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संयुक्त सचिव
Saraswati Prasad, I.A.S
Joint Secretary

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New Delhi, the 10th April, 2013

Dear Sir / Madam,

Proper management of solid and liquid wastes at Gram Panchayat level is the important aspect of improvement of environmental sanitation. Under the NBA programme, this has been given due importance. It has been realized during discussions in several meetings that unavailability of information on sustainable technologies on Solid and Liquid Waste Management (SLWM) in rural areas is causing a deterrent for proper implementation of the programme in some states.

2. A manuscript on "Technical options for solid and liquid waste management in rural areas" has been prepared by the Ministry and uploaded in the Ministry's website with this letter. You are requested to get the attached manuscript reviewed and provide suggestions/ inputs, before it is compiled for final printing.

3. It will be highly appreciated if you can send your inputs and suggestions to Dr.P.K.Jha, Consultant (Sanitation and Waste Management) on his email drpkjha@yahoo.com positively before the end of April 2013.

With regards,

Yours sincerely,

(Saraswati Prasad)

To

Principal Secretaries/ Secretaries
In- Charge of Rural Sanitation
All states/ UTs

Technical Options for
Solid and Liquid Waste Management in Rural Areas

Waste Stabilisation Ponds in a village

Vermi Composting

Ministry of Drinking Water and Sanitation,
Govt. of India

(Manuscript prepared by Dr. P.K.Jha, Consultant, Sanitation & WM, NRC)

March 2013

Technical options for
Solid and Liquid Waste Management in Rural Areas

Contents

Foreword

Proper management of solid and liquid wastes in rural areas has been a major challenge for all the concerned stakeholders. To achieve the goal of Nirmal Bharat Abhiyan (NBA), adequate efforts are required to improve environmental sanitation including management of solid and liquid wastes at household as well as community levels. Inadequate management of solid and liquid waste leads to increase in water and vector borne diseases, mortality and morbidity and decrease in environment quality, health and quality of life of common people.

In rural areas, most of the solid and liquid wastes are of organic in nature. There is ample chance of safe recycling and reuse of such wastes for economical uses. Under the Nirmal Bharat Abhiyan Scheme of the Ministry of Drinking Water and Sanitation, there is adequate financial support for the solid and liquid wastes management (SLWM). SLWM is to be taken up in project mode for each Gram Panchayat (GP) with financial assistance capped for a GP on number of household basis to enable all GPs to implement sustainable SLWM projects. Further, there is financial support under the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) for some sustainable technologies for SLWM at Panchayat level. Proper convergence of funds from NBA and MGNREGS will be helpful to minimise the problem of SLWM in rural areas.

Improvement of sanitation is a socio-technical issue. Required impact of waste management can be achieved through social mobilizations supported by socio-culturally acceptable and economically affordable technology. The book describes several technologies for solid and liquid waste management. Technologies should be selected taking into account their sustainability in terms of social, economical and environmental aspects. Success or failure of a technology depends on incorporation or ignorance of social issues like awareness, motivation etc. It needs adequate awareness to all the concerned stakeholders and support from the local governments to achieve this gigantic task for our heterogeneous society.

I am pleased to note that the book has been written by Dr. P. K. Jha, Consultant (Sanitation & Waste Management), National Resource Centre, Ministry of Drinking Water & Sanitation, with needs of many stakeholders of sanitation programmes. It will prove useful for public health engineers, sanitarians, NGOs, CBOs and communities involved in the field of solid & liquid waste management in rural areas.

Chapter- 1

Introduction

Proper management of solid and liquid wastes is an important determinant of improved sanitation in any community. The goals of sanitation fail miserably when solid and liquid waste management aspect is not given proper attention to improve health and living environment of the community. In rural areas this aspect is mostly neglected due to lack of proper infrastructure; unavailability of sustainable technology at household or community level and moreover lack of adequate awareness of common people. In most of the rural areas it is not a felt -need problem.

Management of solid or liquid wastes in rural areas is much easier and profitable business than in urban areas due to the fact that it is mostly organic in nature and does not contain toxic compounds. In rural areas, waste can be safely reused for beneficial purposes with limited resources. This handbook aims to provide complete information on sustainable technologies for waste water as well as solid wastes for rural areas.

A number of waste prevention techniques for solid and liquid waste management are available, and they are commonly summarized as the so-called 4Rs: reduction, reuse, recycling and recovery. In India with its great diversity of climate, terrain, resource availability, livelihood, culture and habit, the quantity and characters of waste generated vary significantly. In general, typical indigenous systems prevail in different regions, whereby a chain of material use exists based on zero disposal and discharge. There are specific uses attributed to each part of the farm products. For example, rice is used for cooking, rice husk for fuel, rice straw as fodder, cattle dung for fuel and compost and ash as manure in rice fields etc., such that there is no waste generated beyond the assimilative capacity of the environment. However, due to increasing population, growing consumerism, changing food habit, increasing use of plastics, packaging and use and throw items etc, the management of waste is emerging as an issue needing urgent attention from the point of view of health and environment even in rural settings.

There are also increasing concerns on liquid waste, especially the grey water generated in households, institutions and common places as wash water from kitchen, bathroom, markets etc. The stagnant water provides conducive domain for breeding for disease vectors. The absence of storm water drains or dilapidated streamlets etc. enhances the water logging scenario, creating unhygienic and anaesthetic conditions. The liquid waste also poses serious problems by contaminating surface water as well as ground water, the later especially in high water table regimes.

Solid and Liquid Waste Management under the NBA guidelines

Solid and Liquid Waste Management (SLWM) is one of the key components of the NBA. SLWM is taken up in project mode in each Gram Panchayat (GP) with financial assistance capped for a GP on number of household basis to enable all GPs to implement sustainable SLWM projects. Under this component, activities like compost pit, vermin composting common and individual biogas plants, low cost drainage, soakage channel / pits, reuse of waste water and system for collection, segregation and disposal of household garbage etc. can be taken up. Project should be approved by state scheme sanctioning committee. The total assistance under NBA for SLWM projects is worked out on the basis of total number of households in each GPs, subject to maximum of Rs 7 lac for a GP having up to 150 households, Rs 12 lac up to 300 households, Rs 15 lac up to 500 households and Rs 20 lac for GPs having more than 500 households. Funding for SLWM projects under NBA is provided by central and state governments in the ration of 70:30. Any additional cost requirement is to be met with funds from the State / GPs. NGO cooperation may be sought to develop / test / document / replicate such models.

Considering the increase in waste generation and environmental and health implications of indiscriminate waste disposal, few States, local governments and institutions have given importance to establish waste management systems by evolving certain guidelines and criteria. The rural waste scenario throughout the country indicates that an urgent necessity is emerged for addressing the management of domestic waste, both solid and liquid, as part of Total Sanitation Campaign. The Nirmal Gram Puraskar has enhanced the construction of toilets in the Panchayats, as a result, collection of waste in rural areas is concentrated to households. So, an efficient & economic disposal system or reuse is needed to be taken up under waste management activities.

Financial support for SLWM under MGNREGS

While taking up works under MGNREGA, the following conditions must be followed:

i) Only those works can be taken up which result in creation of durable assets

ii) The order of priority of works will be determined within the GP and will be reflected in the Annual Plan ratified by the Gram Sabha on 15th August.

iii) The 60:40 ratio for wage and material costs should be maintained at the Gram Panchayat level

iv) No contractors and no labor-displacing machinery shall be used in execution of works

Activities under MGNREGAS for SLWM include

Liquid Waste Management

(i) Construction of low cost drainage,

(ii) Construction of soakage channels/ pits, reuse of waste water,

(iii) Construction of stabilization ponds.

B. Solid Waste Management

(i) Construction of Compost pits/common compost pits,

(ii) System for collection, transportation, segregation and composting and disposal of household garbage. A typical SLWM project for a population of 1000 people comes to Rs.5 lakhs. The labour: material cost ratio is 35:65.

C. For Soak Pit- Rs. 2000 with labour: material ratio of 50:50.

D. For NADEP Composting - Rs. 8000 per compost unit with labour:material ratio of 25:75.

E. For Vermi composting - Rs. 9000, with a labour:material ratio of 25:75.

Chapter 2

Technological options for liquid waste management

2.1 Criteria for selection of technology

There is a range of technological options for waste water and solid waste management. Selection of technology should be made taking in account its sustainability in terms of social, economical and environmental aspects. Selected technology should be socially acceptable, economically affordable and environmentally friendly. The following points should be considered in selecting any technology:

- **Health**- differences in risk of infection between the options
- **Environmen**t - differences in emissions into air and water and the use of energy and natural resources.
- **Economy** - annual and recurring costs related to the options
- **Socio-cultural aspects** - the appropriateness to current or local cultural context, institutional viability.
- **Technical function** - robustness against extreme conditions, maintenance requirements, risk of failure, effect of failure, structural stability.

2.2 Collection system of waste water in rural areas

In rural areas, per capita water supply is very less. It ranges from 40 lpcd to 70 lpcd only. Consequently, generation of waste water is too low to make conventional trunk sewer system effective. Further, the system requires a lot of mechanical and electrical devices to pump waste water that is not sustainable in rural areas.

Small bore sewer systems

For grey water, surface drain is the cheapest option for collecting such waste water. For black water, mixed with grey water, small bore /swallow sewer is the appropriate and sustainable options for collecting waste water in rural areas. Small bore sewer systems are designed to receive only the liquid portion of household wastewater for off-site treatment and disposal, (Richard and Duncan Mara, 1985). Grit, grease and floating materials are separated from the waste flow in interceptor tanks. Such interceptor tanks are installed after each household or group of households as per the site conditions. Depending upon the size of interceptor tanks and inflow of waste water, settled solids are removed periodically from the interceptor tanks.

The Small bore system has the following advantages:

(a) **Reduced water requirements.** It is suitable where per capita waste water generation is very low. It is more suited in rural areas where per capita water supply is low, making conventional sewer system technically unfeasible.

(b) **Reduced excavation costs.** With the troublesome solids removed, the sewers can be designed with minimum depth, required to maintain self cleansing velocity when the slope is kept minimum, excavation costs are minimised.

(c) **Reduced materials costs.** Peak flows, for which the small bore sewers must be designed to handle, are lower than those experienced with conventional sewers because the interceptor tanks provide some surge storage. Expensive manholes are not required in case of small bore system.

(d) **Reduced treatment requirements.** Interceptor tanks arrest floating materials, oil and grease and most of the settleable solids from wastewater. Therefore, it reduces cost of the treatment, as it requires lesser hydraulic retention time for treatment of such waste water.

Thus, small bore sewer systems provide an economical way to upgrade existing sanitation facilities to a level of service comparable to conventional sewers. Because of the lower costs of construction and maintenance and the ability to function with little water, small bore sewers can be used where supply of water is low and consequently low volume of waste water is generated per household.

