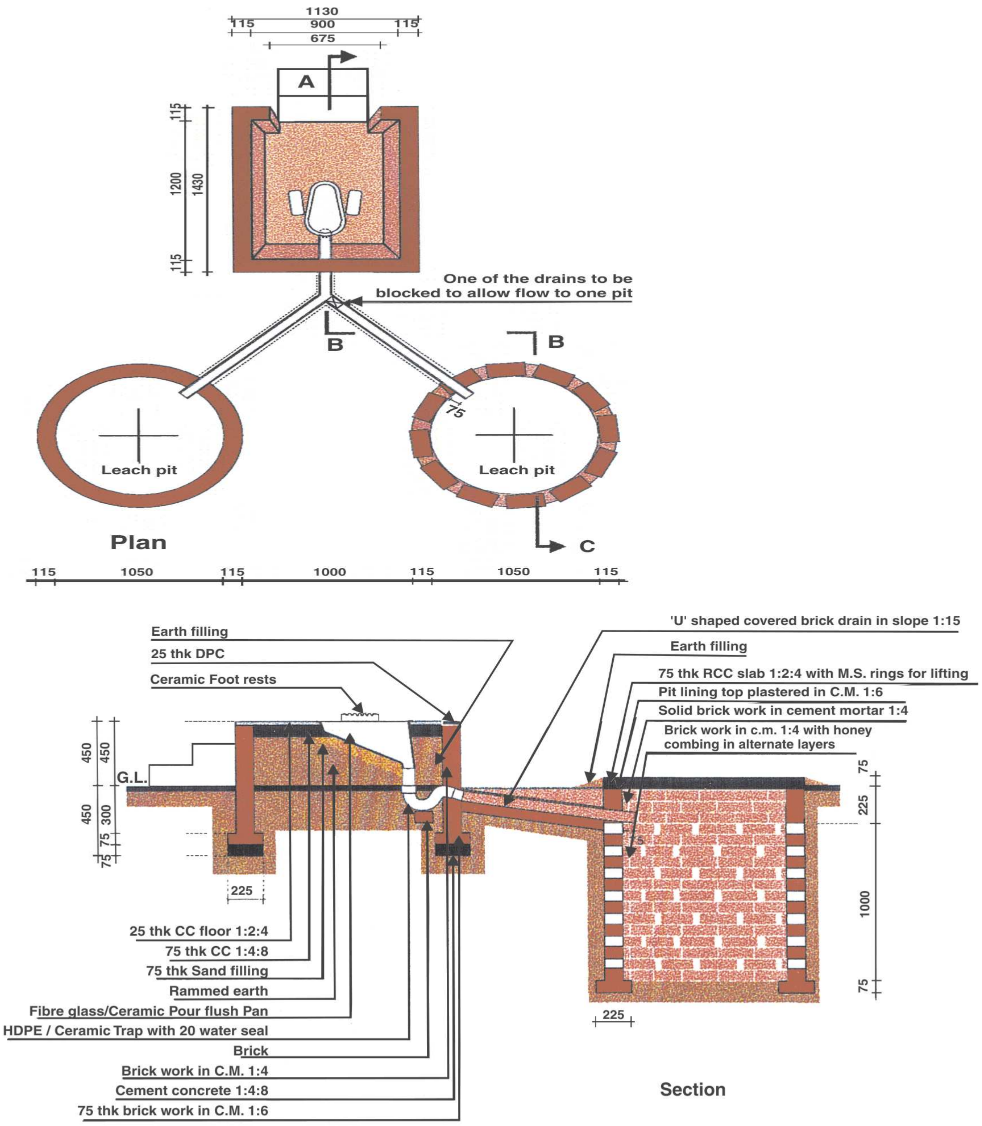


Fig. 4.5

Pan and trap / water seal:

The pan used in the pit toilet has steep slope of 28^0-29^0. It may be of ceramic, mosaic or fiber. People normally do not accept mosaic pan as the surface of such pan is not smooth on which the excreta sticks. Therefore, it requires more water for cleansing. Fiber pan is cheaper, lighter and easy in handling. However it is also not acceptable to many beneficiaries due to its colour. After some years of operation, it develops yellowish colour which is not aesthetically appealing to most of the beneficiaries.

Ceramic pan is used in most of the cases where it is available (Fig 4.6). Such rural pans are also easily available in the markets. It is aesthetically acceptable and requires less quantity of water (1.5 to 2lts). There are only few manufacturers of Ceramic pans in India, resulting into higher cost in comparison to other pans due to high transportation cost.

Fig 4.6 A ceramic pan

Trap / Water seal in rural pans is of 20 mm only. Therefore, such pans require only about 1.5- 2 lts of water to flush out excreta with 20mm water seal. Thus, the system is also suitable for water scarce areas. Such water seal may be of ceramics, mosaic or made of fiber (Fig 4.7). A drawing of water seal as given below (Fig 4.8).

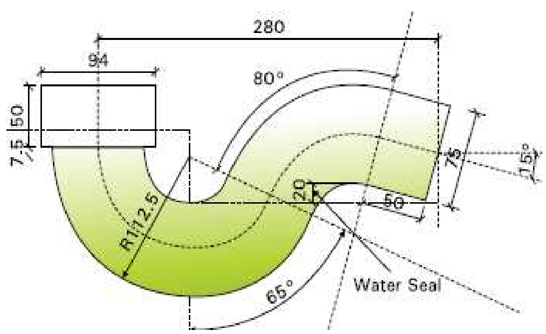


Fig. 4.7 A fiber water seal

Fig 4.8 Drawing of a Water seal

Vent pipe not required:

A pit toilet does not require vent pipe. Gases produced in the pit are diffused in soil through honey combs. Such gases are mainly Carbon dioxide and Methane. Thus the system also helps in reducing air pollution, arising out of such Green House Gases.

