



उत्तर प्रदेश प्रदूषण नियंत्रण बोर्ड
UTTAR PRADESH POLLUTION CONTROL BOARD

87

Ref. No. 472720

सी-6/सामान्य-634/ओ०ए० नं० 170/2021/

Dated 11-3-22

To,
The Registrar General,
Hon'ble, National Green Tribunal,
Copernicus Marg,
New Delhi

Sub: Regarding submission of Compliance Report in compliance of the order dated 29.10.2021 in OA no. 170/2021, In the matter of Nooral Sehar Lari Vs State of U.P. and Ors.

Sir,
Kindly refer the subject mentioned above. In compliance of the order dated 29.10.2021 in OA no. 170/2021, In the matter of Nooral Sehar Lari Vs State of U.P. and Ors, the compliance report is enclosed herewith for your kind perusal and further necessary action.

Sincerely Yours,

Enclosures: As above


(R.K. Singh)

Chief Environment Officer
(Circle-6)

Copy to: Following for information and further necessary action.

Shri Pradeep Misra Advocate, Supreme Court, B-235, Sector-XIX, Noida, District-GB Nagar, 201301.


Chief Environment Officer
(Circle-6)

**REPORT
PLACED BEFORE HON'BLE NATIONAL GREEN
TRIBUNAL(NGT), NEW DELHI**

OA No. 170 of 2021

In the matter of Noorul Sehar Lari V/s State of U.P. and Ors.
other connected matters,

01. Background

Taking note of discharge of untreated sewage at Lar, District Deoria, UP in open on-land having Khasra No. 1712 with area of 0.1980 hectares, Hon'ble NGT ordered on 29.10.2021. The verbatim of the relevant para of the order is mentioned below:

".....Accordingly, let a five member joint Committee of Regional Officer of CPCB, Lucknow with one nominee of CPCB from Delhi, an officer of State PCB of the rank of Chief Engineer, an officer of the rank of Chief Engineer of the Public Health Department and a Chief Engineer of the Department of Rural Development nominated by Additional Chief Secretary, Rural Development, UP undertake visit to the site to ascertain the compliance status and recommend a model which may be helpful for tackling the problems of septage management at such small places such as places with less than one lac population. They will be free to co-opt any other Expert/Institution. The State PCB will be nodal agency for compliance. The Committee may meet within 15 days and undertake visit to the site...."

02. Action Taken

In compliance of the referenced Order, efforts were made by UPPCB to constitute designated Committee. In spite of exhaustive efforts made, nomination of member from Department of Rural Development and Department of Public Health could not be received (as on 12.11.2021). In strict compliance of the referenced Order, meeting of nominated

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members of CPCB and UPPCB was convened on Nov. 12, 2021. However, with limited nominations received the meeting ended with recommendation to expeditiously follow up with the concerned Departments for nominations and ensuring further Action.

Further, having made exhaustive efforts, committee of following members could be constituted:

1. Dr R.K.Singh, Regional Director, CPCB RD Lucknow
2. Dr Ramgopal, Chief Environment Officer, UPPCB HO Lucknow
3. Sh Rakesh Tripathi, Superintending Engineer, Medical and Health Services, Lucknow, UP,
4. Sh Vishal Gandhi, Scientist 'D' CPCB, Head Office

(Member, Department of Rural Development could not be nominated)

The Committee carried out on-site surveillance visit to Lar Township, District Deoria, hereinafter referred as the "Subject Area" on Dec. 21, 2021 and interacted with representatives of concerned departments next day i.e. Dec 22, 2021 at Deoria. During on-site surveillance, the Committee carried out following activities:

- A. Interaction with local residents in the subject area
- B. Survey of the drain (Ghata 1724), adjoining area (Ghata 1712) and other localities in the subject area
- C. Monitored bioremediation activities in the drain referred above
- D. Collection of drain water (sewage) sample at three locations in its stretch viz. before, middle and after the bioremediation activity for evaluation of the efficacy
- E. Visit to Fani Tola (waterlogged area of Indiranagar ward) to and R. Chhoti Gandak to take a first-hand status of drainage and sanitation scenario in the subject area

03.Observations

A. Based on physical verification on-site during the visit, the Committee reviewed the status of action taken Report dt 20.09.2021 filed by the (earlier) designated Committee constituted vide Hon'ble NGT Order dt 20.07.2021. The updated status is summarized as per below:

S.No	Action Point	Status as on 21.12.2021
1.	In question Gata number: 1712, (area 0.1980 hectares), at present, the dumping of drain water by the Nagar Panchayat Lar has been completely stopped.	The flow of the drain (uncovered) has been diverted to nearby open private land and the flow gets accumulated without any drainage/dilution. As such the drain was observed to be with very feeble flow and with occasional lumps of garbage
2.	In revenue record Gata no. 1724 is recorded as Nala, passes besides Gata No. 1712. Which was half pucca and the rest was kachha. Due to overflow in raining season sometimes overflow in Gata no. 1712. But now the remaining part of 1724 which is not pucca got deepen and all measures taken so that it will not overflow in all the surrounding land.	
3.	The water of the drain is not being dumped in any natural flow.	
4.	The flow of solid waste is being stopped by putting a net in the drain.	The iron mesh has been introduced in the drain for stoppage of solid waste.
5.	For preliminary purification of drain water, bleaching powder is being cleaned.	Reported as being done. Could not be verified during the visit
6.	The water from the drain is being treated by the process of bioremediation, being dropped in Gata No: 1724. So that the ground water does not get polluted.	As an interim measure Bio-remediation has been introduced in the drain. The remediation is executed by dosing of (active) culture of microbes claimed to achieve treatment. Microbial culture is filled in the drums placed on

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		the edge of the drain and droplets of the culture keep dosing in the flowing drain water (sewage). The process is executed by M/s Maple Argtech India Ltd, Kolkata. Samples of drain water (sewage) were collected and analyzed in UPPCB Central Laboratory, Lucknow. Result of sample discussed ahead in the Report
7.	Sewer water is not being discharged in the drain in question, nor is there any sewer line in the Nagar Panchayat Lar. Septic tank, is used for domestic toilet in Nagar Panchayat Lar. A survey conducted and from 13 persons discharging sewer in open drain. Now septic tank made and now no flow of sewerage in Nala.	The Committee observed flow in the drain. The characteristics (discussed ahead) of the sample tested reveal that inflow of sewage cannot be completely ruled out
8.	In the order of the directions of Hon'ble National Green Tribunal, on 03.08.2021, a meeting was held under the chairmanship of Additional Chief Secretary, Urban Development Department, Uttar Pradesh Government, Lucknow. In the meeting an instructions given to the District Magistrate, Deoria to form of committee for survey in questioned area by Letter No. 791/(1-7) LBC-2021, dated 03.08.2021. The committee submitted its report to District Magistrate Deoria on 10.08.2021. (Annexure-1) After then a meeting of the District Environment Committee was held on 11.08.2021. In which the report of the committee constituted by the District Magistrate was read out and it was decided that the problem which has been raised by Nurul Sehar Lari, resident Nagar Panchayat Lar Deoria, before Hon'ble NGT, for its solution, by	Status apprised in S.No. 06 & 07

	Nagar Panchayat Lar. By taking the land on lease, the water of the drain in question should be treated by bioremediation process and it should be ensured that the sewage water does not fall directly into the drain.	
9.	In compliance of the above, quotations have been invited from firms/agencies for adopting bioremediation process for water purification of the drain in question, for temporary solution of the problem. In which the quotations of Maple Argtech, Aqua Infratech, Sri Sai Construction have been received. In which the lowest rate has been presented by Maple Argtech, for which the work order has been issued. Water purification work has been started by the firm through bioremediation process. At present, the water of the drain in question is going through Fani Tola (waterlogged area of Indiranagar ward) to Chhoti Gandak, river via Ropan Chhapra Tal. The water flow of Fani Tola stops rest of the rainy season. In such a situation, under the temporary arrangement, has been made to discharge treated water in Gata No. 1724 of Nagar Panchayat Lar, which is recorded as a drain in the revenue record.	Status apprised in S.No. 01,04,06 & 07
10.	Consent has been obtained to take the water of the drain in question on lease for dumping it under short-term arrangement in Gata No. 1603, 1604, and 1748, which is the land of the cultivator. For this, the survey work has been completed by the Construction and Design Services (C&DS) Unit-14 Gorakhpur, to divert the drain in question to the above mentioned number. The design and detailed estimate is being prepared. Which will be sent to the Uttar Pradesh government for the allocation of funds as soon as possible.	Design details are ready for submission by C&DS. Lar Nagar Panchayat is scheduled to forward consolidated proposal to Dept of Urban Development, UP State for provision of funds (As reported by Executive Officer, Lar Nagar Panchayat)

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B. The Committee was apprised by the Executive Officer (EO), Lar Town, that the flow of the drain (In question Gata number: 1712) has been diverted to nearby open private land and same gets inundated as pond. As informed by EO, Lar, the said drain carries 25 % of cumulative wastewater generation of the subject area.