Disadvantages with small bore sewer system

The principal disadvantage of the small bore sewer system is the need for periodic evacuation and disposal of solids from each interceptor tank in the system. Thus concerned Panchayat / community should be able to exercise effective control over connections to the system and cleaning of interceptors.

2.3. Centralised and decentralised waste water treatment

Centralised treatment of waste water: Centralised treatment of waste water is normally used for urban areas where water supply is normally adequate to generate sufficient waste water for its flow in sewer system. There are several Sewage Treatment Plants (STPs) based on different technologies to treat such waste water. However, only a few sewage treatment plants in India are functioning satisfactorily. Many STPs in urban areas are non functional due to various problems associated with centralised treatment system. Due to lack of required operational and maintenance facilities untreated and semi -treated waste water flows into river (Fig 1) causing sever health and environmental problems. Problems with centralised waste water treatment system are summarised as follows:

- It requires high operation and maintenance costs
- Highly experienced technical persons are required to implement and operate the system
- Due to high electrical energy requirement, the system does not work where such facility is not available on a continuous basis.
- Disposal or reuse of sludge is a major problem due to high contents of heavy elements, other toxic compounds. Their negative synergistic effects on land use are unpredictable, unmonitorable and unregulatable.

Fig. 1 Flow of untreated wastewater in a river

Decentralised treatment of waste water

Decentralised treatment of waste water in rural areas is more suitable. In such areas waste water contains only organic wastes that can be treated easily by the help of natural microbes present in waste water. Due to absence of toxic and heavy metals in such waste water, treated waste water as well as sludge can be effectively used for agricultural purposes.

Importance of decentralised waste water treatment system can be summarised as follows:

- Low operational and maintenance costs.
- Semi skilled persons can operate whole system.
- Energy consumption is nil or very low depending upon technology applied.
- Depending upon the technology there is economic return.

- Can be designed as per the site condition and requirement – reuse or disposal of effluent can be easily regulated.
- There is safe reuse of treated effluent as well as of sludge.
- It is suitable for all the site conditions including undulating topography where conventional sewage treatment can't be implemented.

In rural areas, waste water contains only organic wastes, free from any contamination of heavy metals or other toxic elements. It can be effectively treated and safely reused for agricultural/ horticultural purposes with sustainable technologies through decentralised system of treatment. Therefore, only technologies for decentralised treatment of waste water are being presented below.

2.4 . Decentralised waste water treatment options

I. Stabilisation pond system for waste water treatment
II. Duckweed based waste water treatment with pisciculture
III. Root zone treatment system
IV. Anaerobic DEWATS
V. Aerobic DEWATS
VI. Soakage pit system

I. Stabilisation pond system for waste water treatment

Waste stabilization ponds (WSPs) are a low-cost, low-energy, low-maintenance and, above all, a sustainable method of wastewater treatment. Waste stabilization ponds are an extremely appropriate method of wastewater treatment in India particularly in rural areas. They are highly appropriate under many conditions in India. The climate in India is very favourable for the efficient operation of WSP. The high temperatures that occur throughout the year in most of the country are especially favourable for anaerobic ponds.

Waste stabilization ponds (WSP) are shallow man-made basin into which wastewater flows and from which, after a retention time of few days a well-treated effluent is discharged. WSP systems comprise of a series of ponds – anaerobic, facultative and maturation ponds in series. All these ponds have different functions **(**Duncan Mara**,** 1997). The advantages of WSP systems, which can be summarized as *simplicity, low cost* and *high efficiency*, are as follows:

Simplicity

WSPs are simple to construct. Earthwork is the main aspect of work. It contains construction of different ponds of desired depth and capacity with proper lined or protected embankments, inlet and outlet chambers and interconnecting pipes. It is simple to maintain. Observations to blockage of pipes, scum removal, repair of embankments whenever required, are only routine management aspects of the system.

Low cost

Because of their simplicity, WSPs are much cheaper than other wastewater treatment processes. There is no need for expensive, electromechanical equipments (which requires regular skilled maintenance), nor for a high annual consumption of electrical energy.

High efficiency

Up to 90% Biochemical Oxygen Demand (BOD) from waste water can be removed from a well designed WSP technology. Total nitrogen removal of 70-90 percent, and total phosphorus removal of 30-45 percent can be achieved through the system, making the effluent suitable for reuse in agriculture purposes.

Effluent treatment quality

In India, general standards for the discharge of treated wastewaters into inland surface water and irrigation purposes are given in the Environment (Protection) Rules 1986. The discharge norm of effluent is as follows.

Standard of Discharge of Sewage, 1986
Central Pollution Control Board, Government of India,

Parameters	Inland Surface Water	Land for Irrigation
Suspended Solids (mg/l). Max.	100	200
pH Value	5.5 to9.0	5.5 to9.0
Oil & Grease (mg/l)., Max	10	10
Total residual chlorine (mg/l).	1.0	--
Ammonical Nitrogen (as N) (mg/l).	50	50
Total Kjeldahl Nitrogen (mg/l).	100	--
Free Ammonia , (mg/l).	5	--
Nitrate Nitrogen, (mg/l).	10	--
Biological Oxygen Demand, (mg/l).	30	100

Chemical Oxygen Demand, (mg/l).	250	---
Arsenical (as As), (mg/l).	0.2	0.2
Lead (Pb), (mg/l).	0.1	--
Dissolved Phosphate (as P), (mg/l).	5.0	--
Sulphide (as S), (mg/l).	2.0	--
Phenolic compound, (mg/l).	1.0	--

A well designed WSP is supposed to meet the above norms of effluent discharge from waste water in rural areas.

Pond location

Ponds should be located at least 200 m (preferably 500 m) away from habitation. Odour release, even from anaerobic ponds, is most unlikely to be a problem in a well-designed and properly maintained system. A minimum distance of 200 m normally allays any such fears.

Functions of different ponds under WSP system

WSP system comprises of a single series of anaerobic, facultative and maturation ponds, or several such series in parallel. In essence, anaerobic and facultative ponds are designed for BOD removal and maturation ponds for pathogen removal, although some BOD removal also occurs in maturation ponds and some pathogen removal in anaerobic and facultative ponds. In case of waste water having low BOD level (< 150 mg/l), like grey water, maturation ponds may not be required. Moreover number of ponds for treatment depends on nature of reuse / disposal of effluent. In case of agriculture use of treated effluent such maturation pond is not required. In general maturation ponds will be required only when the treated wastewater is to be used for unrestricted irrigation and has to comply with the WHO guideline of < 1000 faecal coliforms per 100 ml, and when stronger wastewaters (BOD >150 mg/l) are to be treated prior to surface water discharge. However, if WSP effluents can be accessed on the basis of filtered BOD (after filtering algae from effluent) anaerobic and facultative ponds will be sufficient without the need for maturation ponds for the treatment of wastewaters with a BOD up to 300 mg/l. A schematic diagram of Waste Stabilisation pond is as Fig 2. Based on the schematic diagram Waste Stabilisation Technology has been implemented in some villages in Punjab (Fig 2.1)

A Schematic Diagram of Waste Stabilisation Pond

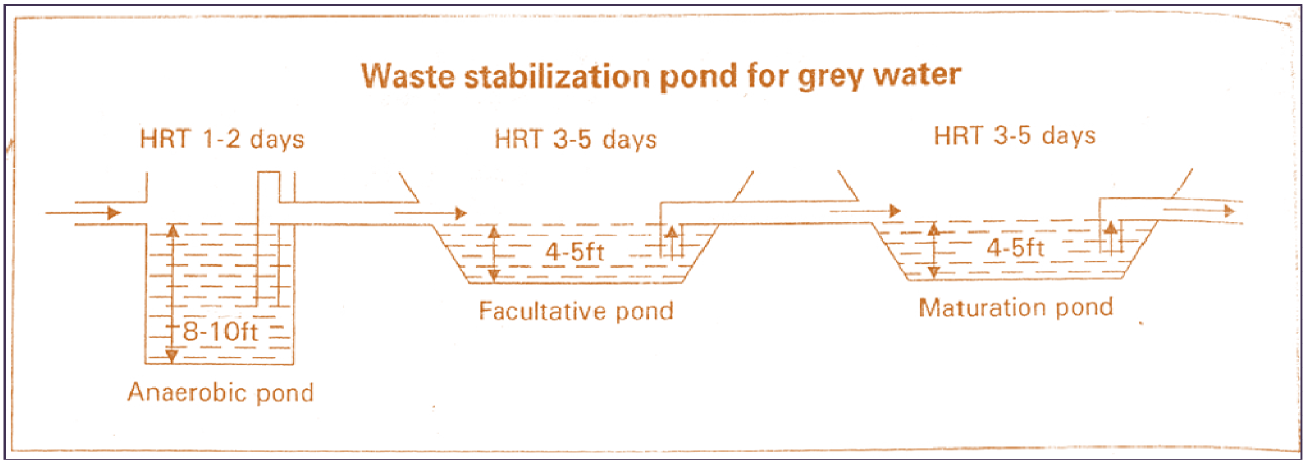

Fig. 2.

Anaerobic ponds

Anaerobic ponds are commonly 2-5 m deep and receive a high organic loading therefore, they contain negligible dissolved oxygen and algae. Their primary function is removal of BOD. Anaerobic ponds work extremely well in warm climates. A properly designed pond will achieve around 70 per cent reduction of BOD at 25^0 C and above temperature. Wastewater with a BOD of up to 300 mg/l, hydraulic retention time of 1 day is sufficient at temperatures $>20^0$ C. If the resulting volumetric BOD loading is <30 g/m^3d, then anaerobic ponds may not be used.

BOD is removed by sedimentation of the settleable solids and their anaerobic digestion in the resulting sludge layer. Heavy metals are also precipitated and many toxicants are also degraded to non toxic forms. Floating materials, such as scum and oils etc, are also retained in these anaerobic ponds.

Fig 2.1. A Stabilisation Pond System in Dewatwal village (Ludhiana District, Punjab)

In areas having high water table there is chance of ground water pollution through stabilisation pond system. It is equally true for any pond - based technology of wastewater treatment. To avoid such problem it is recommended that the base of the ponds should be made impervious by having brick lining or covering base of the pond with plastic sheet topped with soil (Fig-3). Use of plastic sheet is a cheaper option and will not affect the overall cost of the system much.

Fig. 3

To check the embankments of the pond from soil erosion particularly during rainy season, there should be provision of putting boulders at the base of embankments up to the height of water level in the pond It will help minimise the maintenance of embankment of ponds (Fig 4).

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Facultative ponds

Facultative ponds (1-1.8 m deep) are designed for BOD removal on the basis of a relatively low surface loading (100-400 kg BOD/ha d) to permit the development of a healthy algal population.