Size of the pit

The sizes of pits where ground water level is always below the bottom of the pit and infiltration rate of soil is 30 l /m2/day for a 3 years sludge storage volume works out as described in Table 4.1:

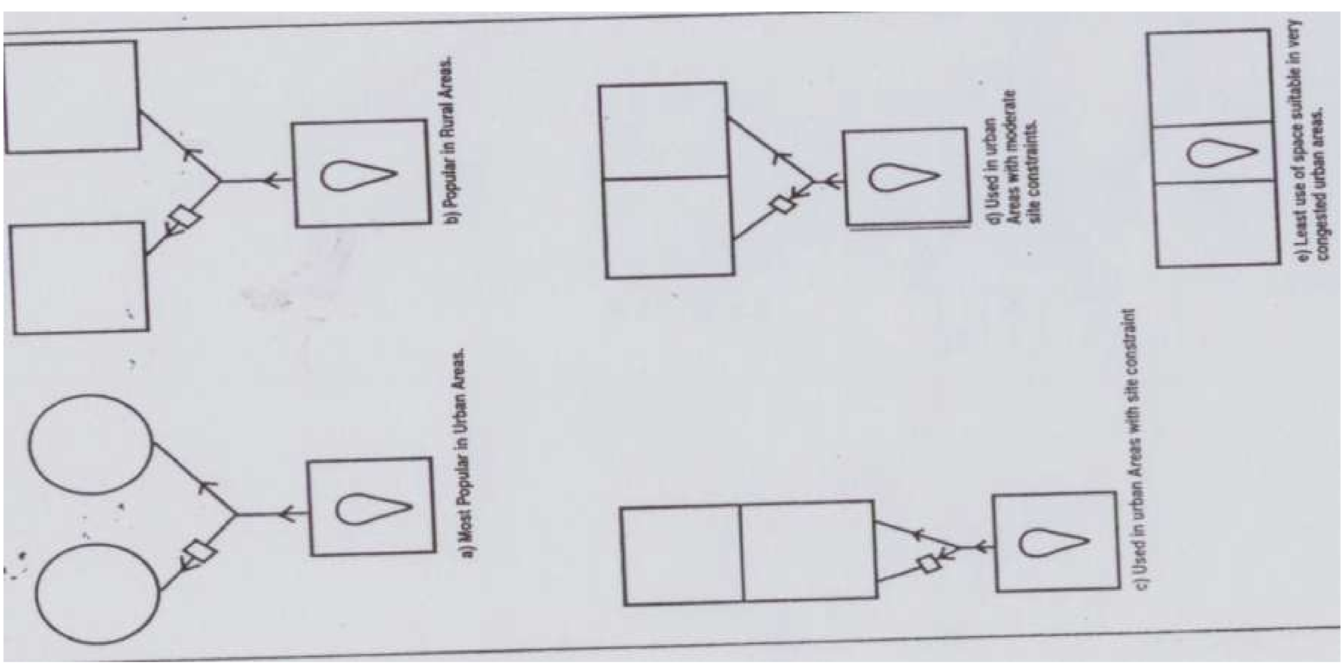
Table 4.1

No. of daily users of toilet	Circular pit		Combined rectangular pit divided by partition wall in two equal compartments. Size of each pit		
	Diameter mm	Depth mm	Length mm	Breadth mm	Depth mm
5	1050	1000	1000	1000	800
10	1200	1500	1250	1250	1050
15	1400	1630	1400	1400	1200

Shape of the pit

A pit may be circular, square, rectangular or linear in shape depending on the availability of space for household toilets. However, effective volume of each pit should be as per the above table. Circular and square pits (separated completely) are better than the linear or rectangular pits (when separated by dividing wall only), as in the former case space for leaching out effluent is more than in the later case. A graphical presentation of different shapes of pits is described (Fig 4.9).

Fig 4.9



Source- (Pickford & Reed,1992)

Advantages of two pit pour flush toilets

i. It is a permanent solution for on- site household human waste disposal
ii. It requires only 1.5 to 2 lits of water per use of toilet
iii. Digested human wastes, when taken out of the pit after 2 years, is semi solid, free from odour and pathogens, that can be easily dug out by the beneficiaries.
iv. Degraded sludge has good percentage of plant nutrients and can be used for agriculture and horticulture purposes.
v. It does not require scavenger to clean the pits.
vi. It can be easily upgraded and connected to sewer when ever such facility is available in future
vii. Its maintenance is easy

Limitations of two- pit pour flush toilet

a) Pit toilet (single or double pit) is not suitable for high water table and rocky areas. In high water table areas, there is chance of ground water contamination. In coastal areas also these toilets are not suitable at all. Further, due to high water table, adjoining soil of the pit becomes saturated and further percolation from pit reduces significantly causing frequent filling of the pits.
b) In case of rocky areas, there is no chance of percolation of water from pits. Consequently, pit gets filled in frequently. Due to unavailability of mechanical devices to clean the pits, it is not acceptable by the beneficiaries. Moreover, even after the pit is emptied, it is quite difficult to dispose the sludge safely.

II. Toilet for high water table and /rocky areas.

For coastal and other areas having high water table and also for rocky areas the following technologies are appropriate.