C. The analytical results of drain water (sewage) mentioned in report of sub-committee dated 10.8.2021 depicted BOD- 52 mg/l and COD-280 mg/l. This is indicative of mixed flow of (digested) wastewater from septic tank and other domestic wastewater (Kitchen and bathroom).

D. The characteristics of Sample collected from the drain are mentioned below:

Location of sample	Parameters*						
	pH	TSS	TDS	Nitrate	COD	BOD	Fecal Coliform
10 meter before (u/s) Bioremediation	6.90	40.0	882	1.95	146.0	37.0	1300000
05 meter After (d/s) Bioremediation stage -1	7.01	36.0	904	2.08	123.0	34.0	1100000
10 meter after (u/s) Bioremediation stage-2	7.05	38.0	914	2.18	118.0	30.0	790000
Standards Schedule-VI, E(P) Rules 1986	5.5-9.0	100	-	-	250	30	-

*Fecal Coliform in MPN /100 ml; all others except pH, in mg/l

Note: u/s : Upstream; d/s : Downstream

E. The above characteristics reveal following observations:

1. The water quality of drain shows that it still carries mixed flow of digested wastewater from septic tank and other domestic

wastewater. Although the quality appears diluted and conforming to the standards, yet in absence of dilution and long-term accumulation may lead to adverse impact on-land and unhygienic conditions in a thickly inhabited locality.

2. The system of Bio-remediation introduced has been very unorganized in the sense that there is no system of dose regulation and homogenization for ensuring its uniform application. It can not bear any shock load in terms of any accidental spill / discharge in the drain.
3. The dosing drums are open-to-sky amounting to any possible dropping of untoward object, rainwater or incident of their insecurity.
- F. Lar, Town as such is a low-lying area and there is no proper drainage system. The wastewater usually gets inundated in vacant plots such as plots no. 1209, 2801 and 2802. Further, there is no discharge point for excess flow especially during monsoon. Storm water also finds its way into said plots and overflow of pond occasionally reaches inside houses adjoining such areas of inundations.
- G. With population of 28360 as per 2011 census (current 33,994 projected as per growth pattern, as per Lar Nagar Panchayat) the cumulative sewage generation of the subject area is estimated at 3.6 MLD. It is reported that majority of household have septic tanks and overflow of septic tanks and other domestic wastewater is discharged through local drains.
- H. The septage waste of septic tanks are cleaned through suction machines available with Nagar Panchayat Lar. However, with no provision for treatment of septage waste, the septage waste is indiscriminately discharged on-land / flow through drains and gets accumulated in ponds dotting the town.

4. Conceptual Plan

With the approach of suggesting the wastewater and septage management for small size towns typical of the subject area, it is pertinent to come out with a concept of sewage and septage management with minimum power requirement, low cost and easy maneuverability. In specific case of the subject area, the hydraulic and organic load of wastewater, terrain / geography and practices of sewage management, it is recommended that Nagar Panchyat Lar should adopt best economical practices of sewage management as per the guidelines / manuals of Ministry of Housing Urban Affairs (MoHUA), Govt. of India.

MoHUA has issued National Policy on Fecal Sludge and Septage Management and manual on Sewerage and Sewage Treatment Systems in cities with less than 1 lakh population. MoHUA guidelines developed under Swachh Bharat Mission are available to ensure that no untreated fecal sludge or used water is discharged into the environment. The used water (including sewerage and septage, grey water and black water) is safely contained, transported and treated, along with maximum reuse. Further, MoHUA has a provision for funding under the following scheme/ interventions:

1. Desludging equipment, for scheduled and need-based desludging of all septic tanks;
2. Interception and diversion of drains (I&D) (including last mile connectivity for nearest sewer network);
3. Construction of Fecal Sludge Treatment plants (FSTPs) for used water treatment.

In view of above facts, sewerage management plan for Nagar Panchyat Lar can be formulated with following suggestive approach :

1. To start with, Nagar Panchyat Lar must ensure that the design of septic tank at each households conforming to guidelines of CPHEEO.

(**Annexure-I.**). Such approved designs shall not only provide a basic tool for sewage/septage treatment, but also ensure proper (primary) digestion of fecal sludge/septage as a pre-requisite for its environment friendly disposal.

2. Further, Manual on Sewerage and Sewage Treatment Systems published by Central Public Health and Environmental Engineering Organization (CPHEEO), Ministry of Housing and Urban Affairs, Govt. of India, has envisaged Onsite sanitation system wherein, design of septic tank as per user requirement are defined.
3. Septage waste of septic tank is required to be managed as per National Policy on Fecal Sludge and Septage Management.
4. Regular cleaning of septic tanks through a systematic extraction and collection procedure is essential to check environmental pollution. The frequency of cleaning is determined by the desired performance of the OSS (Onsite sanitation) system for the local conditions.
5. Collected septage waste shall be disposed off either into nearby Sewage Treatment Plants (STPs) or in the present case of the subject area into (proposed) Fecal Sludge Treatment Plant for further treatment and safe disposal. Treatment and Disposal techniques of Septage waste are discussed in manual of Sewerage and Sewage Treatment Systems (**Annexure-II.**)
6. For treatment of septic tank's combined overflow and other domestic wastewater, Waste Stabilization Pond or Decentralized Wastewater Treatment System (DEWATS) are recommended.

7. The natural Ponds which are typical of the subject area, given its flat(gentle) topography, can be exploited for the purpose of Waste Stabilization. Such an attempt can start with two / three major ponds in the town (described above).

8. Waste Stabilization Ponds (WSPs) are large, man-made water bodies in which blackwater, greywater or fecal sludge are treated by natural processes under the influence of sunlight, wind, microorganisms and algae . Such ponds can be used individually, or linked in a series for improved treatment. There are three types of ponds, (a) anaerobic, (b) facultative and (c) aerobic (maturation), each with different treatment and design characteristics. WSPs are noted with their low Operation and Maintenance cost and high removal of BOD and pathogens. However, large surface areas and proper design are a pre-requisite.

9. Another self-driven system (referred in S.No. 07 above), is DEWATS system. This system is recommended for isolated habitations typical of the subject area, where there is a need for non-mechanized and self-operating treatment technology, given the premise that adequate land area is available. This system requires to group the toilets or at least bring the sewage from the various centers to the DEWATS facility. The typical treatment in the facility includes :
 - i. Pre-treatment settler: retention time of about 2 hours; BOD reduction by about 30%
 - ii. Anaerobic Baffled Tank Reactor: retention time of about 24 hours; BOD reduction by about 80%
 - iii. Anaerobic filter: retention time of about 8 hours; BOD reduction by about 90%
 - iv. Planted gravel filter: retention time of about 36 hours; BOD reduction by about 90%
 - v. Polishing pond

Specific design details of WSP and DEWATS can be referred (**Annexure-III**)

10. For the sake of taking reference to operational systems working on the above suggested technological interventions, case study of Neela Hauz and Rajokri Lake in Delhi may be referred, which work principally on DEWATS / WSP system. In both the cases, weak sewage of small region is collected and provided with the treatment through self-driven natural system and treated water is stored in low-lying area to form lake / pond which may be further developed as a recreational facility. Specific details of case study of Neela Hauz and Rajokri Lake also mentioned in CPCB's Published Document (*Report on Alternate Treatment Technologies for wastewater in drains*). Relevant portion of report is attached (**Annexure-IV**). Additionally, suggestive treatment options specific for the subject area, suggested by CPHEEO, are appended in **Annexure-V**

05. Recommendations

- A. Initiate a drive to restructure design of septic tank of each households conforming to CPHEEO Guidelines
- B. Nagar Panchyat Lar shall ensure that proper drainage system is designed for open drains carrying domestic sewage / storm water / septic tank overflow generated in different parts of the town upto the natural ponds designated in the subject area.
- C. Nagar Panchyat Lar should ensure that system is in-place and functional for an organized and periodic collection of septage through geotagged suction machine. The septage waste as a contingent option, can be disposed at nearby STP at Deoria. Till the

time, STP at Deoria gets commissioned, septage waste of Lar can be disposed in low -lying and lined pit, suitably located.