Oxygen for BOD removal by the pond bacteria is mostly generated by algal photosynthesis. Facultative ponds should have a minimum retention time of 4 days at above 20°C and 5 days at lower temperatures. Liquid depths are usually in the range of 1 – 1.8 mts, 1.5 mts being most common.

Fig - 4 Use of boulders to check erosion of embankment

Depth of less than one metre result in formation of vegetation and must be avoided otherwise the pond becomes an ideal breeding ground for mosquitoes. Similarly with depth of more than 1.8 mts, the pond becomes anaerobic, which is also undesirable. There should be provision to check erosion of embankments by providing boulders (Fig.4)

Maturation ponds

A series of maturation ponds (1-1.5m deep) receives the effluent from a facultative pond, and the size and number of maturation ponds is governed mainly by the required bacteriological quality of the final effluent. Maturation ponds usually show less vertical biological and physicochemical stratification and are well oxygenated throughout the day. Their algal population is thus much more diverse than that of facultative ponds. The primary function of maturation ponds is the removal of excreted pathogens, and this is extremely efficient in a properly designed series of ponds. Maturation ponds achieve only a small removal of BOD, but their contribution to nutrient (nitrogen and phosphorus) removal can be significant.

Faecal bacteria are mainly removed in facultative and especially maturation ponds. There is some removal in anaerobic ponds also, principally by sedimentation of solids-associated bacteria.

The principal mechanism for faecal bacteria removal in these ponds and also in the facultative ponds, are temperature, high pH values and high light intensity. Faecal bacteria and other pathogens die off due to higher temperatures, high pH or radiation of the Sun, leading to solar disinfection. Effluent from a well designed WSP can be safely used for agriculture purpose or surface discharge.

II. Waste Water Treatment through Duckweed with Economic Return

Treatment of wastewater, particularly in rural areas has always remained a major problem due to the fact that available conventional technologies are not sustainable for such areas. Lack of required infrastructure, adequate knowledge and awareness are other inherent limitations in adopting any technology for such purpose. Moreover, there is no economic return out of waste water treatment through any available technology that results in least interest of community and local bodies in the waste water treatment in rural areas, is not sustainable.

Duckweed based waste water treatment technology is a completely indigenous and biological method having direct economic return in terms of pisciculture and employment avenue in rural areas with least recurring expenditure on operation and maintenance of the system.

Duckweed is a group name belonging to botanical family Lamnaceae that consists of four genera namely Spirodela, Lemna, Wolffia and Wolfiella; first 3 genera are commonly found in India. It is cosmopolitan and found everywhere in organic nutrients rich stagnant water. It has very high growth rate; at optimum nutrient environment it doubles within 2-3 days. It tolerates wide range of temperature - between 10^0-46^0C, depending upon the genera. Size of the plant is very small. Wolffiella is the smallest plant having pin head size, while Spirodella is the largest one, having its size of 2-3 cms only. The most important feature with this plant is that it contains up to 30 % edible protein, vitamins A and C. It is a complete feed for certain species of fish like Grass carp, Silver carp, Common carp, Rehu and Mrigal. High yield of fish has a direct linkage with economic return and thus, employment avenue with the system. The system is being adopted in several developing countries *(*Sascha Iqbal, 1999***).***

Principle of Waste water treatment through duckweed

Since duckweed grow very fast in waste water, it uptakes nutrients from waste water very quickly. It is harvested and fed to fish pond such nutrients and so, are removed from waste water. Thus, in addition to normal settling of waste water, there is bioaccumulation of nutrients in duckweed. The duckweed has the ability to bio accumulate up to 99% of the nutrients, dissolved solids and even heavy and toxic elements of wastewater up to certain extent. These are permanently removed from wastewater as plants are harvested. Hence, it reduces Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), suspended solids, bacterial and helminthic pathogens, some organic compounds, ions of potassium, nitrogen, phosphate and even heavy metals of wastewater to a level, quite safe for disposal. A schematic diagram showing mechanism of treatment is depicted (Fig 5.).

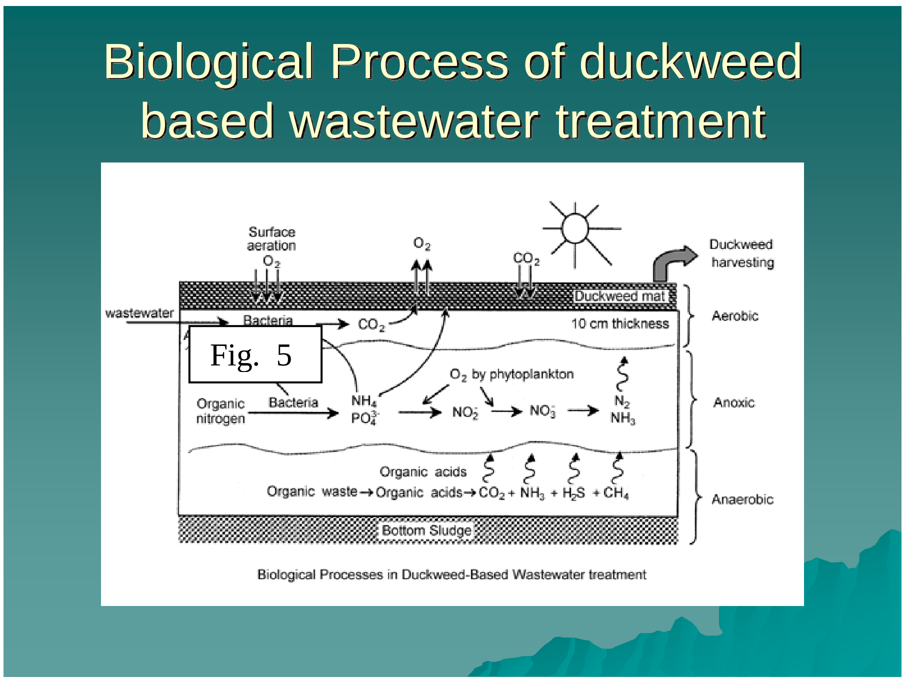

Fig 5

Materials required for duckweed based treatment technology

No external materials are required for the purpose. In villages, plenty of ponds are available without much economical use. Such ponds can easily be used for duckweed ponds, for the treatment of waste water from village. It is always useful to have two nos. of nearby ponds one for treatment and another for pisci-culture. Since duckweed is a free floating plant, it requires only bamboos or PVC cubicles (4m x5 m- or so), to check drifting of duckweed to one end, along with wind (Fig 6). Bamboos are more preferred as there is chance of theft of PVC articles in villages. Duckweed can be found everywhere in stagnant water in villages. No other equipments are required for this treatment process.

Fig 6. A Duckweed pond with bamboo barrier, duckweed being harvested

Size of the pond

Required size of the pond depends on quantity of waste water generated per day. For half mld of waste water, one hectare of, pond surface area (0.5hac for duckweed and 0.5 for fish pond) is required. It is suitable for a village having population of 4000-5000. Size of the fish pond normally should be half of the treatment pond. However, additional larger size of the fish pond is more useful to have more economic return in terms of fish production. Duckweed forms a green mate over waste water, thus reduces the chance of mosquitoes to breed in waste water. (Fig.6)

Since duckweed grows very fast, its regular harvesting is required. 25% of the area of duckweed pond should be harvested daily and put into fish pond. There should be four nos. of fish feeding stations made up of bamboos, where duckweed should be put at any fixed time daily (Fig 7). It fixes biological clocks in fish and the same accumulates at the fixed time at fixed locations.

Economic return through Fish yields

Fig 7. A pond with fish feeding stations

Fig 7A. Duckweed fed fish being harvested

Up to 10 tonnes of fish can easily be harvested per year per hectare of fish pond (Fig 7A). Taking the fish rate of Rs 35 / kg at pond site, a total income from fish sell can be 3.5 lakhs per year. Little specific information is available on the health risks associated with bioaccumulation of heavy metals and toxins in fish and other animals fed on duckweed grown in (industrial) wastewater. There is no chance of such effects when duckweed is grown in domestic sewage as it does not contain higher than permissible level of heavy metals. Krishnan and Smith (1987) reported acceptable levels of heavy metals and pesticides in fish grown in sewage stabilisation ponds. The reason could be growth rate of fish being much higher than the bioaccumulation of heavy metals, resulting in acceptable level of such metals in fish.

Reuse of treated waste water

The treated sullage from the duckweed pond is allowed to flow to the pisciculture pond through culvert pipes, encased with fine mesh, as and when required and excess water if any, is used for irrigation purposes. It's BOD and other chemical parameters are quite below the permissible limits of discharge or reuse for agriculture purpose.

A guideline on Duckweed based waste water treatment system has been published in 2001 by the Central Pollution Control Board, Govt. of India. It is based on the results of a R&D cum demonstration project on "Duckweed based waste water treatment system with economic return in term of pisciculture", funded by the Ministry of Environment & Forests and implemented by Sulabh International, New Delhi in technical collaboration with the Central Pollution Control

Board, Govt. of India. The project was demonstrated in Wazirabad (Delhi) and Halisahar (West Bengal). The guideline is useful for implementing the technology in rural areas. Based on these results, several projects in rural areas have been implemented in India.

III. Root Zone Treatment System

The Root Zone Treatment System (RZTS) has been used widely for treatment of waste water through nutrient removal in many countries. In spite of having its more adaptability in tropical regions, its use to treat waste water has not been exploited on large scale in India.

Root zone Treatment Systems (RZTS) use natural processes to effectively treat domestic effluents. They are not only eco-friendly but also have low operational costs, producing high water quality (up to bathing water standards), suitable for re-use and reliable in both the short and long term. It has been established that a horizontal filter bed area of about 2 m^2 /PE is sufficient for the complete secondary and tertiary treatment of wastewater including the removal of pathogenic germs (Sonavane et.al 2008), (CPCB, 2008).

Salient features of Root Zone system technology

i. Require simple construction methods.
ii. No machinery (pumps, aerators, etc.) and no inputs of energy or chemicals are required for the treatment process.
iii. In the root zone treatment process no sludge is generated, therefore the sludge handling and disposal problem is restricted only to primary sludge tank. This is a unique and remarkable feature of RZTSs.
iv. Can handle a large variety of pollutants.
v. Does not require skilled personnel for operation and maintenance.
vi. It has very low operation and maintenance costs; typically in root zone systems these are less than 1% of the cost of the system per year.
vii. Can be built to suit both decentralized and centralized sewage treatment systems; in decentralized situations considerable drainage costs may be saved.
viii. High efficiency in removal of pathogens. In other system chemicals or UV/ Ozone are used for elimination of pathogenic germs, that is cumbersome process.
ix. Allows re-cycling and safe re-use of waste water.
x. Capital costs are comparable to other similar wastewater treatment systems.
xi. Long life span of systems.