A. Balram Model
B. Ecosan toilet

A. **Balram Model** is more suitable for areas where people use water for ablution. The system consists of 2nos. of chambers connected at the middle. It may be a brick-cement or ferro-cement structure. Cost of a ferro-cement structure is cheaper than the brick- cement structure. Bottom of both the chambers are sealed with P.C.C. (Plane Cement Concrete). During the use of the toilets human waste comes into first chamber and after settlement, it flows to the second

chamber. From this second chamber, it flows through the covered drain to its outlet. Toilet seat with pan and trap in the design remains the same as discussed under two pit pour flush toilet.
This model of toilet is useful also in low water table and coastal areas. This is also useful in rocky areas where water of leaching pit may not be absorbed by the ground. The detention period of the soak will increase to a great extent and for a family of 5 members, the detention period will be about 20-25 days and so the B.O.D of the effluent will also be less.
A typical drawing of Balram model is described in Fig 4.10:

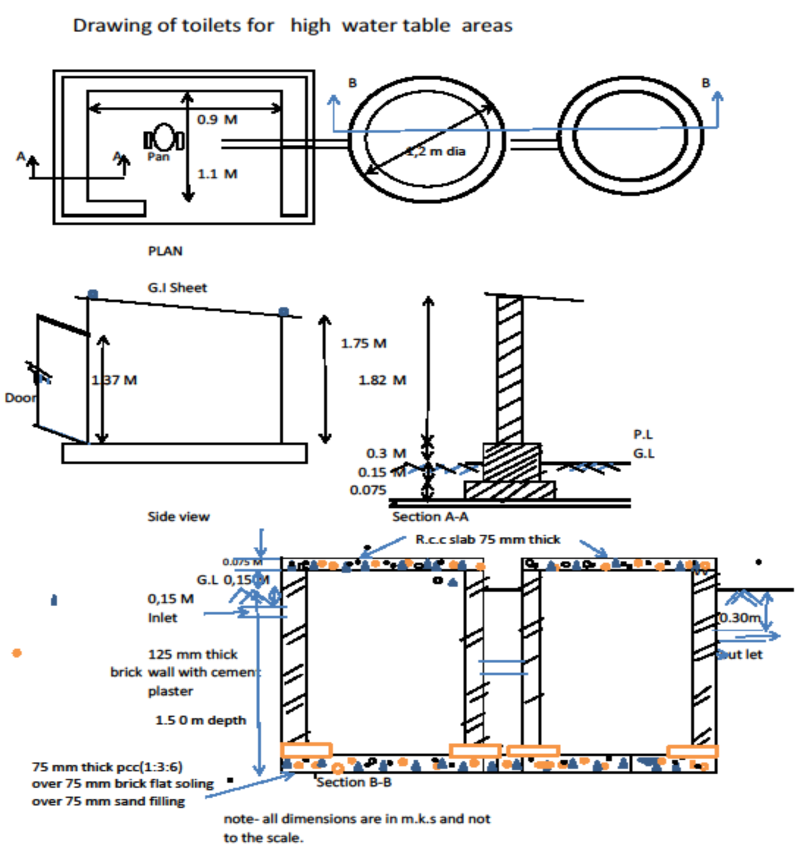


Fig 4.10

Following provisions are made in this type of toilet design:

a) Internal size 0.9mx1.10 m

b) Height of wall is1.82 m from front and 1.75 m at back

c) Roof cover is of G.I Sheet/Asbestos sheet

d) Two nos. of leaching pits of internal size 1.20 m and 1.50 m depth up to ground level.

e) Doors of size 0.76x1.37 m size ,20 gauge G.I framed with M.S angle

f) Thickness of cover slab in each leaching pit -75 mm thick

Advantages of Balram Toilet

i. It is suitable even for high water table without any chance of ground water pollution, as the bottom of human waste collecting chamber is kept sealed.
ii. There is no chance of odour with this toilet
iii. In rocky areas also this type of toilet is suitable

Limitations with Balram Toilet

i. Cost of this toilet is higher than leach pit toilet
ii. Cleaning of chambers is cumbersome when they are filled. Chambers are to be emptied only through mechanical devices. In rural areas such device is not easily available.

B. Ecosan Toilet

Ecological Sanitation or Ecosan toilet is based on the principle of minimizing the loss of nutrients in human wastes and using such wastes, including urine for agriculture purposes. It is a closed- loop system, which treats human excreta as a resource. In this system, excreta is processed on site until it is free of pathogenic organisms. In the system, faeces and urine are collected separately in containers (Fig 4.11). Urine is used in agriculture land directly, whereas faeces are stored for 6 months or so, to degrade it and its use in agriculture. In this system, water is not used for cleaning purpose. To prevent foul smell, dry ash is put after each use of toilet, in the container. Degraded human waste is directly used for agriculture purposes.