- D. Plot no. 1209, 2801 and 2802 which are natural ponds collecting domestic waste water (Sewage) from different parts of the subject area shall be considered for execution of Conceptual Plan in the First Phase as system of self-driven, low-cost and with least energy input mechanism of sewage treatment. These ponds can be developed as decentralized system for sewage treatment provided with system (sectors) for anaerobic digestion, gravel-bed-filtration, phyto remediation and natural oxidation. The final treated waste water stored (in ponds) can be used for recreation by proper landscaping. All the sectors / unit of treatment shall be designed to ensure gravitational flow, thus minimizing use of (electrical) power. A working example similar to the Conceptual Plan proposed above, can be referred at Neela Hauz and Rajokri Lake, Delhi.
- E. A natural drainage system be developed to carry over-flow of these ponds in monsoon season, leading ultimately to River Choti Gandak, a perennial river at appx 03 km from the subject area. For specific detail on design, policy issues and financial support, the Nagar Panchayat Lar may opt for a professional agency of repute and refer following documents and take assistance from MoHUA:
- (a) National Policy on Fecal Sludge and Septage Management
 - (b) Manual on Sewerage and Sewage Treatment Systems of CPHEEO
 - (c) MoHUA's Operational Guidelines on SBM Urban 2.0
- F. Conceptual plan of the suggestive approach is appended in **Annexure-VI**

G. Once the system is found feasible, optimized and delivering the expected outcome, it can be replicated to other natural ponds in the township.

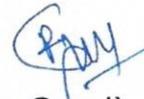
H. Financial assistance for execution of concept suggested above can be executed with the assistance of MoHUA under Swachh Bharat Mission (Urban) 2.0.



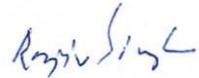
(Rakesh Tripathi)
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Health Services,
(UP) Lucknow**



(Vishal Gandhi)
**Sc.'D' CPCB,
Head Office**



(Ram Gopal)
**CEO
UPPCB,
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(Dr. R.K. Singh)
**Regional Director,
CPCB, RD, Lucknow**



MANUAL ON SEWERAGE AND SEWAGE TREATMENT SYSTEMS

PART A: ENGINEERING
THIRD EDITION - REVISED AND UPDATED

MINISTRY OF URBAN DEVELOPMENT, NEW DELHI
<http://moud.gov.in>

**CENTRAL PUBLIC HEALTH AND
ENVIRONMENTAL ENGINEERING ORGANIZATION**

IN COLLABORATION WITH



JAPAN INTERNATIONAL COOPERATION AGENCY

NOVEMBER 2013

CHAPTER 9: ON-SITE SANITATION**9.1 OVERVIEW OF ON-SITE SANITATION**

The areas that are not served by piped sewer systems can adopt on-site systems. The treatment can be either on-site or off-site like in the case of septage management. These are interim measures till a decentralised or a full sewerage system is implemented.

It is strongly recommended that the town planning agencies / authorities / ULB / metropolitan development authorities earmark adequate spaces for laying of sewer lines, construction of SPS and STP.

9.1.1 On-site Sewage Treatment System

Unlike off-site centralized treatment (sewerage), on-site sewage treatment features individual and distributed treatment. The on-site treatment system includes a wide range of facilities, such as a basic sanitation facility like a pit latrine, a simple sewage treatment system that consists of a septic tank and a soak pit for anaerobic treatment, and an advanced facility like Johkasou that treats sewage by sophisticated methods.

In an urban area with high population density, an STP intensively treats sewage collected by pipes laid over a wide area. The on-site system treats sewage near the source.

Accordingly, the latter uses various kinds of treatment technologies according to treatment scale and the surrounding conditions. Sludge generated in each on-site treatment facility is collected and treated separately.

9.1.2 On-site Classification

This subsection summarizes the classification of toilets and on-site treatment methods as well as their features.

9.1.2.1 Historical

The historical pit latrines are rather rudimentary sanitation facilities at least serving to contain the spread of faecal organisms from the night soil and bringing about interactions between soil organisms and faecal organisms in the pit. These have since been upgraded to various types as in Figure 8.3. In respect of community toilets, installations such as Dewats have also come up.

9.1.2.2 Simple Treatment Method

A septic tank system is a typical on-site treatment facility that consists of a septic tank and a soak pit and employs two technologies: the first is anaerobic treatment and the second is the methods of letting treated sewage penetrate the ground.

It shows stable performance, provided that the water temperature is kept suitable to digestion and the soil has good permeability.

However, the septic tank reduces BOD up to 50%, so if underground penetration is impossible due to high groundwater levels, rocky strata, non-availability of land for soak-pit, another method must be employed to hygienically treat sewage passing through the septic tank such as anaerobic filter and contact aeration. When this system is applied to an urban area with high population density, care must be taken not to have a negative effect on the surrounding environment.

9.1.2.3 Advanced Treatment System

Conventional septic tanks system, if properly designed and with proper septage removal frequency can effectively remove about 40-50% BOD and 50-70% TSS. However, due to partial treatment and associated health hazards the effluent can only be discharged into soak pits. Due to recent groundwater pollution related episodes, unavailability of space for soak pits and under rocky strata, soak pits are avoided and the effluent is commonly discharged to open stormwater drains. Hence, it is causing another type of pollution menace such as unsightly conditions, eutrophication, odour, vector and water related diseases.

Some of the interim solutions are the improved design of septic tanks such as anaerobic baffled reactor or the post treatment of septic tank effluents by anaerobic filters. Both configurations can partially solve the pollution related problems by increasing the overall BOD removal to more than 70%. These systems can lessen the burden of organic pollution without any extra energy cost. The capital cost of these systems may not be more than 20-30% of the conventional septic tank cost. Nevertheless, due to the limitation of anaerobic sewage treatment, these systems cannot bring down the BOD and TSS levels up to the national effluent discharge standards. Hence, alternate solution could be the aerobic type post treatment such as contact aeration. This system can bring down effluent BOD to less than 30 mg/l and TSS to less than 50 mg/l but at the expense of electrical power requirement for 24×7 operating air blower with standby equipment and standby power.

One such system is the Japanese type Johkasou system. This system is an integrated septic tank-anaerobic filter-contact aeration-final settling tank and effluent disinfection facility. However, due to higher cost considerations, these systems may be affordable only in very fragile environment. These systems have also been upgraded for even nitrogen removal by providing internal recirculation. The detail of these systems is provided in the following sections. There are many other similar package treatment systems elsewhere that can also be used.

9.2 THE PROHIBITION OF EMPLOYMENT AS MANUAL SCAVENGERS AND THEIR REHABILITATION ACT, 2013

The aforesaid act was notified by the GOI in September 2013. The act shall come into force from 6th December 2013. The text of the act as in the Gazette is in Appendix A 1.1. The time frame specified under the Act for the fulfilment of responsibilities and carrying out certain activities are mentioned in Appendix A 1.2.

9.3 INTERIM MEASURES

There are various on-site systems which can be used but with a caution to prevent ground water and surface water pollution due to indiscriminate disposal of sewage from these on-site systems.

9.3.1 Public and Community Toilets

A public toilet, a kind of common toilet installed in stations and on streets, is open to everyone rather than specified users. In contrast, a community toilet has limited users such as residents. These common toilets are controlled by local governments, residents, or private sector organizations. A common toilet normally has two sections: one is for males and the other is for females. In addition, another section special to persons in a wheelchair (unisex) is sometimes provided.

In general, an on-site common toilet includes a special sewage treatment facility such as a septic tank. The flow rate of sewage to be treated is derived from the total number of users based on how many toilet bowls are installed and how frequently they are used.

The toilet is equipped with a water supply unit, a ventilator, and a lighting device. Figure 9.1 shows example arrangements of faeces, urine, and hand-washing units.