Principle of Root Zone treatment system

RZTS are sealed filter beds, consisting of a sand / gravel / soil system, planted with vegetation which can grow in wetlands. After removal of coarse and floating material, the wastewater passes through the filter bed where biodegradation of the wastewater takes place, making final effluent odourless and reusable for different purposes.

The treatment processes through Root Zone system are based essentially on the activity of microorganisms present in the soil. The oxygen, for microbial mineralisation of organic substances, is supplied through the roots of the plants, and atmospheric diffusion. The roots of the plants intensify the process of biodegradation, also by creating an environment in the Rhizosphere, which enhances the efficiency of microorganisms and reduces the tendency of clogging of the pores of the bed material, caused by an increase of biomass. RZTS contains aerobic, anoxic and anaerobic zones. This, together with the effects of the rhizosphere causes the presence of a large number of different strains of microorganisms and consequently a large variety of biochemical pathways are formed. This explains the high efficacy of biodegradation of substances, that are difficult to treat.

The filtration by percolation through the bed material is the reason for the very efficient reduction of pathogens, depending on the size of grain of the bed materials and thickness of filter, thus making the treated effluent suitable for reuse. A conceptual diagram of Root zone treatment system is described (Fig 8)

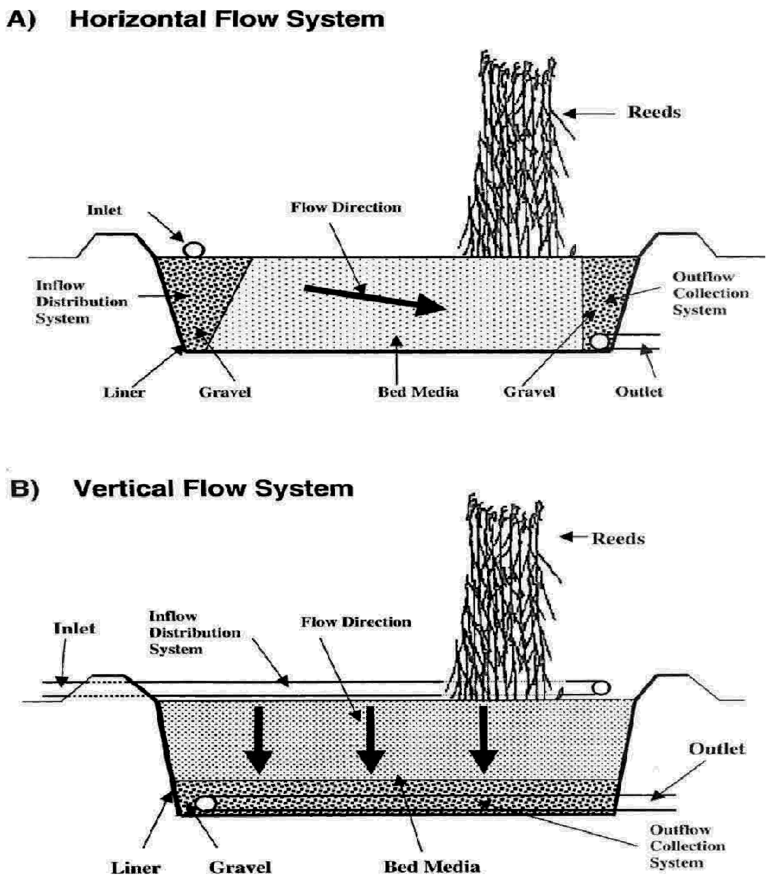

Fig. 8

Unit size range of RZTS

RZT Systems are very suitable for treatment of small quantities of wastewater (minimum 250 g BOD per day), since a homogeneous flow of wastewater through small RZTS can easily be maintained. For sewage treatment, up to 50 kg BOD per day is considered as a maximum quantity of effluent to be treated in one plant.

Process of RZTS

Pretreatment

Settleable solids and floating materials should be removed from waste water before it is taken into RZTS, it can be achieved through proper pre-treatment. Insufficient pretreatment can cause surface clogging. Sand settling devices, grease traps, gratings and sieves have to be used, according to the characteristics of the raw wastewater. In principle all proven pretreatment systems can be combined with RZTS. The following anaerobic pretreatment systems are especially suitable for small RZTS dealing with domestic sewage:

- Multi-compartment Septic Tank

- Imhoff Tank
- Baffle Reactor

After pretreatment through any of the above methods wastewater can be taken into RZTS.

Filter media

The filter media, effective for the such biological treatment, consists of sand / gravel and a carefully mixed soil. The design of the correct filter media according to the available material is the most important step in the design process. If the material is too coarse the wastewater will flow too fast; if it is too fine clogging and overflow will occur. Both cases cause poor treatment efficiency. Sand and gravel with rounded grains are ideal as it provides more surface areas for bacterial growth. Media of relatively smaller grain size, like river sand or sieved materials are best.

Depth of filter bed:

The recommended depth of the filter media is:

- For horizontal filters : 50 - 100 cm
- For vertical filters : 60 - 120 cm

If a horizontal system is used, increasing the depth up to more than one meter is not useful, because of the limited root growth of the plants, which is the only oxygenating factor. In vertical systems an increase in depth of more than 120 cm will enhance the treatment efficiency further, but this is normally limited due to increased cost of filter material.

Sealing of filter bed

RZTS have to be sealed with an impermeable layer at the bottom and the sides, so that untreated or partly treated wastewater cannot infiltrate to groundwater. Sealing is also required to recover the treated water for reuse. Sealing can be done by using concrete or plastic sheet and providing plastic liner of > 1mm, preferably from polyethylene or similar material.

Inlet - and outlet constructions

Inlet structures must be so constructed that they distribute the incoming wastewater uniformly over the surface of the bed, in case of Vertical RZTS, or across the infiltration cross-section in case of Horizontal RZTS, without leading to the formation of erosion furrows on the bed surface or to siltation or clogging of the filter media.

Selection of species

With the available experience the following list of species can be given:

i. *Phragmites australis* (reed)

ii. *Phragmites karka* (reed)

iii. *Arundo donax* (mediteranean reed)

iv. *Typha latifolia* (cattail)

v. *Typha angustifolia* (cattail)

vi. Juncus (bulrush)

vii. Iris pseudacorus

viii. *Schoenoplectus lacustris* (bulrush)

For horizontal RZTS, in principle, all helophytes can be used, which are deep rooted and oxygenate the Rhizosphere through the roots. For vertical systems, the plant selection is less critical, because the oxygen input is enhanced by the intermittent surface application.

Planting Techniques

Planting of reeds can be done in the following ways:

- Reeds can be planted as rhizomes, seedlings or planted clumps.
- Clumps can be planted during all seasons. (2 / m 2)
- Rhizomes grow best when planted in Pre-Monsoon. (4 - 6/ m2**)**
- Seedlings should be planted in Pre-Monsoon (3 - 5/ m2)

Capital cost

It includes the availability of land space; Infrastructure development; including sewerage system; excavation and construction of beds; Filter media; Plants; and construction of pretreatment facility

Operation and maintenance cost

It includes sludge removal; treatment and disposal from pretreatment facility; removal and disposal of plant material and maintenance of the system.

Limitations

RZTS are based on filtration mechanism; therefore, they are sensitive against clogging. Overloading of RZTS with organic matter can also cause clogging. These problems can be avoided by appropriate pretreatment of wastewater, proper design of the filter bed and proper operation of the system. Land requirement of RTZS is more than the stabilisation and other technologies.

IV. Anaerobic Decentralised Waste Water Treatment System (DEWATS):

In rural areas waste water contains mostly organic matters, making it more suitable for reuse for agricultural purposes. There are several technologies under DEWATS. Under the present heading, the technology developed by the BORDA (Bremen Overseas Research and Development Association), Bremen, Germany, in collaboration with various organisations in India, is being described (Sasses, L, 1998). This technology has widely been implemented in rural as well as urban areas in different States in India.

Principle of DEWATS.

Basic principle of DEWATS is proper settling of setleable solids of influent through different chambers in series and increase bacterial activity through proper bacterial growth media in different chambers for the growth and consequently, bacterial degradation of dissolved solids in effluent. Such treated effluent has much less Biochemical Oxygen Demand (BOD) suitable for use for agriculture and horticulture purposes.

It is a modified septic tank system. In this system there are three or four or more chambers, depending on the quality and quantity of waste water. The first chamber is always a settling chamber and the rest are treatment chambers where bacteria grow on growth medium in the forms of stones/ cinders/coir/ or any other rough plastic material. Effluent quality is good enough to be used for agriculture purpose. Important advantage with the system is that it takes total waste water, including bathing and washing water, along with black water. A schematics drawing of DEWATS is mentioned (Fig 9). A DEWATS under construction (Fig 10) and after completion (Fig 11) is presented below. A drawing of DEWATS is presented in Fig. 12.

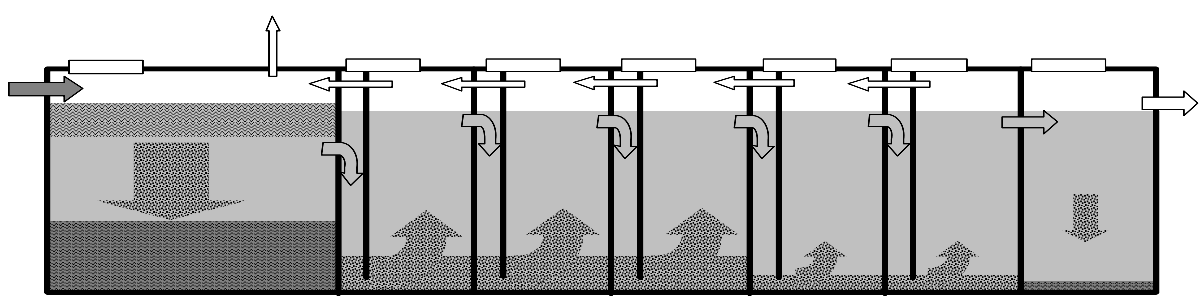

Fig 9. Flow of wastes water showing settling of solids in different chambers in DEWATS

Fig 10. A DEWATS under constrution

Fig 11. A DEWATS after completion

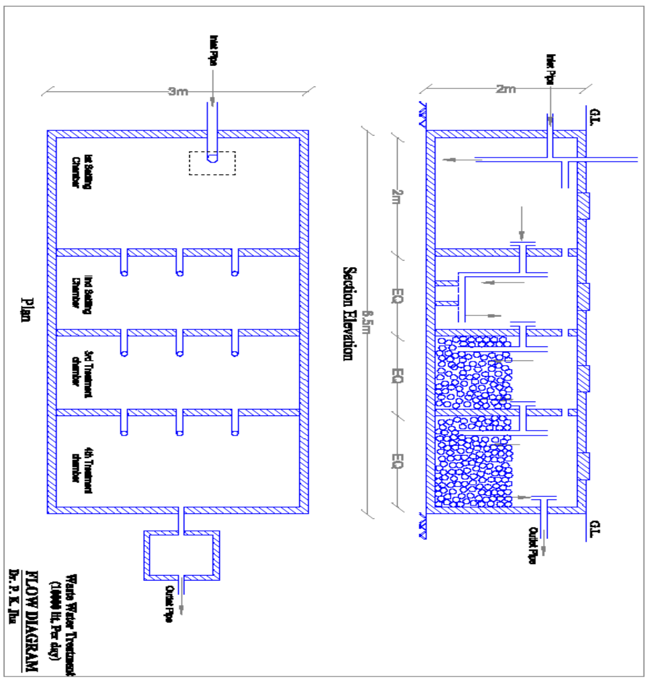

Fig. 12

Advantages of DEWATS

i. The system has least operation and maintenance costs

ii. The system can be operated by semiskilled persons

iii. Requirement of space for treatment of waste water is very low in comparison to WSP and RZTS technologies

iv. Final effluent is suitable to be used for agriculture purpose.

v. In case of high organic load , biogas can also be produced through the system

Limitations with the system

i. The system has high implementation (capital) cost

ii. When gravitation flow of waste water is not available, there is need of pumping of waste water to inlet chamber of DEWATS.

iii. Lack of required electricity in rural areas may hamper the system to function properly.