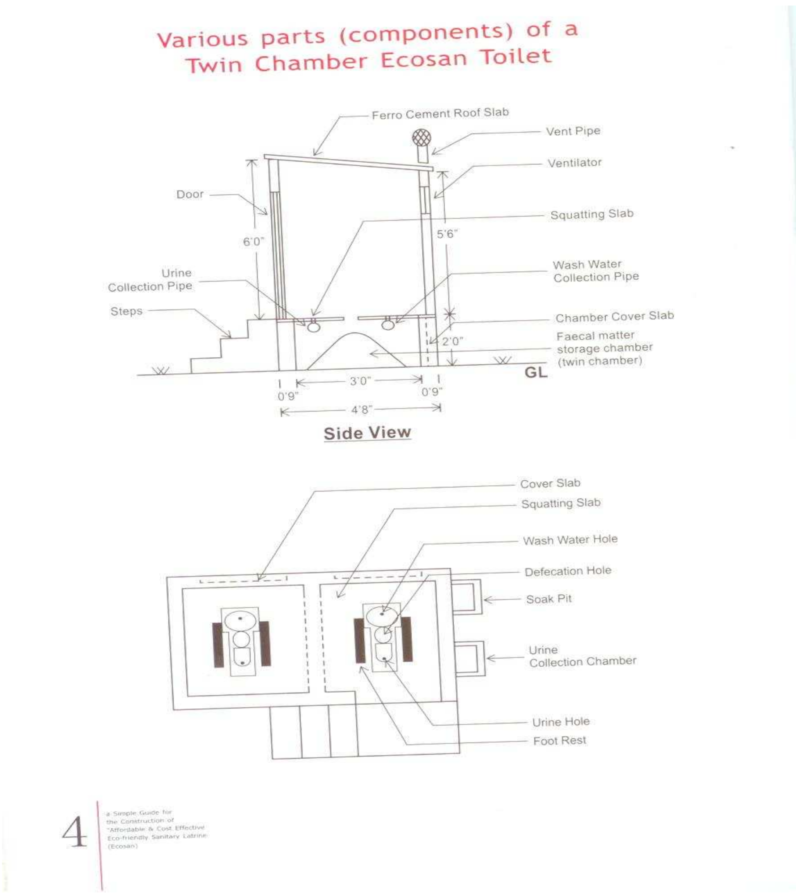


Fig 4.11

If ecological sanitation could be adopted on a large scale, it would protect our groundwater, streams, lakes and seas from faecal contamination at the same time less water would be consumed. Farmers would also require less chemical fertilizers, most of which is washed out of the soil into water, thereby contributing to environmental degradation. Since in rural areas, more agricultural land is available, therefore, Ecosan toilet system can be made a productive sanitation system for such areas. The system is also suitable for high water table areas, and also for, flood prone and rocky areas, where conventional pit toilets are not suitable.

Advantages of Ecosan toilet

i. It saves water
ii. Protects ground and surface water from contamination
iii. Recycles valuable nutrients
iv. Contains and sanitizes excreta
v. Creates no waste

vi. Does not smell

vii. Provides no place for mosquitoes to breed

viii. Self-contained and can be totally managed by the family.

Limitations: Ecosan toilet is more suitable where people don't use water for cleaning and instead, papers, napkins etc. are used for such purpose. In Indian conditions, cultural aspect does not appear suitable for such Ecosan system in most of the communities. Moreover, cost of the Ecosan toilet is much higher than the pit toilets. More awareness and motivation is required to make Ecosan toilet acceptable at community level in rural areas.

III. Biogas toilet

Generation and utilization of biogas from human excreta and other wastes has three major advantages- it improves sanitation, gives bio energy at low cost and provides better quality of manure for agriculture purposes. It is suitable for all hydro geological conditions and where people use water for ablution.

However, household biogas plant solely based on human waste for a family is not economically viable as the biogas produced per family is not adequate for any useful purpose. In a family having 5 users of toilet, only around 5 cubic feet (cft) of biogas would be produced per day and minimum requirement of biogas is about 40 cft for cooking for 2 meals in a day for a small family. Therefore, biogas can't meet cooking requirement of a small family, if produced from human waste of a family. However, it can be made viable, when mixed with cattle dung along with human wastes. Biogas from dung of at least 2 nos. of cattle when mixed with human wastes can cater to the need of cooking for a small family.

Design of biogas plant

For family size biogas plant there are basically two designs (1) Floating drum type popularly known as KVIC model and (2) Fixed dome type, popularly known as Deenbandhu Model.

In the KVIC model gas holder is made up of iron sheet (mild steel). During winter season when temperature falls down to about 10^{o}C or so, this model ceases to function as the iron sheet gas holder acts as good conductor of heat and inner temperature of the digester also attains the same temperature. Secondly, this gas holder requires regular care and maintenance to prevent from getting worn out because of corrosion and has short working life. Manufacturing of gas holder requires sophisticated workshop facility which is rarely found in rural areas. Therefore, in rural areas, success rate of this model of biogas plant is far below the level of satisfaction. Below is the description of materials requirement of only Deenbandhu Model of biogas plant.

Quantity of biogas production from different feed materials

- **i.** From animal dung, Around 10 kg dung is available per animal per day. Biogas production rate from dung is about 1.5 cft per kg, i.e., per animal per day 15 cft of biogas is produced
- **ii.** From human waste, per person per day, 0.35 kg of waste is produced and gas production from per kg of human wastes is 3.6 cft. Per day per person only one cft biogas is produced.
- **iii.** A total amount of biogas of one cum can be produced per day from a family having 5 members and 2 cattle heads.

Utilizations of biogas

One cum of biogas per day can be utilized in a family as follows:

- i. Cooking of 5 family members for two times a day
- ii. Mantle lamps (2nos.) can be used for 6 hours per night. Such mantle lamps give illumination equivalent to 40 Watt bulb at 220 volts of electricity.
- iii. Can run an engine of one Horse Power for 2 hours

Manure value of sludge from biogas plant

Besides biogas, the manure of the plant has good plant nutrient value. It is directly used for agriculture purpose. The following is the comparative value of plant nutrients (N,P,K, value) from biogas manure and other compost (Table 4.2).

(Table 4.2)

Sl.No.	Name of constituent	Compost Manure (%)	Biogas slurry (%)
1.	Nitrogen	0.50-0.75	1.30-1.50
2.	Phosphorus	0.70-0.80	0.85-0.92
3.	Potash	1.20-1.50	1.50-1.65

Deenbandhu Model:- Deenbandhu model of family size biogas plant is predominately used in India. It is a complete brick structure, having very negligible operation and maintenance costs. There is no separate gas holder; biogas is stored inside the plant, through liquid displacement chamber. The cost of Deenbandhu plant is lesser than the KVIC model. It has least affect on biogas production during extreme low or high atmospheric temperature, as the soil cover over the top of the dome acts as an insulator. In a small family, biogas plant of 2 cum (Fig 4.13) and 4 cum (Fig 4.14) capacities are normally used, depending upon the number of family members and cattle heads. Drawings of such plants with material requirements are as under:-