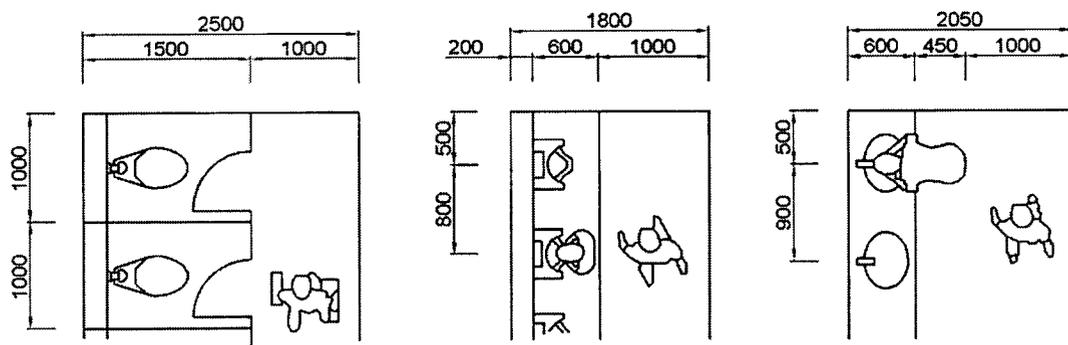


Figure 9.1 Examples of common toilet arrangements

Example of design

The following shows an example of estimating the number of public toilet users.

Basic Setting

Number of toilet bowls [c]: 10 (in total)

Total number of users [n]

$$\begin{aligned} n &= 16c \\ &= 16 \times 10 = 160 \end{aligned}$$

9.3.2 Mobile Toilet

Mobile toilets are temporarily installed in places where there is no toilet, such as shelters during natural disaster, venues for events, and construction sites, or where the number of existing toilets is short. A mobile toilet box has a tank for storing excreta in its lower part. If the tank is full, a vacuum tanker collects the stored sewage. Each toilet has a single room or multiple rooms with a hand washing unit, which is selected according to the flexibility of installation sites and ease of transport by a truck. In addition, there is a mobile flush toilet that is equipped with a water tank and a pedal.

Stepping on the latter activates a manual pump to cause washing water to flow. The box is made by assembling fiberglass-reinforced plastic (FRP) side panels, so its weight is light. Local governments keep these toilets to prepare for disasters and events, or rental companies lease them. The mobile toilet features easy installation work on the ground. Figure 9.2 shows a mobile toilet having faeces, urine, and hand washing units.

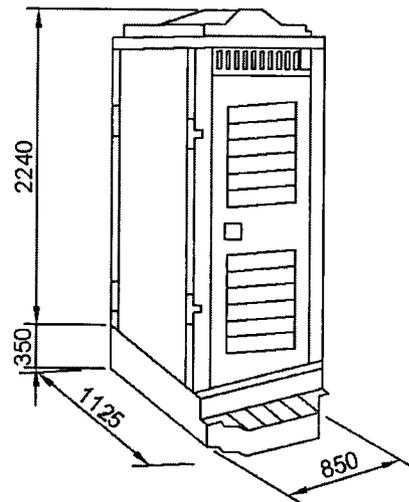


Figure 9.2 Mobile toilet

9.3.3 Pour Flush Water Seal Latrine

In a conventional water flush latrine, the excreta is normally flushed with 10 to 14 litres of water from a cistern. In a pour flush latrine, as the name suggests, excreta is hand flushed by pouring about 1.5 to 2.0 litres of water. These pour-flush leaching pit latrines were first developed in India in mid-forties with a single leach pit and squatting pan placed over it. When the pit in use gets filled up another pit is dug and the squatting slab is removed and placed over the new pit. The first pit is covered with earth and the excreta is allowed to digest. After one or two years, the digested excreta is used as manure.

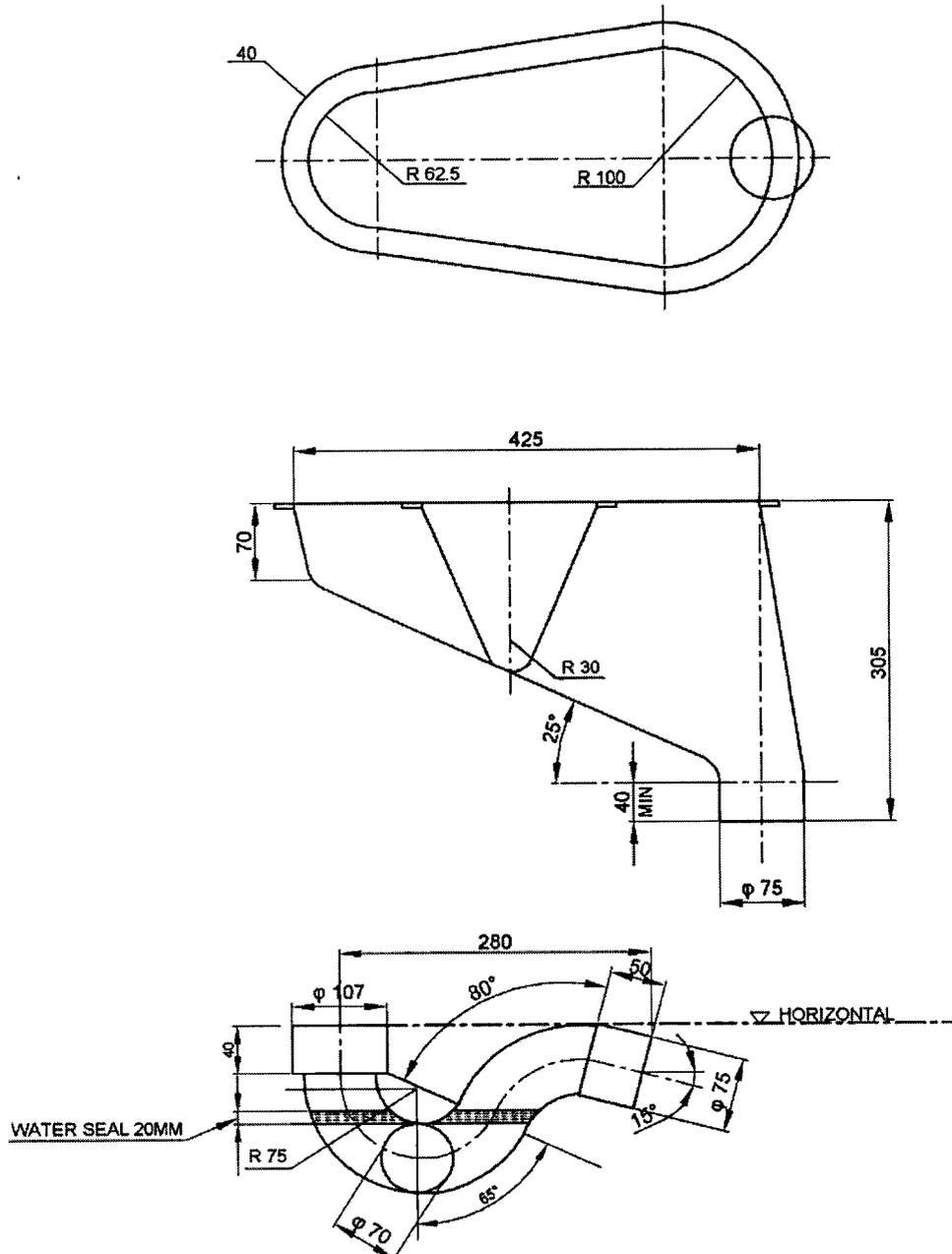
In the late fifties, a modified design of the system was developed. In this system the leach pit is kept away from the seat instead of placing it underneath the pan. In a single pit system, desludging has to be done almost immediately after the pit has been filled up to enable its re-use; this involves handling of fresh and undigested excreta containing pathogens which is a health hazard. Single leach pit is appropriate only if it is desludged mechanically by a vacuum tanker. To overcome this shortcoming, the twin-pit design was introduced and in this case when one pit is full, the excreta is diverted to the second pit. The filled up pit can be conveniently emptied after 1.5 to 2 years, when most of the pathogens die off. The sludge can safely be used as manure. Thus the two pits can be used alternately and perpetually.

With simple care, pour-flush water-seal latrine is a very satisfactory and hygienic sanitation system and hence it can be located inside the house since the water-seal prevents odour and insect nuisance from the pit.

9.3.3.1 Design and Materials

9.3.3.1.1 Squatting Pan, Trap, Footrests, and Connecting Drain

The squatting pan is of special design with steep bottom slope 25 - 28° and a trap having 20 mm water seal set on a cement concrete floor. The hydraulic design of the pan is such that the human excreta can be flushed by pouring only 1.5 to 2 litres of water. The squatting pan and trap design details are shown in Figure 9.3.



Source: CPHEEO, 1993

Figure 9.3 Squatting pan and trap

The squatting pan can be of ceramic or glass reinforced plastic (GRP), High Density Polyethylene (HDPE) or Poly Vinyl Chloride (PVC), Polypropylene (PP), Cement mosaic or even concrete. The squatting pan is connected to the leaching pit through a trap and a pipe or covered drain. The design and material details for latrine units squatting pan, trap, footrest and the connecting drain are summarised below in Table 9.1.