V. Aerobic DEWATES

Aerobic DEWATS is suitable where continuous electricity is available in the area and of higher effluent quality is needed. The system requires only two chambers instead of three or more chambers in case of anaerobic DEWATS. First chamber works as settling chamber and second chamber as aerobic chamber (Fig 13). Third chamber may be added as storage chamber. However, if there is provision of continuous use or discharge of effluent third chamber is not required.

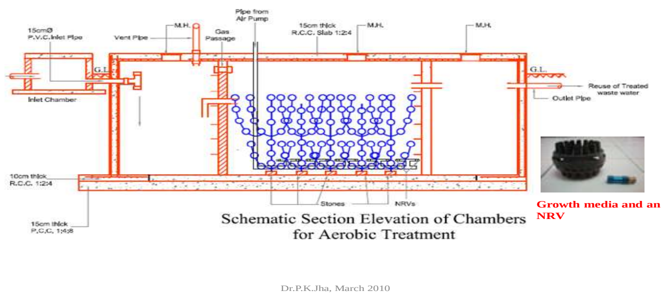

Fig. 13

Hydraulic Retention time of the settling chamber is kept as one day, while that of aerobic chamber is of two days only. Aeration in the second chamber is provided through air pump of low air flow- 60 to 100 lmp (lit per minute). Such pumps operate on 50-100 watt (depending on quantity of waste water and consequently required rate of air flow). Continuous air flow is desirable; however, it is essential to have at least 15-16 hours air flow per day to have better quality of effluent. Flow of air inside chamber should be at multiple points that it can be achieved through connecting different pipes through ‘T’ and NRVs (Non- return valves).

For proper growth of bacteria inside chamber, some bacterial growth media are used. Such media are available in the markets. However, any rough plastic or other non-degradable material can be used. Coir ropes are quite rough having huge surface area for the growth of bacteria. It can with withstand for a long time (more than 4 years) under waste water and can be used for bacterial growth media (Jha, P.K, 2010). It is cheaper and easily available in markets. Final effluent of the system is completely colourless, odourless having Biochemical Oxygen Demand (BOD) around 10 mg/l which can be easily achieved through the system. The system can be made up of bricks, cement or RCC structure.

I. Soakage pit

Soak pit is the most simplest method of construction and use for grey water (Fig 12A). It is dug out nearby the generation of waste water. It is a pit structure having length, breadth and depth of 1 m each. Pit is filled with stones or burnt bricks. Filling of stones/ cinders in pit should be at bottom different graded stones followed by earth cushion and polythene cover.

Bottom 30 cm with stones of size 250mm by 125mm to 150 mm, followed by 25 cm layer of stone size 100mm to 125mm followed by 25 cm layer of boulder size 50 to 75 mm. Such materials help bacteria in waste water to grow and degrade organic matters present in water. Bacteria stick to the rough surface of media/boulders and therefore, there is least chance to their movement along with water into soil. Therefore, there is least chance of ground water pollution through soak pit system.

Advantages

i. It is the simplest and cheapest method of household grey water management.
ii. Operation and maintenance cost is very low
iii. Vector borne diseases can be reduced, as there is little chance for mosquitoes to breed on stagnant water.

Disadvantages

i. In case of high volume of waste water released there is chance of overflow of soakage pit. In such case it creates more nuisance
ii. It may be suitable for sandy or sandy clay soil. For clay or black soil size to make it suitable pit size would be much larger. Such space may not have available at household level near the generation of waste water.

Chapter -3

3.1 Solid Waste Management in Rural Areas

Solid waste management in rural areas is perhaps the most neglected aspect of environmental sanitation**.** However, it is comparatively much easier to maintain solid wastes in rural areas than in urban areas.

A number of waste prevention techniques are available, and they are commonly summarized as popularly known as 4Rs: reduction, reuse, recycling and recovery. To overcome the problem of solid wastes, following steps need to be taken:

i. Wherever possible, waste reduction should be preferred.
ii. Every effort should be made to reuse produced wastes
iii. Recycling should be the third option for the wastes.
iv. There are several options for recycling. Such options should be selected taking in view social and economical acceptability.
v. Attempts should be made to recover materials or energy from waste which cannot be reduced, reused or recycled.

In rural areas most of the household contains organic wastes, with little quantity of inorganic wastes and it is completely free from toxic wastes. Due to organic nature of wastes, composting is the most suitable, sustainable and environment friendly method of recycling and reuse of solid wastes in rural areas. Composting of household wastes in rural areas is an age old practice. As per the information available in literatures, these are based on the practices adopted in field conditions. In recent years there has been improvement of composting by using systematic and scientific methods.

Principle of composting

Decomposition and stabilisation of organic waste matter is a natural phenomenon. Composting is an organised method of producing compost manure. Compost is particularly useful for organic matters. In rural areas there is higher percentage of organic matters making more applicability of composting technology.

Composting can be carried out in two ways i.e., aerobically and anaerobically. During aerobic composting aerobic micro-organisms oxidize organic compounds to Carbon dioxide, Nitrite and Nitrate. Due to exothermic reaction, temperature of the mass rises up to 65^0 C. During anaerobic process, the anaerobic micro organisms, while metabolising the nutrients, break down the organic compounds through a process of reduction. In this case temperature inside the heap does not raise much. The gases evolved are mainly Methane and Carbon dioxide.

Advantages of composting

i. Large amounts of vegetation, such as crop remains, garden weeds, kitchen and household wastes, hedge cuttings, garbage, etc, are put to use.
ii. When properly made, compost becomes immediately available as plant food without the need to be first broken down by soil microorganisms.
iii. Compost does not cause excessive weed growth, as is the case with ordinary farm manure.
iv. Good crops can be obtained without the need for extra chemical inputs.
v. All farmers, regardless of their financial abilities, can make and use compost.

Limitations for composting

i. Compost requires a lot of labour to prepare and spread it over the farm.
ii. The nutrient composition of the compost varies a great deal. It depends on the materials used and the preparation methods.

3.2 . **Technology options for composting of organic wastes**

There are following options of composting of wastes

I. **Pile Method of composting**
II. **NADEP Method**
III. **Bangalore method**
IV. **Indore method**
V. **Coimbatore Method**
VI. **Vermi composting**
VII. **Thermophilic Composting**
VIII. **Biogas Technology**

I. Pile method of composting

This method is suitable for areas with higher rainfall. For low-rainfall areas, pit method is more suitable. In this method composting materials along with animal dung are put in piles above the ground surface in a systematic manner to have better compost quality (Ranjith K. A. et. al. 2012, Nagavallemma et al **2006).** following method should be applied to make a pile of wastes for composting.

i. Composting site should be close to the household. The place should be sheltered from the rain, sun and runoff. Proper attention should be given to avoid compost site either very dry or very wet.

ii. Pile space should be 4 feet wide and 5 feet or more long. In rainy places, it is best to make compost in a pile above the ground.

iii. Dig a shallow pit about 1 foot deep. Put the soil on one side

iv. Begin building a compost pile by putting a bottom layer of one ft. of rough materials such as maize stalks and hedge cuttings in the pit. Larger parts of wastes should be cut into pieces before put in pile. Some water should be sprinkled on each layer to keep moisture level suitable for the growth of bacteria involved in composting.

v. Add a second layer of dry vegetation, hedge cuttings or grass. This layer should be about 6 inches thick. The pile should be moist throughout.

vi. Put on a third layer of animal manure or biogas slurry. The manure contains micro-organisms which are vital for decomposition.

vii. Sprinkle some ash or dust on this layer. The ashes contain valuable mineral including potassium, phosphorus, calcium and magnesium. The ashes also neutralize the acids produced during decomposition, especially by the animal manure.

viii. The next layer should be of green materials, about 6-8 inches thick. Use green leaves from high-protein leguminous trees.

ix. Sprinkle little water on topsoil or old compost. The topsoil contains bacteria which are useful in the decomposition process.

x. Add more layers in turn, starting with dry vegetative materials, then animal manure or biogas slurry, followed by wood ash, green vegetation and topsoil. Remember to sprinkle water on every layer. Build the pile up to 1.5 m (5 feet) high. A well-made pile has almost vertical sides and a flat top.

xi. To complete the pile, cover it all over with a layer of soil, about 10 cm (4 inches) thick. This layer prevents plant nutrients from escaping from the compost pile. Lastly, cover the whole pile with dry vegetation such as banana leaves to reduce moisture loss through evaporation.

xii. Take a long, sharp, pointed stick and drive it in at an angle so that it passes through the pile from top to bottom. This stick will act as your "thermometer". After three days, decomposition will have started in the pile, and the stick will be warm when you pull it out.

xiii. Sprinkle water on the pile occasionally (about every 3 days, depending on the weather). If it has been raining, it would not be needed to water the pile.

xiv. Distance between two piles is kept for 4 -5ft. to help turning the piles.

xv. After 2-3 weeks, turn the pile over. Turning the pile is important because it mixes the different layers, making the decomposition faster and more complete.

xvi. The compost should be ready after 8 weeks

II. NADEP Method

The NADEP method of organic composting was developed by a Gandhian follower namely NarayanDeotao Pandharipande of Maharastra (Pusad) (N.D. Pandharipande 2008). Compost can be prepared from a wide range of organic materials including dead plant material such as crop residues, weeds, forest litter, cattle dung and kitchen waste. Compost making is an efficient way of converting all kinds biomass into high value fertilizer that serves as good alternative to\ farmyard manure, especially for crop-growing households without livestock. In this method composting materials are put in layers (Fig 13)

Description

This method of making compost involves the construction of a simple, rectangular brick tank with enough spaces maintained between the bricks for necessary aeration (Figs. 14, 15). The size of the tank is 3m x 1.8 m or 3.6 m x 1.5 internally with 25 cm thick perforated brick wall all around in mud or cement mortar to a height of 0.9 m above ground. The above ground-perforated structure facilitates passage of air for aerobic decomposition. The floor of the tank is laid with bricks.