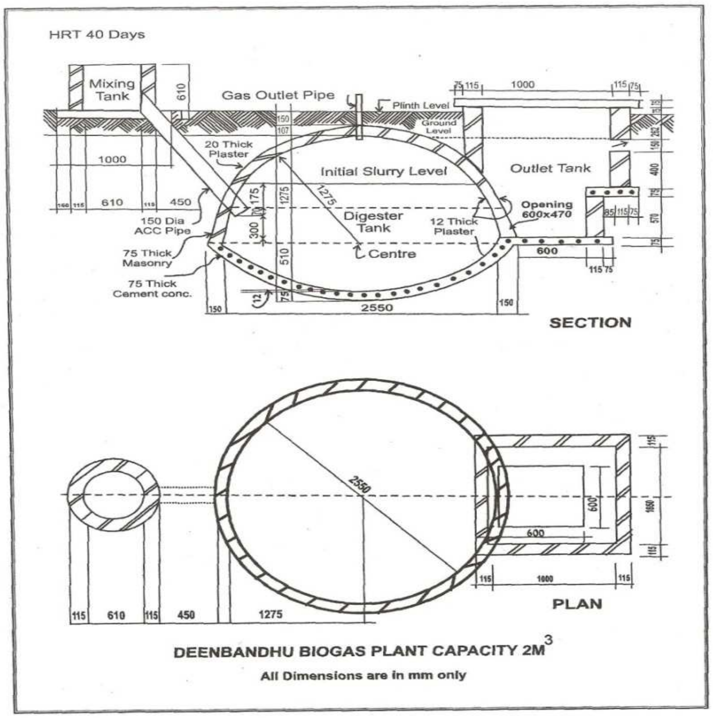


Fig 4.13

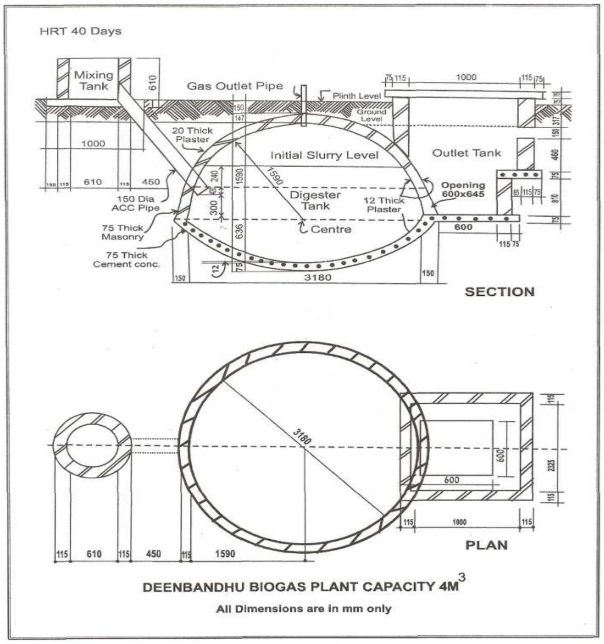


Fig 4.14

Materials required to construct different capacities of biogas plant

Table 4.3

Materials	Unit	Capacity $2m^3$	Capacity $4\ m^3$
Bricks (1st Class)	Nos.	1000	1600
Cement	Bags	14	22
Stone chips	Cft	40	60
Sand	Cft	40	60
Coarse sand	Cft	40	60
G.I. Pipe $^1/_2$" dia. with sockets	Inch	7	7
A.C. Pipe 6" dia.	Feet	6	6
Iron bars (6mm dia) for outlet tank cover	Kg.	7	12
Black Enamel Paint	Ltr.	1	2

IV. Toilet for physically handicapped and old age people

For physically challenged persons, squatting toilet is not suitable. It needs a suitably modified commode toilet to suit their needs. Such toilet is also useful to elderly people or people having knee / joint pain. For physically challenged people using wheel chair, they need a proper space to move with such wheel chair inside the toilet. A grab bar is needed to provide support to such persons while using the toilet. Taking all these factors in consideration following should be the elements of a toilet for disabled persons:

i. One special W.C. should be provided for the use of handicapped persons with essential provision of wash basin near the entrance.

ii. A normal toilet has an average height of around 32-40 cms while handicap toilets have an average height of about 42-48cms. Many people who have no disabilities also find this toilet more comfortable, while it is a necessity for people with back and leg problems.

iii. The minimum size of toilet cubicle should be 1500mm x 1750 mm

iv. Minimum clear opening of the door shall be 900 mm. and the door shall swing out.

v. Suitable arrangement of vertical/horizontal handrails with 50 mm. clearance from wall shall be made in the toilet.

vi. Toilet floor shall have a non-slippery surface.

vii. Guiding block near the entry should have a textural difference,

viii. Light-weight PVC door shutter should be provided as a sliding door

ix. Provision of vertical and horizontal rail as 40 mm steel pipe

x. The rear wall grab bar shall be 36 inches long minimum and shall extend from the center-line of the toilet 12 inches minimum on one side and 24 inches minimum on the other side.

xi. Additional options for handicap toilets include adding a handicap bidet to wash the backside. Some people are unable to reach that area with toilet paper or have trouble in wiping.
A typical inside photo of a disabled toilet is placed at Fig 4.15 and drawings at Fig 4.16 and 4.17