Table 9.1 Material and other details for latrine unit

No.	Squatting Pan	Trap	Footrests	Connecting Drain
1	Horizontal length of pan should be at least 425 mm and longitudinal bottom slope 25 -28°	It should be 70 to 75 mm with 20 mm water seal	It should be 250×125 mm with 15 to 20 mm height	May be non-pressure pipes of PVC minimum 75 mm dia
2	Material: Ceramic, FRP, PP, HDPE, PVC, Cement mosaic or Cement concrete	Fibre Glass, Ceramic, HDPE or CC traps	Ceramic or concrete with mosaic finish brick or stone	Bricks or stone semi-circular bottom
3	Should conform to IS: 2556 (Pt. III), IS: 11246, GRP Sq. Pan	Should conform to IS: 2556 (Pt. XIII)	Should conform to IS: 2556 (Pt. X)	Slope should be 1 in 5 to 1 in 15 as per site conditions
4	(A)			(B)

(A)- Ceramic, FRP, PP are smooth and require less water for flushing. FRP cheaper, lighter and easier to transport than the other

(B)- The inlet pipe should project 100 mm in to the leach pit. A junction chamber of 250×250 mm should be provided in case of pipe

Source: CPHEEO, 1993

9.3.3.1.2 Leach Pits/Twin Pit Latrine

Leach pits serve a dual function of (a) storage and digestion of excreted solids and b) infiltration of the waste liquids and are therefore, to be designed on the basis of the following parameters:

- Sludge accumulation rate
- Long term infiltration rate of the liquid fraction across the pit soil interface
- Hydraulic loading on the pit
- Minimum period required for effective pathogen destruction
- Optimal pit emptying frequency.

9.3.3.1.2.1 Sludge Accumulation Rate

The sludge accumulation rate is a function of a wide range of variables including water table level, pit age, water and excreta loading rates, microbial conditions in the pit, temperature and local soil conditions and the type of material used for anal cleansing.

The leach pit is classified as wet or dry depending on whether the ground water table is above the bottom of pit or below. In dry pits, the pit volume needed is calculated on the basis of solids accumulation rate, but in wet pits though the sludge accumulation rate is lower - the sludge digestion rate is high in the presence of water, yet volume of pit has to be increased to prevent flooding due to surcharge of pits. The sludge accumulation rates given below in Table 9.2 may be used to calculate the pit volume.

Table 9.2 Sludge accumulation rates

Material used for anal cleansing	Effective Volume in m ³ per Capita per Year (A)		
	Pit under dry conditions	Pit under Wet conditions	
		With successive desludging intervals	
		2 years	3 years
Water	0.04	0.095	0.067
Soft Paper	0.053	0.114	0.080

(A) Effective Volume is the volume of the pit below the invert level of pipe or drain.

Source: CPHEEO, 1993

9.3.3.1.2.2 Long Term Infiltration Rate

On account of clogging of soil pores around the leach pits, the long term infiltration capacity (after clogging) of the soil is always less than the natural percolative capacity. The recommended design values of the long term infiltrative capacity can be derived for the typical soil conditions as given below in Table 9.3.

Table 9.3 Long term infiltration rates of different types of soils

No.	Soil type	litres / sqm / day
1	Sand	50
2	Sandy loam, loams	30
3	Porous silty loams, porous silty, silty clay loams	20
4	Compact silty loams, compact silty clay loams, clay	10

Source: CPHEEO; 1993

9.3.3.1.2.3 Hydraulic Loading

The hydraulic loading rate is the total volume of liquids entering the leach pit and is expressed in litres per day although it is often more convenient to consider per capita loadings (litres per capita per day). For computing the pit hydraulic loading, sewage contribution of 9.5 litres per day per person, including water used for ablutions and flushing, urine, excreta, etc., can be taken as the basis.

The outer surface area (perimeter) of the pit from pit bottom to invert level of pipe or drain is to be considered for infiltration. The pit bottom is not taken into account as it gets clogged in course of time. The infiltration area required is the total flow in the pit per day divided by the long term infiltrative rate of the soil where pits will be located. The infiltrative area of leach pits, sized on the basis of sludge accumulation rate should conform to the computed infiltrative area.

9.3.3.1.2.4 Pathogen Destruction

After a period of almost all pathogens viruses, bacteria, protozoa and helminths die off in the leach pit or in the surrounding soil, but not *Ascaris Lumbricoides* (the large human round-worm) particularly if the leach pit is wet. After about one or one and a half years of storage in the pit, it may not be hazardous to handle the contents of the pit for use as manure.

9.3.3.1.2.5 Optimal Pit Emptying Frequency

The minimum acceptable design interval between successive manual desludging of each twin leach pit could be one-and-a-half-years. However, to provide a reasonable degree of operational flexibility, it is desirable to provide three years storage volume in urban areas and two years in rural areas.

9.3.3.1.2.6 Size of Pits

Sizes of leach pits, [designed as above for different number of users, using water abluion and for different subsoil water levels], with 3 years sludge storage volume, are in Table 9.4.

Table 9.4 Size of leach pits

	5 Users		10 Users		15 Users	
	Dia	Depth(A)	Dia	Depth(A)	Dia	Depth(A)
Dry Pits	900	1,000	1,100	1,300	1,300	1,400
Wet Pits	1,000	1,300	1,400	1,400	1,600	1,500

Note: (A) Depth from bottom of pit to invert level of incoming pipe or drain (all dimensions in mm)

Source: CPHEEO, 1993

The surface area of these is adequate for soils with long term infiltrative rate down to 20 l/m²/day. The above depths should be increased by 300 mm to provide a free board depth of pit from invert level of pipe or drain to bottom of pit cover.

9.3.3.1.2.7 Design of Pits under Different Conditions

A typical pour flush latrine with circular pits is shown in Figure 9.4.

In water logged area: The pit top should be raised by 300 mm above the likely level of water above ground level at the time of water logging. Earth should then be filled well compacted all round the pits up to 1.0 m distance from the pit and up to its top. The raising of the pit will necessitate raising of latrine floor also. A typical pour flush latrine in water logged areas is shown in Figure 9.5.

In high subsoil water level: Where the subsoil water level rises to less than 300 mm below ground level, the top of the pits should be raised by 300 mm above the likely subsoil water level and earth should be filled all round the pits and latrine floor raised as stated above. A typical pour flush latrine with leach pits in high subsoil water level is shown in Figure 9.6

In rocky strata: In rocky strata with soil layer in between, the leach pits can be designed on the same principle as those for low subsoil water level and taking the long term infiltrative capacity as $20 \text{ l/m}^2/\text{d}$. However, in rocks with fissures, chalk formations, old root channels, pollution can flow to very long distances; hence these conditions demand careful investigation and adoption of pollution safeguards as stated in paragraph below.

In black cotton soil: Pits in black cotton soil should be designed taking infiltrative rate of $10 \text{ l/m}^2/\text{d}$. However a vertical fill (envelope) 300 mm in width with sand, gravel or ballast of small sizes should be provided all round the pit outside the pit lining.

Where space is a constraint: Where circular pits of standard sizes cannot be constructed due to space constraints, deeper pit with small diameter (not less than 750 mm), or combined oval, square or rectangular pits divided into two equal compartments by a partition wall may be provided. In case of combined pits and the partition wall should not have holes. The partition wall should go 225 mm deeper than the pit lining and plastered on both sides with cement mortar. A typical pour flush latrine with combined pits is shown in Figure 9.7

Design example of leach pit is given in Appendix A.9.1.