The tank is covered on top with a thatched roof. The ingredients for making compost are agro-wastes, animal dung and soil in the ratio of 45:5:50 by weight. The ingredients are

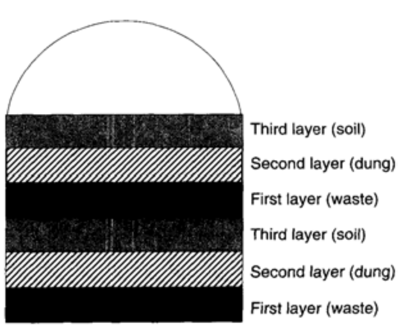

Fig 13

added in layers starting with vegetable matter, followed by dung and soil in that order. Each layer can be of about 45 kg vegetable matters, 5 kg of dung mixed in 70 lts of water and 50 kg of soil so that 30 layers will fill the tank. For Convenience, the number of layers could be reduced to half, this number the quantities of ingredients in each layer. After 15-30 days of filling the organic biomass in the tank gets automatically pressed down to 2 ft. The tank is refilled by giving 2-3 layers over it and is resealed. After this filling, the tank is not disturbed for about 3 months, when organic matters are almost completely degraded by the help of different groups of micro organisms. About 22-50 lts of water is to be sprinkled twice a week after the tank is fully loaded. After degradation, nutrients produced in the compost tank are absorbed by the soil layers thus preventing their loss. In some compost methods such nutrients especially nitrogen is lost in soil.

Fig. 14

Fig. 15.

One tank can be used three times in a year. With production of 3 tons to 3.5 tons of compost produced per cycle, about 9 to 10 tons of compost can be made annually from one tank. The compost can be stored for future use. It is advisable to sprinkle cultures like Trichoderma, Azatobacter, whenever available to enhance the composting process. It enhances nitrogen contents of manure.

It is necessary that a farmer should have at least 2 tanks so that when one is filled up the other one is available for loading the material generated in the farm.

Advantages of NADEP

In addition to have organic manure for its economical use and improvement of sanitation in villages, the NADEP method of composting has the following advantages:

i. It is very simple to construct and easier to operate.
ii. In this method, compost can be prepared with small quantity of cow dung (5Kg) and hence, it can be considered as appropriate rural model.
iii. Labour is required only for the construction and one time filling of the tank and excavation of manure. No labour is required during composting period for churning of wastes.
iv. There is no loss of plant nutrients in compost. Therefore, percentage of nutrients in manure is high in comparison to other composting methods.

Limitations with NADEP method

a. Filling of tank is cumbersome during the raining season,
b. Expenditure on transport of soil is high when the unit is away from the field. However, if the tanks are installed in the same field, where agro-wastes are generated and manure to be used, this is not a limiting factor.

III. Bangalore Method

Acharya (1939) had initiated the work of composting the town refuse and night soil. This process is also called ***Hot Fermentation Mechanism*** of composting or the **Bangalore method.** This is a pit method of composting where anaerobic condition is conventionally carried out in pits. Initially the waste is anaerobically stabilized in pits where alternate layers of organic wastes and animal dung is laid (Manual on municipal solid waste management – CPHEEO 2000). The pit method of making compost conserves moisture, so it is useful in areas with low rainfall and a long dry season. It should not be used in wet areas, as the compost may become waterlogged.

a. Dig a pit 4 feet wide and 2 feet deep,
b. Build a pile in the pit, using the same method as in the pile method.
c. Add little water, if necessary.

The pit is completely filled and a final soil layer is laid, to prevent fly breeding, entry of rain water into the pit. The material is allowed to decompose for 4 to 6 months after which the stabilised material is taken out and used as compost. The Bangalore method requires longer time for stabilisation of the material & hence needs larger land space. The gases generated in this anaerobic process also pose smell & odour problems.

IV. Indore Method

This process was developed by Howard and Wad in 1931 at Indore, Madhya Pradesh. In this method, waste materials such as plant residues, animal wastes, weeds, street refuse and other organic wastes can be composted. The waste materials are cut into small pieces and spread in layers of 10-15 cm thickness

either in pits or in heaps of 1 m wide, I m deep and of convenient length. It is properly moistened with cow dung using earth. To ensure *50* % moisture sufficient water should be sprinkled for making the composting materials moist. Periodically, three to four turnings are given. This method of composting in pits involves filling of alternate layers of similar thickness as in Bangalore method. For starting the turning operation, the first turn is manually given using long handled rakes, 4 to 7 days after filling. The second turn is given after 5 to 10 more days. Third turn is also given after 5-10 days. Further turning is normally not required and the compost is ready in 4-5 weeks. The Indore method on the other hand stabilizes the material in shorter time & needs lesser land space. As no odourous gases are generated in this process, it is environment friendly & hence commonly preferred. The composted material obtained by this method will contain 1.5 % nitrogen, 1.0 % phosphorus and 1.5 % potassium.

Advantages and Limitations

The Indore process is not one of the best method of composting due to the relatively high labour requirement and inadequate protection from rain, sun and wind. Loss of nutrients is rapid. Upper portion of heap gradually dries as a result of poor decomposition. However, this method can be applied by a farmer easily. No much technical inputs are required to complete the process.

V. Coimbatore Method

Coimbatore method is an anaerobic decomposition mathod. Size of the pit is normally 2m wide, 4 m length and 1 m depth. First crop residues as well as farm wastes, kitchen wastes are filled in pits to a thickness of about 15 cm. **A** five cm cow dung slurry is spread over this layer to increase its biodegradation. Over this layer 1 kg ground rock phosphate is applied to minimize nitrogen loss. In this way, application of farm waste crop residue, cow dung slurry and rock phosphate is applied in alternate layers, till the height reaches 0.5 m above ground level. After that the piled up material above ground is covered with soil or mud to prevent the entry of rain water. After 35 to 40 days turning of material is done to make it an aerobic process. Thereafter the compost will be ready within 4 to *5* months.

Advantages and limitations

There is no loss of nitrogen from the manure due to application of rock phosphate. Content of phosphorus is also increased. Churning of waste is done once only, thus minimising labour cost. Odour problem can't be avoided in this method, due to anaerobic condition there is chance of odour problem.

VI. Vermicomposting

Vermi compost is a natural compost of organic wastes through Earthworms,(Fig. 16) who take up organic wastes and after degradation and digestion, convert such wastes in the form of granules, rich in nitrogen content. Such vermin cast or vermin compost has good plant nutrients and therefore compost. This is a natural composting method being used in India and other countries for centuries. However, in recent years there has been systematic methods developed to enhance such composting by using improved methods and strains of earthworms in rural as well as urban areas in India also.

Fig 16

Advantages of vermicompost:

a) Vermi compost is rich in all essential plant nutrients.
b) Vermi compost is easy to apply, handle and store and does not have bad odour.
c) It improves soil structure, texture, aeration, and water holding capacity. Vermi compost contains earthworm cocoon and increases the population and activity of earthworm in the soil.
d) Vermi compost is free from pathogens, toxic elements, weed seeds etc.
e) Vermi compost minimizes the incidence of pest and diseases.
f) It enhances the decomposition of organic matter in soil.
g) It contains valuable vitamins, enzymes and hormones like auxins, gibberellins etc.

Nutrient content of vermin compost

Depending upon the types of substrate, contents of plant nutrients vary with vermin compost. However, a typical vermicompost has the following percentage of plant nutrients:

Nitrogen- 1.5 – 2.5 % Calcium- 0.5 – 1.0 %, Phosphorus- 0.9 – 1.7 % Magnesium- 0.2 – 0.3 % Potash- 1.5 – 2.4 % Sulphur- 0.4 - 0.5 %, and other micronutrients with enzymes and hormones.

Materials for preparation of Vermicompost:

Any type of biodegradable waste is suitable for vermicompost. Kitchen wastes, animal/ cow dung and leafy biomass are more suitable for vermicompost.

Efficient earthworm species:

The following species of earth worm commonly found in India are used for vermicomposting:

i. *Eisenia foetida*

ii. *Amyanthes diffrigens*

iii. *Eudrillus engineac*

Methods of preparation of pit for vermicompost

i. The vermicompost can be prepared in concrete tank (Fig 17) or in soil pit lined with plastic sheet (Fig.18). The size of the tank should be 10 ft. length or more depending upon the availability of land and raw materials, breadth 3- 5ft and height 3 ft.

ii. The available bio-wastes should be collected and are to be heaped for pretreatment for 4-5 days

iii. Sprinkling of cow dung slurry to the heap may be done.

iv. A thin layer of half decomposed cow dung (1-2 inches) should be placed at the bottom of the pit.

v. Place the chopped weed biomass and partially decomposed cow dung layer wise (10-20 cm) in the tank / pot up to the depth of 2 ½ ft. The bio waste and cow dung ratio should be 60: 40 on dry wt. basis.

Fig. 17

Fig. 18

vi. Release about 2 kg earthworms per tonne of biomass or 100 nos. earthworms per one sq. ft. area.

vii. Place wire net / bamboo net over the tank to protect earthworm from birds.

viii. Sprinkling of water should be done to maintain 70-80 % moisture content.

ix. Provision of a shed over the compost is essential to prevent entry of rainwater and direct sunshine.

x. Sprinkling of water should be stopped when 90 % bio-wastes are decomposed. Maturity could be judged visually by observing the formation of granular structure of the compost at the surface of the tank.

xi. Harvest the vermicompost by scrapping layer wise from the top of the tank and heap under shed. This will help in separation of earthworms from the compost. Sieving may also be done to separate the earthworms and cocoons.

Advantages of using Bio-fertilizer

i. Can replace 20 to 50 % of chemical fertilizer 'N' and 15 – 25 % of phosphatic fertilizers.

ii. Bio-fertilizers being cheap, provide highly cost effective supplement of chemical fertilizers.

iii. Increase farm productivity, generally 10-40 % in grain yield and 15 – 30 % in vegetable growth.

iv. Activates soil biologically thereby increasing natural fertility of soil, which causes sustainable agriculture.

v. Help in stimulating plant growth in general and roots in particular as they serve various growth promoting hormones like auxin, gibberellins etc. They help in better nutrient uptake and increase tolerance towards drought and moisture stress.