A Typical Toilet for handicapped person

Fig 4.15

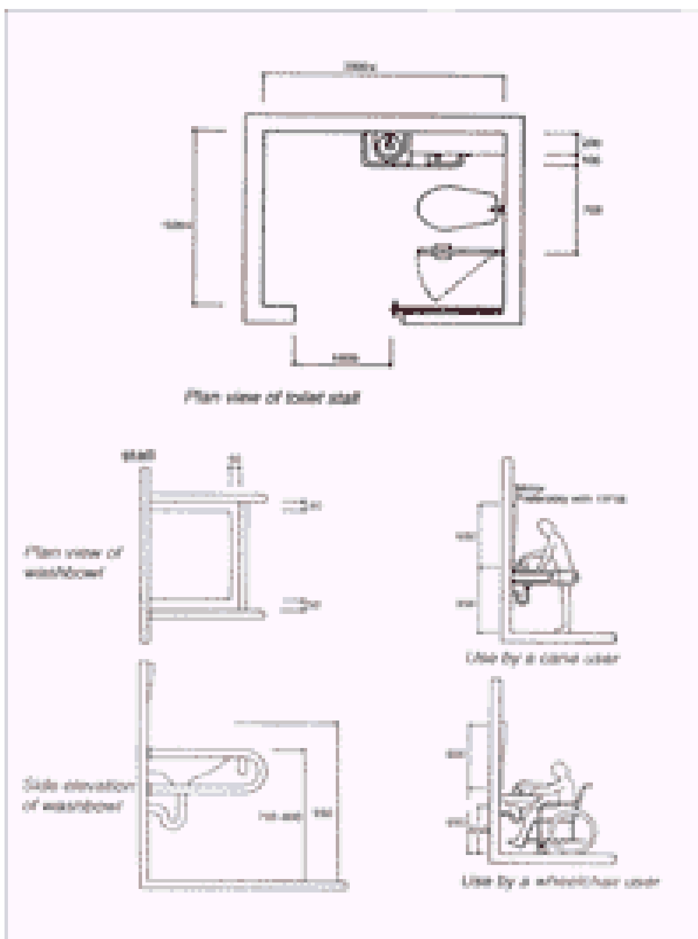


Fig 4.16

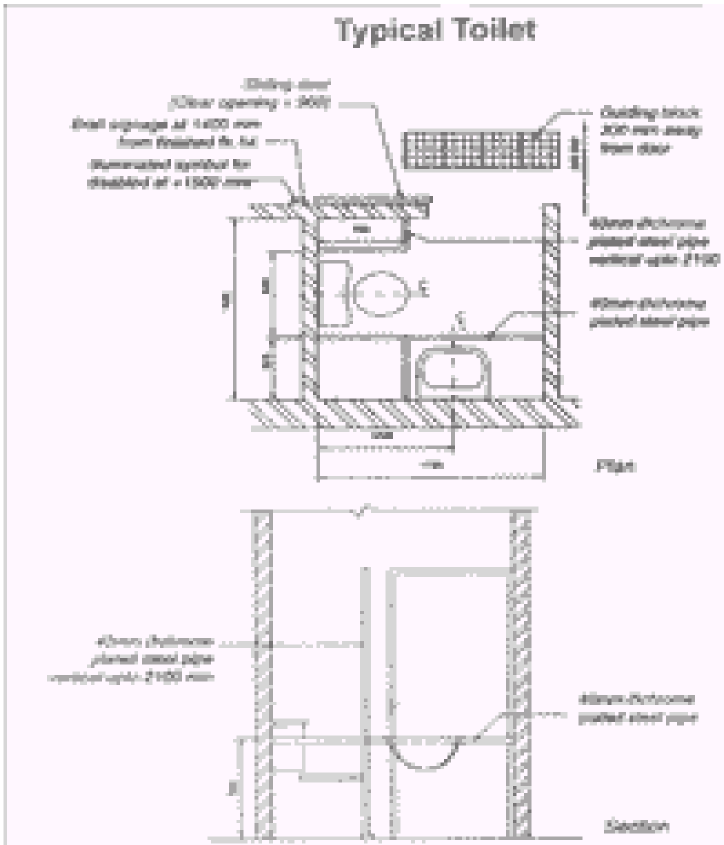


Fig 4.17 **An inside view of a handicapped toilet**

V. Different types of superstructures for household toilets affordable for different economic groups of people

Superstructure with brick, cement and RCC roof and wooden door

Superstructure with stone wall, RCC roof and iron door

Superstructure with thatch

Superstructure with G.I. sheet

Supersaturate with thatch, and roof of G.I. sheet

Ecosan toilet superstructure with brick, cement, and RCC roof and iron door

Ecosan toilet superstructure with brick, cement, and red stone roof and Tin door

VI. Assessment of some widely used technologies for household toilets in rural areas.

	1	2	3	4	5	6	7	8	9
Sl. No	**Type of Technology**	**Important Features**	**Requirement of Land**	**Degree of skilled labor**	**Suitable for soil conditions**	**Requirement of Water**	**Ease of O&M**	**Meeting Hygiene**	**Overall Cost of Technology**
1	Simple Pit Toilet	Squat plate with a hole, a lid (or cover), Foot rests near squat hole. A pit below the squat hole	Low	Low	Permeable/ not suitable for high water table or rocky soil	Little water	Easy	Low	Low
2	Single pit pour flush	Squatting pan with water seal having single offsite leach pit	Low	Medium	Permeable/ not suitable for high water table or rocky soil	Medium- 2 lts per use	Easy	Low	Low-Medium
3	PourFlush Toiletwith Twin Pit	Pour Flush Squat platform two pits with honey combs	Medium	High	Permeable/ not suitable for high water table or rocky soil	Medium (2 lts per use)	Fairly Easy	High	Medium
4	Eco-san Toilet	Separate collection of faeces and urine in water-tight chambers	High medium	Very High	Suitable for any soil including rocky and high water table	No Water	Difficult	High	High
5	Septic Tank toilet	Squatting or commode with cistern, 2 to 4 tanks in series for settling of wastes	High	High	Stable soil, but not suitable for rocky soil	High	Difficult	High	High
6	Biogas plant linked with toilet	Squatting pan, pour flush, instead of pits underground biogas plant is required	High	High	In all soil types	Medium	Needs training	High	High

Chapter 5

Design criteria for pit and chamber for a household toilet

Design criteria of latrines depend on several factors that vary considerably in different geological conditions. The basic dimensions for most common designs of toilets adopted in rural areas are being given below.

Design criteria for two -pit pour flush latrine

To design a pit latrine (single pit or double pit) the following must be taken into account:

- Volume of pit should be sufficient enough to store sludge for the intended period – minimum of 2 years
- There should be sufficient pit wall areas available for leaching of liquid from pit to soil. It can be determined through the infiltration rate of the soil.

Sludge accumulation rate and its storage volume

Not much information is available regarding rate of accumulation of sludge in pit latrines. It varies widely depending on water table, geological conditions of area, quantity of water use for cleaning etc. Degradation of human wastes under water is much higher than in dry condition. In India people generally use water for ablution. Under such conditions, in West Bengal, Wagner & Lanoix, (1958) reported a sludge accumulation rate of 25 litres per person per year. However, later Baskaran (1962) reported it to be 34 litres in the same area. In case of degradable cleaning materials, Wagner & Lanoix (1958) reported sludge accumulation rate to be much higher- 60 lit per person per year.