9.3.3.2 Construction of Pour Flush Latrine

9.3.3.2.1 Squatting Pan and Trap

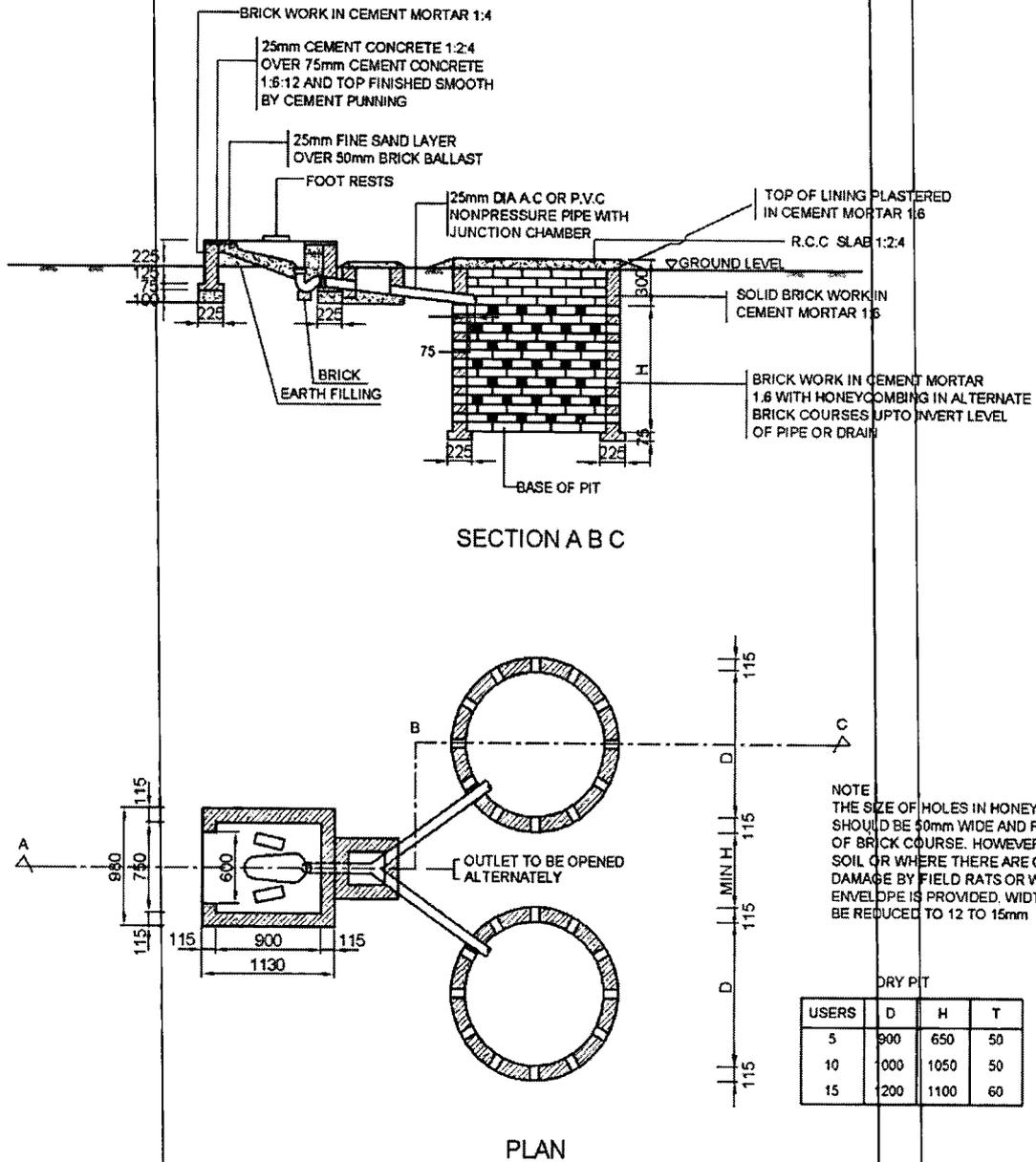
The pan could be ceramic, GRP, PVC, PP, Cement Concrete or Cement Mosaic. Ceramic are the best but costliest. Mosaic or cement concrete pans have the advantage that these can be manufactured locally by trained masons but the surface tends to become rough after long use. Their acceptance is less compared to other types. Traps for ceramic pans are made of the same material but in case of GRP pans, HDPE traps are used. For mosaic pans, traps are of cement concrete.

9.3.3.2.2 Foot Rests

These can be of ceramic, cement concrete, cement mosaics or brick plastered. The top of the footrest should be about 20 mm above the floor level and inclined slightly outwards in the front.

9.3.3.2.3 Pit Lining

The pits should be lined to avoid collapsing. Bricks joined in 1:6 cement mortar are most commonly used for lining. Locally manufactured bricks should be used wherever available. Stones or laterite bricks cement concrete rings could also be used depending upon their availability and cost. However, for ease of construction, use of concrete rings will be advantageous where the subsoil water level is above the pit bottom.



Source: CPHEEO, 1993

Figure 9.4 Pour flush latrine with circular pits

9.5 DEALING WITH SEPTAGE

The effluent from the septic tank can be collected in a network of drains and/or sewers and treated in a treatment plant designed appropriately on the lines discussed in Chapter 5. The accumulating sludge at the bottom of the septic tank however, has to be also removed and treated once it has reached the designed depth or at the end of the designed desludging period whichever occurs earlier. Such a removal is possible only by trucks. While sucking out the sludge, the liquid in the septic tank will also be sucked out. Such a mixture is referred to as septage. Obviously, the removal of septage from a household septic tank will occur approximately once in two or three years only.

9.5.1 Characterisation of Septage

9.5.1.1 Septic Tanks used only for Water Closets

In general, the septic tank is intended to be used only for the water closet and hence, the night soil alone is the causative factor for the organic load. Thus, as far as the BOD is concerned, the per capita contribution of night soil and the volume of ablution water and its frequency per day are relevant. The urine is the factor for the nitrogen content. The septic tank system reported in the twin drain system has recorded a range of characteristics of BOD, COD and SS as in Table 9.12 and in Table 8.1.

Table 9.12 Range values of BOD, COD and SS at inlet to septic tank in India

No.	Indicator	BOD, mg/L	COD, mg/L	SS, mg/L
1	Mean	1,290	2,570	4,140
2	Standard Deviation	143	290	542
3	Range	970 to 1,550	1,920 to 3,050	2,550 to 4,860

The average amount of ablution water used at this location was about 6 litres per use. The BOD from defecation is about 8 grams/day. This corresponds to the BOD value in the above table. This value of BOD can however vary drastically based on the volume of ablution water and the number of times per day though the usage rarely exceeds one usage per day. It stands to reason to infer that the BOD of septage is relatable to the liquid portion and the suspended matter and the rates at which these have undergone some degradation by anaerobiasis in the tank and the accumulation especially in the sludge zone. All these are highly variable and as such a theoretical basis for arriving at the characteristics of septage is fraught with uncertainty. In respect of the literature values reported from advanced countries in the west, the personal habits of ablution water vs. toilet paper is a crucial influencing factor defying the flat out adoption of the characteristics reported from those locations.

9.5.1.2 Septic Tanks used for all Domestic Sewage

The per capita BOD being 36 g per day and a water usage at about 100 lpcd will imply a BOD of 360 mg/l though it will be higher if the lpcd goes down.

9.5.1.3 Septic Tanks used for Sewage from Water Closets and Bathing

The US EPA "Handbook on Septage Treatment and Disposal - 62568409" identifies Septage as arising from water closets and bath tubs. This is understandably off the mark for the average Indian conditions where the bath tub is first of all a non-entity in the household except in high profile urban living, where incidentally the conventional sewage prima facie eliminates the septage issue.

9.5.1.4 Values Reported from Elsewhere

Given the above understanding of the overall scenario, it stands to reason not to be guided by the characterization data from western countries in the bath tub usage category. A value reported is "BOD concentrations between 2,000 and 20,000 mg/l and TSS values in excess of 50,000 mg/l, where septic tank effluent has values averaging 200 mg/l BOD and 300 mg/l TSS" (Septage Management Guide for Local Governments-David M Robbins). The US EPA in "Handbook on Septage Treatment and Disposal - 62568409" has reported the organic and heavy metals in septage as in Table 9-13 and Table 9-14 (overleaf). The characteristics of Septage reported from the city of Surabaya, Indonesia are BOD of 8,250 mg/l, COD of 17,250 mg/l, and TSS of 2,000 mg/l.

9.5.1.5 Values to be considered for Indian Conditions

Given the above wide variations in literature values and the various influencing factors, it becomes risky to hazard a guess on advocating a set of characteristics for septage in Indian conditions. However, in order to bring about an example of treatment of septage, the values in Table 9-15 (overleaf) are proposed to be advocated purely for illustration and it should be mandatory to carry out local sampling and analysis before designing the treatment and disposal system.

9.6 LOGISTICS OF SEPTAGE COLLECTION

Basically the septage collected should be treated as it cannot be let into the environment directly because of the characteristics in Table 9-15. Because of this, a treatment facility shall be set up or the septage added to an existing septage treatment facility. This implies a near uniform loading all the year round instead of peaking the discharge at certain days alone. This in turn demands the planned septage collection logistics round the year by the septage trucks. Hence the establishment of a septage collection unit becomes an adjunct to the decentralized sewerage system where septic tanks are the primary treatment at households.