VII. Thermophilic Composting

Most of the technologies for composting are useful for plain areas where required surface for composting is available. In case of hilly and undulating areas, such composting methods are difficult to implement, as there is normally lack of such surface to make compost. Further, in hilly areas, ambient atmospheric temperature is generally not suitable for composting. To overcome such problems, the technology of Thermophilic Composting developed by Jha, P.K. (1999) is more suitable to make compost from any biodegradable wastes in hilly and cold areas. Thermophilic composting plant is made

Fig 19

up of double layer of G.I. sheet (Fig 19). A gap of 2 cm is provided between the two walls, which is filled with glass wool to insulate the plant. The plant has three chambers partitioned with two perforated plates. Each chamber has its own opening. Waste materials are put on upper two parts after pulverisation. Bottom chamber is used for storage of lechates. Depending upon the quantity of waste, size of the plant can be decided. However, the plant can be operated easily with a garbage of one tonne. In both the upper chambers there is provision of passing of air through a ½” pipe, where compressed air is passed into the plant to make aerobic condition inside it. Such aeration is done twice daily for three minutes each time only. Initially some natural occurring thermophilic bacteria are put on both the upper chambers. As the composter is fixed on wheels, it can be transported at the site easily where required.

Such bacteria are soil bacteria and can be easily obtained from existing land filled sites or where degraded garbage is located. Compost is produced within two weeks of operation only. Compost is taken out through the openings and can be stored in a pit to make it dry, till it is used for agriculture purpose.

Advantages

i. Thermophilic composting requires only 2 weeks to degrade wastes
ii. No manual handling of waste during composting
iii. Much less space is required
iv. Compost is pathogen free
v. It functions at low temperature also.
vi. Suitable for hilly and undulated areas where conventional composting methods are difficult to be implemented due to lack of required plain areas
vii. More suitable for fruit and vegetable markets, hostels, housing colonies, hilly areas etc.
viii. Inside temperature of plant rises to 60-65 degree Celsius within 48 hours, at such temperature thermophilic bacteria acts quickly to degrade wastes.
ix. At high temperature pathogenic bacteria die off making compost free from pathogens.
x. Liquid part, after decomposition, is collected at lower chamber. It has also plant nutrient value and can be used for agriculture / horticulture purpose. In conventional composting methods, such liquid may create ground water pollution.
xi. After the degraded waste is taken out from the plant, it is put into pits till further use.

A drawing of such plant is presented in Fig. 20

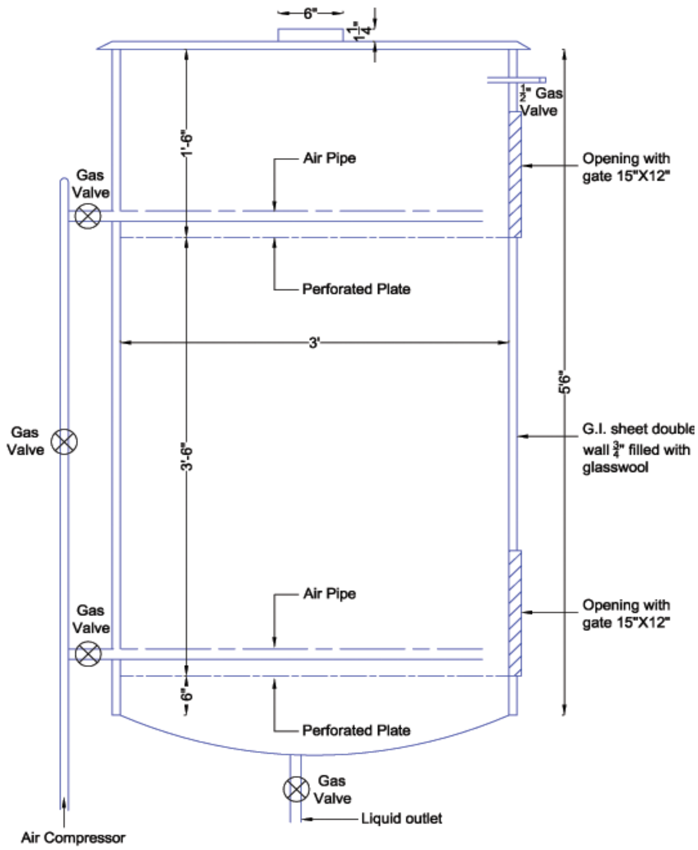

Fig. 20, Section of Thermophilic composter

Limitations of Thermophilic Composting

i. The cost of Theromophilic Composter is higher than the other systems

ii. Requirement of operation and maintenance of the system is more

VIII. Biogas Technology

Quantum of energy utilised is regarded as socio-economic status of any society. Due to lack of fuel, people in villages spend most of their valuable time to collect fire woods for cooking. In villages, most of the people use animal dung- cakes for cooking purpose. Such animal dung along with human wastes can be effectively used for biogas generation through on-site biogas plant linked with toilet. Biogas plant is important in providing sustainable energy sources in rural communities. Generation and utilization of bioenergy has multiple advantages. It helps improve sanitation, provide bioenergy at almost nil recurring expenditure and finally slurry / effluent of biogas plant has plant nutrient value to be used for agriculture purposes. Thus toilet linked biogas plant has additional benefits in terms of improving sanitation. In villages where household wastes contain mainly organics, they are also suitable for biogas generation. Such wastes can also be mixed in the same biogas plant to generate biogas production. In case of community toilets, biogas generation from human waste is sustainable option (Jha, 2005).

Biogas is a mixture of gas produced by methanogenic bacteria while acting upon biodegradable materials in an anaerobic condition. Biogas is mainly composed of 50 to 70 percent methane, 30 to 40 percent carbon dioxide (CO_2) and low amount of other gases. Biogas is an odourless and colourless gas that burns with clear blue flame similar to that of LPG gas.

Quantity of biogas production from different feed materials

- **a.** From animal dung- per animal, per day, around 10 kg dung is available. Gas production rate from dung is about 1.4 cft per kg, i.e., per animal per day, 14 cft biogas is produced.
- **b.** From per person per day 0.4 kg of waste is generated that produces 1.4 cft of biogas.
- **c.** A total amount of biogas of one cum can be produced per day from a family having 4 members and 2 cattle heads.

Utilizations of biogas

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

a) Cooking of 3-4 family members for two times a day

b) Mantle lamps (2nos.) can be used for 6 hours per 24hrs. Such mantle lamps gives illumination equivalent to 4o watt bulb at 220 volt of electricity.

Manure value of sludge from biogas plant

Besides biogas, the manure of the biogas plant has much 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 1)

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

Table 1

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 fall down to 10 degree Celsius 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. It has short working life. Manufacturing of gas holder requires sophisticated workshop facility that is rarely found in rural areas. Therefore, in rural or in urban areas the success rate of this model of biogas plant is far below the level of satisfaction.

Deenbandhu model. — This model is predominately found in India. It is an underground fixed dome digester made up of complete brick or RCC structure (Fig. 23). It is a permanent structure having almost nil operation and maintenance costs. There is no separate gas holder, biogas is stored inside plant through liquid displacement chamber. This design is suitable also for generation of biogas from human wastes along with cow dung and kitchen wastes. There is almost no effect of atmospheric variation of temperature on biogas generation during winter season. It has several advantages over the KVIC design. The following section describes different aspects of Deenbandhu biogas plant..

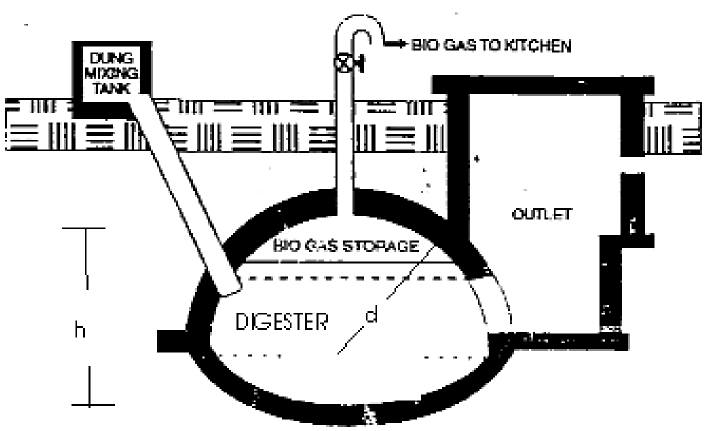

Fig. 23

Selection of site

Site of biogas plant should be selected properly, it should not be water logged and soil should be hard (high bearing capacity). It should not be constructed in a shaded area. Sunlight helps increase digester temperature therefore, production of biogas. Biogas plant should be as near to its use points- cooking and mantle lamps lighting. Longer the distance between biogas plant and its use will reduce gas pressure in gas pipe and hence will create problem.

Selecting a biogas plant size:

A biogas plant of specific capacity can be selected based on the daily availability of cattle dung, users of toilet (in case of toilet linked) and water requirements.

Materials required for biogas plant

The biogas plant can be set up with Bricks, Cement, Stone chips of 1/2" Coarse Sand, G.I. pipe 3/4" dia. sockets, 30 cm,, A.C./ PVC pipe 6" dia, Iron bars (6mm dia) for outlet tank cover, Paint (gas leak proof dibhapoxy), labour for digging pit, labour for construction, skilled masons, BG Stove, 10 m pipe line, lamp, accessories.

Components of a biogas plant:

Foundation

The foundation of the plant is bowl shaped with a collar around the circumference. The construction of the digester dome is based on this collar. Dome is divided in 2 parts, Digester & Gas storage. Digester: The bottom part is called the digester, where the mixture of dung and water passes through inlet chamber and anaerobic digestion by the help of different bacterial groups takes place producing biogas. Retention time of digester is kept normally as 40 days.

Gas storage: gas produced by the bacterial activity is stored in the upper part of the digester dome called gas storage. Capacity of the gas storage is designed for 50 % of the daily gas production capacity of the plant. However, as per requirement, gas storage capacity can be increased, depending on use of biogas.

Gas outlet pipe:

A nipple is fitted on the top of the dome, which is connected to a GI pipe of ½ inch. The gas reaches the kitchen through this pipe.

Inlet chamber:

Inlet is the point where cow dung is mixed with water before it passes to biogas plant through inlet pipe connected with chamber. .

Outlet chamber

Outlet chamber or liquid displacement chamber has two functions- it allows passage of effluent from the biogas plant and it determines the storage capacity of biogas plant.

Factors affecting biogas generation

Temperature

For optimum biogas production, a temperature of 35- 37^{0}C is optimum. At lower temperatures gas production rate decreases. In winter season when temperature falls to 10^0 C or so, gas production almost ceases. However, in case of underground fixed dome digester like that of Deenbandhu model, there is least affect on biogas production due to atmospheric temperature difference. This is due to the fact that digester dome is covered with soil that acts as insulator. It has least impact on inside temperature.

pH

The pH range suitable for biogas production is rather narrow i.e. between 6.6 to 7.5. A pH value below 6.2 (acidic slurry) and above 8.0 (alkaline slurry) becomes toxic to the bacteria.