Storage volume of a pit can be calculated as follows:

V = N x P x R

V = effective volume of the pit (m^3)
N = Cleaning interval of the pit (normally it is 3 years)
P= Average users of toilet per day
R= Sludge accumulation rate –per person per year (m^3)

Depth of sludge in the pit: For calculation of depth of sludge in a pit, plan area of the pit is determined. Depth of sludge is calculated as follows:

Sludge depth = Total sludge volume (V) / Plan area

Infiltration rate and Leaching Area of the pit wall: Rate of infiltration from pits varies and depends on soil type. Clay soil in wet condition has least infiltration rate, it becomes almost impermeable. Sand and silt have more permeability and high infiltration rates due to large soil porosity. The rate of infiltration also depends on ground water table. In case of unsaturated soil, infiltration is induced by gravity and presence of air and water in the soil pores. In the saturated soil all pores are filled with water and infiltration depends on the size of the pores. However, pore size of surrounding soil of a leach pit is never constant. Soil pores get clogged during operation of leach pits due to organic matters in the effluent of pit, it causes reduction of infiltration rate. Therefore, it is quite difficult to determine infiltration rate of any soil in course of operation of a leach pit toilet.

Infiltration rate of different soil types has been studied by many experts and they vary widely. The recommended infiltration rate of different soil types as recommended by the US Environmental Protection Agency (1980) is as follows:

Soil type	Infiltration capacity, settle sewage(lts. per m^2 per day)
Coarse or medium soil	50
Fine sand loamy sand	33
Sandy loam, loam	25
Porous silty clay and porous silty clay loam	20
Compact silty loam, compact silty clay loam and non- expansive clay	10
Expansive clay	<10

In India sandy loam, loam, silty clay and silty clay loam soils are found in most of the areas. On a safer side, a filtration rate of 20 lit. per m^2 per day is adopted for a general design of household leach pit toilet. However, for site specific soil conditions, a separate calculation for design should be done, taking into account the actual infiltration rate.

Design calculation for a two pit pour flush toilet used daily by 5 users, for 3 years capacity

Sludge volume = N x P x L

$$= \frac{3 \times 5 \times 34}{1000}$$

= 0.5 cum

Sludge depth = sludge volume / plan area

Assuming the diameter of the pit to be 1m, the sludge depth would be

0.5 x 4 / 3.14 = **0.6 m**

Liquid depth : Total volume of water for flushing of the toilet, per day by all the 5 users of toilet is taken as 25 litres. However, for a rural pan with 20 mm water seal it requires only 2 lit per use of toilet. The volume is taken on higher side for safety as some may require more water for cleaning and flushing.

For 25 litres water, area required for leaching would be 20 / 30 = 0.66 m^2 (infiltration rate 30l / m^2 per day is taken on a safer side)

Infiltration depth = Area required / circumference of pit

= 0.66 / 3.14 **= 0.21 m**

Depth of each pit =

Sludge depth =	0.6 m
Liquid depth =	0.21 m
Depth to bottom of inlet pipe/ drain * =	0.20 m.
Total depth =	1.01 m

*It is the depth of bottom of incoming pipe from the junction chamber, this part does not have honeycombs and thus can't be considered for leaching area

Thus, total depth of a pit for 5 users and 3 years capacity should be 1.01 m.

Design calculation of chambers for Ecosan toilet

In case of ECOSAN toilet, people use papers for cleaning and cleaning water is separated in a chamber. Ash is put over the waste after each use of toilet. Under such conditions, depending on usage pattern, an ultimate volume of desiccated faeces with additive mixture of 0.25 to 0.40 litres per person per day can be considered (Ecological sanitation Practitioner's book, 2011). The book issued by the Ministry of Drinking Water and Sanitation, Govt. of India and UNICEF, Delhi, gives details of the design, operation and maintenance of Ecosan toilets.

Calculation for a storage chamber for an Ecosan toilet, daily used by 5 users and one year capacity is as follows: People use desiccating materials after each use of toilet.

Volume of storage chamber = N x P x R

= 1 x 5 x 146 liters = 0.7 cum (per day 0.4 litres per person 365 x0.4 l. per year is considers)

Sludge depth = Sludge volume / plan area

Taking length and breadth of chamber are 1m each then depth would be -

0.7 /1 = 0.7 m.

In case of Ecosan toilet there is no chance of infiltration of liquid, as the bottom of the chamber is plastered, infiltration area is not considered.

Soil seal depth: it is assumed to be 0.5 m

Total designed depth of the chamber is 0.7+0.5 = 1.2 m.

Thus for an Ecosan toilet used by 5 users per day having one year of decomposition time the designed dimension of each chamber should be 1 x 1 x 1.2 m, i.e. volume of 1.2 cum.

Chapter 6

Key technological issues in implementing household toilets

I. Technical issues

In rural areas, pit toilets are most appropriate option in most of the cases. It is acceptable also due to its simple design, low cost, and easy to construct. Untrained masons normally modify the design at site without knowing the importance of each component of the toilet. Sometimes such modification is also due to perceived social status. The common problems faced with the implementation of household toilets are follows:

i. **Use of Vent pipe-** In case of pit latrines (single or double pit) vent pipe is not required. Gases produced during decomposition of wastes are diffused in surrounding soil through honeycombs of the walls of pit. Further, if the height of vent pipe is lower- 4-5 feet (that has been observed in most of the cases), there is sometimes foul smell in the surrounding, resulting in avoidance of construction of a toilet. Villagers are normally unaware of the function of vent pipe, they simply take it as status symbol.