9.7 SEPTAGE TREATMENT FACILITY

Sludge generated in an on-site treatment facility is regularly extracted and hygienically treated. The sludge treatment method includes (1) delivery to a sewage treatment facility and treatment with sludge generated in the sewage treatment process, (2) treatment in a special sludge treatment facility, (3) solar drying on a floor, and (4) treatment by a mobile dehydrating truck. This section describes the first and second method.

9.8 TREATMENT OF SEPTAGE IN EXISTING STP

This can be brought about in (a) existing STPs depending on the concentrations of BOD, flows and spare capacity available in them and (b) separate dedicated treatment facility for septage.

Table 9.13 Septage characteristics as per US EPA

Parameter	United States				Europe/Canada				EPA Mean	Suggested Design Value
	Average	Minimum	Maximum	Variance	Average	Minimum	Maximum	Variance		
TS	34,106	1,132	130,475	115	33,800	200	123,860	619	38,800	40,000
TVS	23,100	353	71,402	202	31,600	160	67,570	422	25,260	25,000
TSS	12,862	310	93,378	301	45,000	5,000	70,920	14	13,000	15,000
VSS	9,027	95	51,500	542	29,900	4,000	52,370	13	8,720	10,000
BOD ₅	6,480	440	78,600	179	8,343	700	25,000	36	5,000	7,000
COD	31,900	1,500	703,000	469	28,975	1,300	114,870	88	42,850	15,000
TKN	588	66	1,060	16	1,067	150	2,570	17	677	700
NH ₃ -N	97	3	116	39	-	-	-	-	157	150
Total P	210	20	760	38	155	20	636	32	253	250
Alkalinity	970	522	4,190	8	-	-	-	-	-	1,000
Grease	5,600	208	23,368	112	-	-	-	-	9,090	8,000
pH	-	1.5	12.6	8	-	5.2	9.0	-	6.9	6.0
LAS	-	110	200	2	-	-	-	-	157	150

Note:

- i) Values expressed as mg/L, except for pH.
- ii) The data presented in this Table were compiled from many sources. The inconsistency of individual data sets results in some skewing of the data and discrepancies when individual parameters are compared. This is taken into account in offering suggested design values.

Source: USEPA

Table 9.14 Heavy metals in septage as per US EPA

Parameter	United States			Europe/Canada			Typical US Domestic Sludge Ranges	EPA Mean	Suggested Design Value for Septage
	Average	Minimum	Maximum	Average	Minimum	Maximum			
Al	48.00	2.00	200.0	-	-	-	-	48.00	50.00
As	0.16	0.03	0.5	-	-	-	0-0.7	0.16	0.20
Cd	0.27	0.03	10.8	0.05	-	0.35	0.1-44	0.71	0.70
Cr	0.92	0.60	2.2	0.63	-	5.00	0.9-1,200	1.10	1.00
Cu	8.27	0.30	34.0	4.65	1.25	15.00	3.4-416	6.40	8.00
Fe	191.00	3.00	750.0	-	-	-	-	200.00	200.00
Hg	0.23	0.0002	4.0	-	0.15	0.20	0-2.2	0.28	0.25
Mn	3.97	0.20	32.0	-	-	-	-	5.00	5.00
Ni	0.75	0.20	37.0	0.58	-	2.50	0.5-112	0.90	1.00
Pb	5.20	2.00	8.4	3.88	-	21.25	3.2-1,040	8.40	10.00
Se	0.076	0.02	0.3	-	-	-	-	0.10	0.10
Zn	27.4	2.90	153.0	38.85	1.25	90.00	79-655	49.00	40.00

Note:

- i) Values expressed as mg/L.
- ii) Values converted from µg/g assuming TS=40,000 mg/L.

Source: USEPA

Table 9.15 Illustrative characteristics of septage for Indian Conditions

No.	Source	Type A	Type B
		Public toilet or bucket latrine sludge	Septage
	Characteristics	Highly concentrated, mostly fresh Faecal Sludge; stored for days or weeks only	Faecal Sludge of low concentration; usually stored for several years; more stabilized than Type "A"
1	COD (mg/L)	20-50,000	<15,000
2	COD/BOD	5:1 to 10:1	5:1 to 10:1
3	NH ₄ -N (mg/l)	2-5,000	<1,000
4	TS (%)	≥ 3.5 %	< 3 %
5	SS (mg/l)	≥30,000	7,000 (approx.)
6	Helminth Eggs	20-60,000	4,000 (approx.)

9.8.1 Pre-Treatment of Septage

This is needed to (a) ensure a flow equalization tank for the septage flow so that it can be loaded onto the STP at as much uniform flow as possible through the 24 hours, (b) a degritting facility to segregate the grit content and prevent it from getting into aeration units and pumps etc. and (c) separate the liquid stream and sludge stream.

The equalization tank may be a relatively deeper tank equipped with sub surface mixers to maintain the contents in suspension. The surface aerators and diffused aeration will create odour problems.

The degritting facility is best designed as a vortex separator similar to the one described in Chapter 5. The sludge-liquid separation facility can be a filter press or belt press or screw press or centrifuges depending on the feed solids concentration being within the capacity of these equipment. Their designs will be the same as in Chapters 5 and 6.

The pumps however, can be submersible pump sets with open impellers. A typical receiving station facility is shown in Figure 9.18 (overleaf)

9.8.1.1 Co-treatment in Existing STPs-Liquid Stream

The basic consideration is the spare capacity at the existing STP. Normally, the septage volumes are not unduly significant in relation to the full-fledged STP volumes and would seldom exceed about say 5% and this way, even if the STP is functioning at design capacity, volume wise, it will not be a problem to add even up to 5% of flows. But it is the BOD load that comes in the way.

Considering a typical STP with about 300 mg/l of raw BOD and a septage volume of about 3% with a BOD of say 4,000 mg/l, this would result in a situation mentioned overleaf.

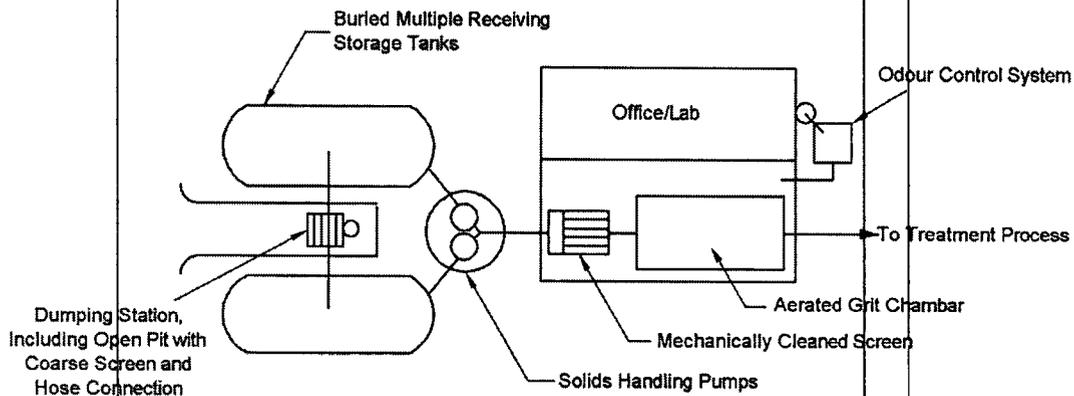


Figure 9.18 Typical septage receiving facility

Design capacity of the STP	= 1 mld
Actual operating capacity	= 0.65 mld
BOD load in to the STP	= 0.65 mld \times 300 mg/l = 195 kg/day
BOD load from septage	= 0.03 mld \times 4,000 mg/l = 120 kg/day
Total resulting BOD load	= 195 + 120 = 315 kg/day
Designed ability of the STP for BOD load	= 1 \times 300 = 300 kg/day

Thus, it may be possible to accommodate the septage as long as the actual flow to STP does not increase. But then, over a period of time both the sewage volume and septage will increase and hence, it is not easy to use this option as a permanent measure. At the same time, if the spare capacity is available, then it is wiser to opt for this instead of rushing into a dedicated septage treatment facility. Yet another option will be to augment or upgrade the STP capacity, which is by far simpler and so far as the liquid stream is concerned.

9.8.1.2 Co-treatment in Existing STPs-Sludge Stream

The computations similar to that in respect of liquid stream shall be evaluated to verify whether the sludge treatment facilities of the existing STP can handle the extra sludge from the septage. Most often, this may be possible. In case it is not possible, add on sludge treatment standalone facilities shall be designed and constructed instead of trying to invasive augmentations of existing facilities.