Total solid concentration in feed material

Total solids in feed material is an important aspect. Around 8% TS is optimum for biogas production. In case of cow dung, this concentration is achieved after mixing cow dung with water in the ratio of 1:1, i.e., 10 kg of cow dung is mixed with 10 lit. of water.

Testing the digester;

The digester of the Deenbandhu plant on completion is tested before commissioning through smoke test for detecting gas leakages. Smoke producing material is burnt inside the digester and thereafter all vents of the digester are closed and checked for leakage. Any section of the dome emitting smoke is identified and can be sealed.

Hydraulic testing for water leakages is done by filling half of the digester with water and marking the level. Thereafter, after a period of 6 to 7 days, the water level is rechecked. In case of leakages the water level will go down.

Starting a digester with feed material;

Initial digestion process with cattle dung feed should start within few weeks depending upon the temperature. If available, effluent (5-10%) from a running biogas plant should be added to new biogas plant once at the start as an inoculums. Cow dung itself contains a lot of mathanogenic bacteria, therefore, in case of unavailability of working biogas plant and its effluent, biogas production will continue.

Uses of biogas for cooking

Common uses of biogas are for cooking and lighting through mantle lamps. Biogas cooking burners are available in markets (Fig. 24). A cooking burner consumes 8-24 cft of biogas per hour depending on its size. Biogas burns in blue flame without any shoot or odour like LPG. It contains around 1 % hydrogen sulphide that has pungent odour, but Fig. 24. for cooking during burning there is no such odour at all such odour is useful to detect any leakage of biogas due to loose connection of pipe etc. In rural areas where people are mostly dependant on fire wood or dung cake for cooking purpose, biogas is a boon in improving health, environment and is economical.

Lighting through mantle lamp is another common use of biogas (Fig 25). Such mantle lamps are available in markets. A Mantle lamp consumes 2-3 cft of biogas per hour. It gives illumination equivalent to 40 watt bulb at 220 volt of electricity. In rural areas in most of the families students can't study in night due to unavailability of electric supply and high cost of kerosene oil, biogas is a sustainable option and boon for such communities

Fig 25.Biogas mantle lamp lighting

Do's and Don'ts

Do's

i. Select the size of the biogas plant depending on the quantity of dung available with the beneficiaries.
ii. Install the biogas plant at a place near the kitchen as well as the cattle shed as far as possible.
iii. Ensure that the outer side of the plant is firmly compacted with soil.
iv. Ensure that the plant is installed in an open space, and gets plenty of sunlight for the whole day, all round the year.
v. Feed the biogas plant with cattle dung and water mixture in the right proportion-add 1 part of cattle dung to 1 part of water by weight to make a homogeneous mixture.
vi. Ensure that the slurry (mixture of dung and water) is free from soil, straw, etc.
vii. For efficient cooking, use good quality and approved burners and gas lamps.

viii. Open the gas regulator cock only at the time of its actual use.

ix. Adjust the flame by turning the air regulator till a blue flame is obtained, this will give maximum heat.

x. Light the match first before opening the gas cock.

xi. Cover the top of the inlet and outlet tank opening with wooden, stone or RCC cover, to avoid accidental falling of cattle and children.

Don't do

i. Don't install a bigger size of biogas plant if sufficient cattle dung or any other feed-stock to be used for biogas production is not available.

ii. Don't install the gas plant at a long distance from the point of gas utilisation to save the cost of pipeline and loss of biogas.

iii. Don't install the plant under a tree, inside the house or under shade.

iv. Don't add more than required quantity of either dung or water-doing so might affect the efficient production of gas.

v. Don't leave the gas regulator (valve) open when the gas is not in use.

vi. Don't inhale the biogas as it may be hazardous.

vii. Don't allow soil or sand to enter into the digester.

viii. Don't use the gas if the flame is yellow. Adjust the flame by the air regulator till it is blue in colour.

ix. Don't use the gas after initial loading of slurry, as it may take 15- 25 days for gas production in freshly loaded plants. No foreign material should be added.

x. Don't let any water accumulate in the gas pipeline; otherwise the required pressure of gas will not be maintained and the flame will not be proper.

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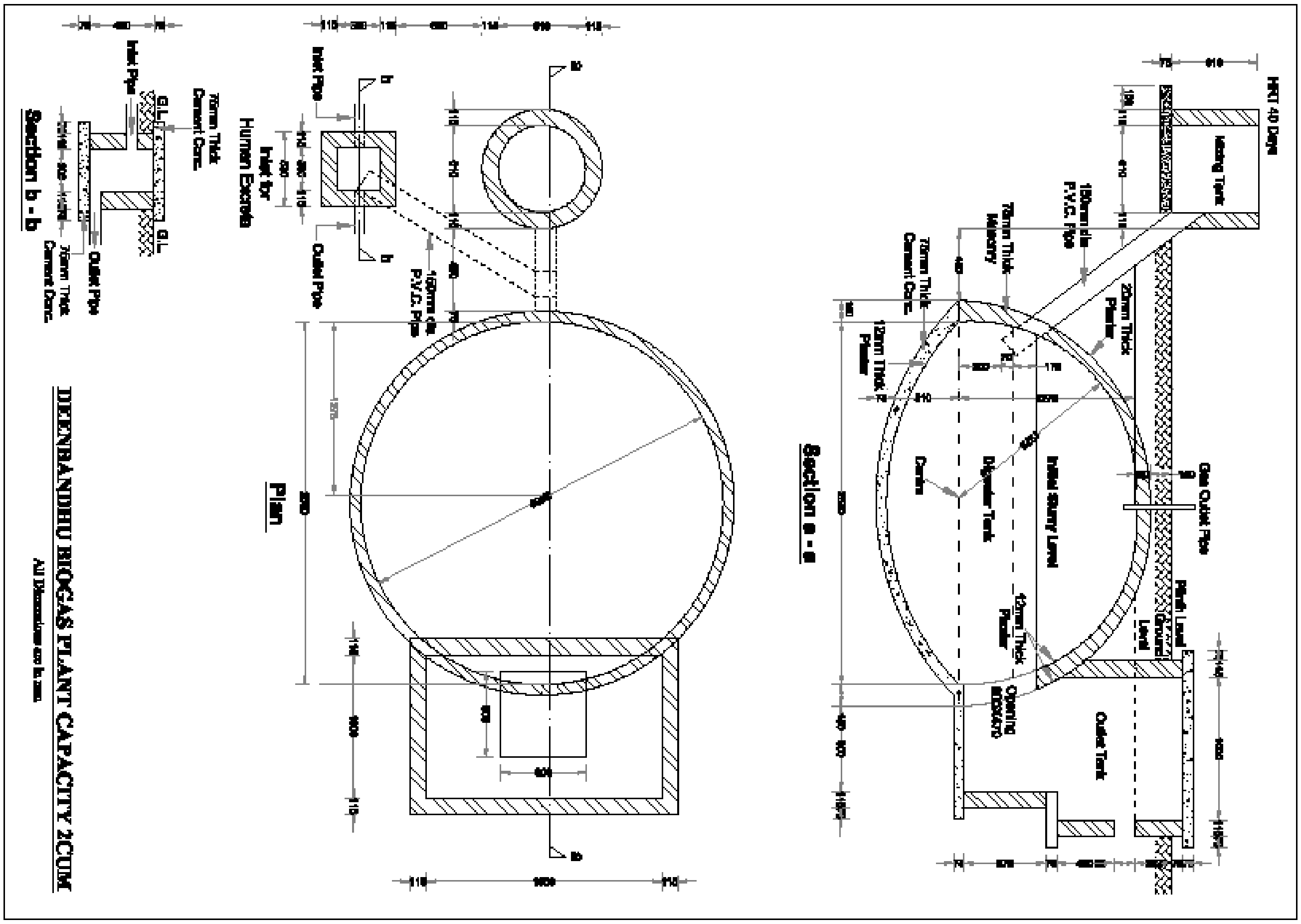
Annexure-I

A Drawing of 2 cum Biogas Plant linked with Toilet



Annexure –II

Bill of Quantity of 2 cum biogas plant linked with toilet

Sl. No.	Item	Unit	Qty.
1.	Earth work in excavation by mechanical means (Hydraulic excavator) / manual means in foundation trenches or drains (not exceeding 1.5 m in width or 10 sqm on plan) including dressing of sides and ramming of bottoms, lift upto 1.5 m, including getting out the excavated soil and disposal of surplus excavated soil as directed, within a lead of 50 m. All kinds of soil	cum	12.12
2.	Providing and laying in position cement concrete of specified grade excluding the cost of centring and shuttering - All work up to plinth level: 1:2:4 (1 cement: 2 coarse sand : 4 graded stone aggregate 20 mm nominal size)	cum	0.29
3.	Brick work 7 cm thick with F.P.S. brick of class designation 75 in cement mortar 1:3 (1 cement: 3 coarse sand) in superstructure.	sqm	11.45
4.	Half brick masonry with F.P.S. brick of class designation 75 in foundations and plinth in Cement mortar 1:3 {1 cement: 3 coarse sand)	sqm	11.12
5.	Centring and shuttering including strutting, propping etc. and removal of form for Arches, domes, vaults up to 6 m span	sqm	13.01
6.	Reinforced cement concrete work in walls (any thickness), including attached pilasters, buttresses, plinth and string courses, fillets, columns, pillars, piers, abutments, posts and struts etc. up to floor five level excluding cost of centring, shuttering, finishing and reinforcement 1:2:4 (1 cement : 2 coarse sand : 4 graded stone aggregate 20 mm nominal size).	cum	0.21
7.	Reinforcement for R.C.C. work including straightening, cutting, bending, placing in position and binding all complete Mild steel and Medium Tensile steel bars.	Kg.	16.50
8.	20 mm cement plaster of mix : 1:4 (1 cement: 4 coarse sand)	sqm	11.45
9.	12 mm cement plaster 1:3 (1 cement: 3 coarse sand) finished with a floating coat of neat cement.	sqm	31.62
10.	12 mm cement plaster of mix : 1:4 (1 cement: 4 coarse sand)	sqm	12.61
11.	Providing and fixing 150 mm dia PVC pipe	R mt	6.00
12.	Providing and fixing single equal plain invert branch of required degree:150x150x150 mm	Each	1.00
13.	Providing and fixing gas outlet fitting	Each	1.00
14.	Finishing with Epoxy paint (two or more coats) at all locations prepared and applied as per manufacturer's specifications including appropriate priming coat, preparation of surface, etc. complete On concrete work	sqm	11.28