ii. **Insufficient honey combs:** In case of pit toilets constructed with bricks, honey combs are normally provided. It has been observed that honey combs are not provided in the ring channel toilets. Some part of the water leaches out through joints of the channel and through bottom of the pit. Most of the water remains in pit resulting in frequent filling of the pit. Under such condition taking out manure from the pit is quite difficult as the content of the pit remains wet for longer time. In sandy areas, large size of honey combs is not required. In such case, sand falls in the pit through honeycombs. In such cases honeycomb of 1" is sufficient for leaching of water.

iii. **Size of the pits:** Size of each pit of toilet is normally 3 ft in diameter and 4 ft in height for 5 users and 3 years capacity .It has been observed that some people construct large size of pits with the idea that such pit will require 10-20 years for emptying. Such unnecessary digging of large pits has unfavorable consequences. High depth of pit may cause ground water pollution; in case of loose soil, more depth may result into collapse of pit wall when sufficient strength is not provided to the brick walls.

iv. **Improper pan and Trap:** Pit latrine is suitable for low consumption of water for flushing of wastes. For low flush of water, pan should be of higher slope (28°-30°) and water seal / trap of 20 mm only. It requires only 2 lit of water to flush human wastes per use of toilet. Such pan and trap are made up of fiber, china clay, mosaic etc. Fiber pan and trap are cheaper and easy to transport due to its light weight. However, it has been observed that in many cases people do not use such pan and the 20 mm trap. Instead, they use ceramic pan with a trap of 60 mm or even higher, that requires more water to flush out excreta. Higher quantity of water to flush the excreta, causes frequent filling of pits, in addition to loss of water which is generally the drinking water, through the pits. Absorbance capacity of any soil is finite. High hydraulic load causes accumulation of water in pit which gets filled up frequently. The reason of using such pans in rural areas could be either people are not well aware of the 20 mm water seal and/ ceramic pan might be taken as a status symbol. However, rural ceramic pan with 20 mm water seal is available in the markets. Villagers should use such pan and water seal.

v. **Improper junction chamber/inspection chamber/ Y chamber:** In case of double pit toilet proper junction chamber is essential. It is required to change over pit when one pit is filled. Junction chamber should be suitable enough to block the pit after it is filled. Such blocking is done normally by putting a piece f brick at the opening of the pipe connecting to the pit. In some cases it has been observed that junction chamber/ Y chamber is not properly designed to block human wastes completely. It results in flow of wastes in both the pits. In such case, contents of the pit remains wet and becomes difficult to take out. In case of single pit toilet also there should be proper junction chamber. It will be required when second pit will be constructed.

vi. **Ground water contamination:** One of the limitations with pit toilet is that there should be a safe distance of 10 meters from drinking water source to the toilet pit. However, not much attention is given by the beneficiaries to this aspect. Due to lack of adequate awareness, people sometimes construct toilet very close to hand pump/ well. A community may face severe water born diseases due to contamination of ground water if safe distance of toilet with drinking water source is not maintained properly.

vii. **Height of the pit above ground level:** Pit should be at least 3-4” above the ground level, to avoid rain water entering into pit. However, it is been observed that in some cases pit cover is made at the level of ground. In such cases during rainfall water flows in to the pit causing inconvenience in use of toilet.

viii. **Problems with rodents:** It has been observed that in some cases rodents in unused pit cause damages and due to several holes in pit caused by rodents, pit collapses. Beneficiary should find out suitable solution to avoid such problem. However, there is a simple solution to avoid such occurrence in case of rectangular pits, separated by a partition wall. At the upper portion of the partition wall, a small hole should be made. Through this hole, gases formed in the pit in use will pass into other pit. Such gases contain methane, carbon dioxide and hydrogen sulphide, therefore, rodents do not come to that pit. However, it is difficult to apply this method for the pits which are completely separated.

ix. **Superstructure:** For a toilet, superstructure is important to maintain privacy, without proper superstructure, no one would like to use toilet. It has been observed that in many cases half superstructure without proper door is constructed. As per the report of TARU/ UNICEF (2008) such poor and unfinished structure of toilets accounts for significant number of toilets not being used. Such practice of making incomplete superstructure should be avoided.

II. Operation and maintenance of a household toilet

For proper operation and maintenance of a household toilets the following do and don’t should be observed.

Do and don’t to maintain a toilet

Dos--

i. Level of slab on the pit should be 3-4 inches above the ground level, otherwise, rainwater may enter into the pit. Therefore, do not make pit with cover slab below the ground level.
ii. Both the pits should be used alternately.
iii. Keep two liters of bucket with water ready in the toilet for flushing.

iv. Pour little quantity of water on the pan before it is used. It helps excreta to slide down the trap and pit easily

v. Use only 20 mm water seal/ pit trap as it requires only 1.5 -2 lits. of water to flush out excreta.

vi. Toilet should be regularly cleaned.

vii. Desludging of pit should be done after 2 years, digested human waste in the pit becomes odourless and pathogen free by that time.

viii. Manure from the pit should not be thrown, rather used in agriculture as it contains good percentage of plant nutrients.

ix. Such digested human waste should be handled with care- hand contact should be avoided/ minimized.

Don'ts-

i. Don't use supply water pipe inside the toilet. It results in more use of water for flushing, causing decrease in efficiency of pit and high hydraulic load may cause ground water pollution

ii. Don't use both the pits simultaneously.

iii. Don't use any chemicals and detergent to clean the pan. It causes killing of microbes also, resulting in less degradation of wastes.

iv. Don't allow kitchen water or bathing water to enter into toilet.

v. Any solid material like plastic or small ball etc. should not be put into the pan, it blocks the pit trap making toilet non-functional.

vi. In case of blockage of pan due to such objects, it should be taken out manually from the pan; it may cause more problems, if stuck in the trap.

vii. Don't throw lighted cigarette butts into the pan

viii. Don't desludge the pit before 2 years, after it is filled up and put out of use.

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The book will help engineers, sanitarians, policy makers and field workers involved in implementation of on-site sanitation systems.

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