9.8.1.3 Points of Addition of the Liquid and Sludge Streams

The points of addition of liquid and sludge streams provided spare capacities are available are suggested in Figure 9.19 (overleaf)

9.9 TREATMENT OF SEPTAGE AT INDEPENDENT STP

When the distance or the capacity of the plant becomes a limiting factor, it is not a feasible option to transport and treat the septage to the sewage treatment facilities.

In this case treatment plants specially meant for septage treatment becomes an attractive option. Independent septage treatment plants are designed specifically for septage treatment and usually have separate unit processes to handle both the liquid and solid portions of septage.

These facilities include mechanical dewatering, sludge drying beds, Waste stabilization ponds, etc. The benefit of using these treatment plants is that they provide a regional solution to septage management. Many septage treatment plants use lime to provide both conditioning and stabilization before the septage is dewatered. Dewatered sludge can be used as organic fertilizer after drying and composting. The remaining effluent/filtrate/supernatant can be released to another treatment process such as WSP, Anaerobic baffled reactor, constructed wetland or combination of these or extended aeration activated sludge where it can undergo further treatment and then finally can be safely discharged.

Choosing an appropriate septage management method relies not only on technical aspect but also on regulatory requirements. The management option selected should be in conformity with local, State and Central regulations. Some of the factors that determine the process of selection include: land availability and site conditions, buffer zone requirements, hauling distance, fuel costs, labour costs, disposal costs and other legal and regulatory requirements.

The technical options could be as follows:

Case 1: Land Area is not limited but Funds are Limited

Option - 1

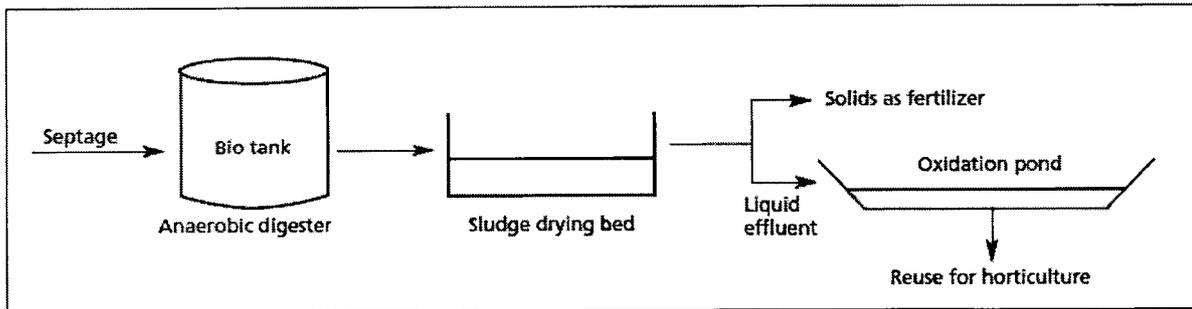
Pretreatment - Anaerobic Digesters - Dewatered and Dried Sludge - Composting - Reuse as Organic Fertilizer; Filtrate of Sludge Drying Bed and Digester supernatant - Pumping - Reed beds (or) Constructed wetlands - Electricity generation from digester gas. Totally nature based system with mechanical equipment as needed.

Constructed wetlands are essentially on-site technologies involving sequential treatment of sewage on-site, in selective filter media and finally greenbelt development and have been developed by IIT Powai and called Soil Bio Technology and also NEERI and called as Phytoid.

A septage treatment facility handling nearly 51 MLD at Nonthaburi in Thailand is widely reported in literature. The treatment process is shown in Figure 9.20.

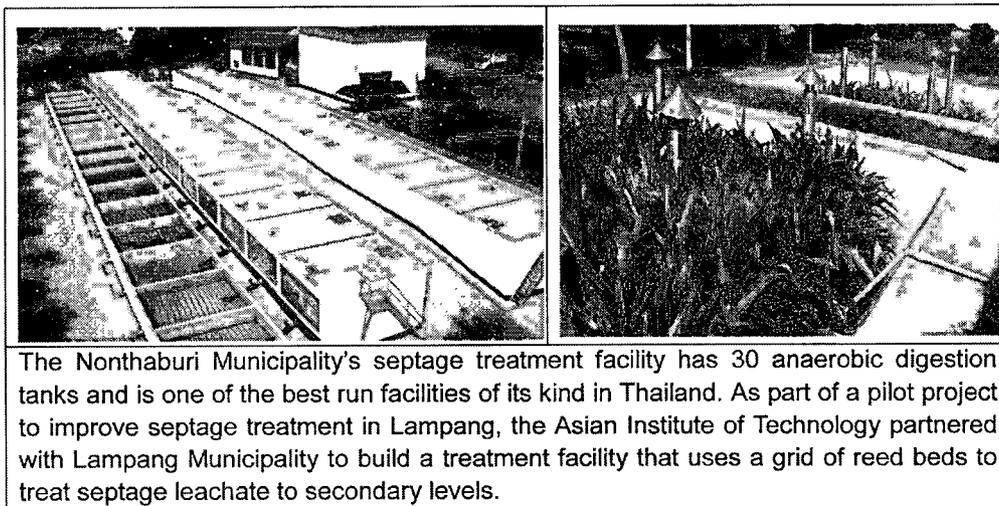
It is reported that the treatment is anaerobic digestion and the digested sludge is sent to drying beds. The filtrate is dewatered in sand beds and is sent to ponds and the pond effluent is used on public parks. The use of constructed wetlands has also been reported with solids loading rate of 250 kg/m²/year, once a week application and percolate impounding for 6 days and harvesting twice a year with COD removal efficiency of 80 to 90%, and solids accumulation at 12 cm/year in the impoundment.

A photo view is presented in Figure 9.21.



Source:USAID, 2010

Figure 9.20 Septage treatment process at Nonthaburi, Thailand



Source:USAID, 2010

Figure 9.21 A photo view of septage treatment process at Nonthaburi in Thailand

Option - 2

Pretreatment - lime stabilization (optional) - Pumping - Sludge Drying beds (FRP covered in regions of high rainfall) - Dewatered & Dried Sludge - Composting - Reuse as Organic Fertilizer; Filtrate of Sludge Drying Bed - Pumping - Anaerobic Baffled Reactor / Covered Anaerobic Ponds - Facultative - Aerobic / Maturation Ponds - chlorination - discharge'

Case 2: Land Area is Limited and Funds are also Limited.

Option - 1

Pretreatment - lime stabilization (optional) - Pumping - Mechanical Sludge dewatering system - Dewatered sludge - Solar drying or/and Composting - Reuse as Organic Fertilizer; Filtrate of Mechanical Dewatering Machine - Pumping - Anaerobic Baffled Reactor / Covered Anaerobic Ponds - Facultative - Aerobic / Maturation Ponds - chlorination - discharge. There should be 25% additional capacity of sludge drying beds in case of maintenance of dewatering machine and or unavailability of polyelectrolyte.

Option - 2

Pre-treatment - lime stabilization (optional) - Pumping - Sludge drying beds (FRP covered in regions of high rainfall) - Dewatered & Dried Sludge - Composting - Reuse as Organic Fertilizer; Filtrate of Sludge / septage Drying Bed - Pumping - Extended Aeration - Activated Sludge Process (Continuous or Batch) - chlorination - discharge

Case 3. Land Area is Limited and Funds are not limited

Pretreatment - lime stabilization (optional) - Pumping - Mechanical Sludge dewatering system - Dewatered sludge - Solar drying or/and Composting - Reuse as Organic Fertilizer; Filtrate of Mechanical dewatering machines - Pumping - Extended Aeration Activated Sludge Process (Continuous or Batch) - chlorination - discharge. There should be 25% addition capacity of sludge drying beds in case of maintenance of dewatering machine and or unavailability of polyelectrolyte.

9.9.1 Pre-Treatment of Septage

The pre-treatment facilities discussed earlier are the same in this case also (Figure 9-18).

In addition, if possible there should be lime stabilization facility to control odour, vector and pathogen destruction. Lime stabilization involves adding and thoroughly mixing lime (alkali) with each load of septage to ensure that the pH is raised to at least 12 for at least 30 minutes.

Lime addition could be done at any of these three points:

- i) To the hauler truck before the septage is pumped,
- ii) To the hauler truck while the septage is being pumped, or
- iii) To a septage storage tank where septage is discharged from a pumper truck is shown in Figure 9.22 (overleaf)

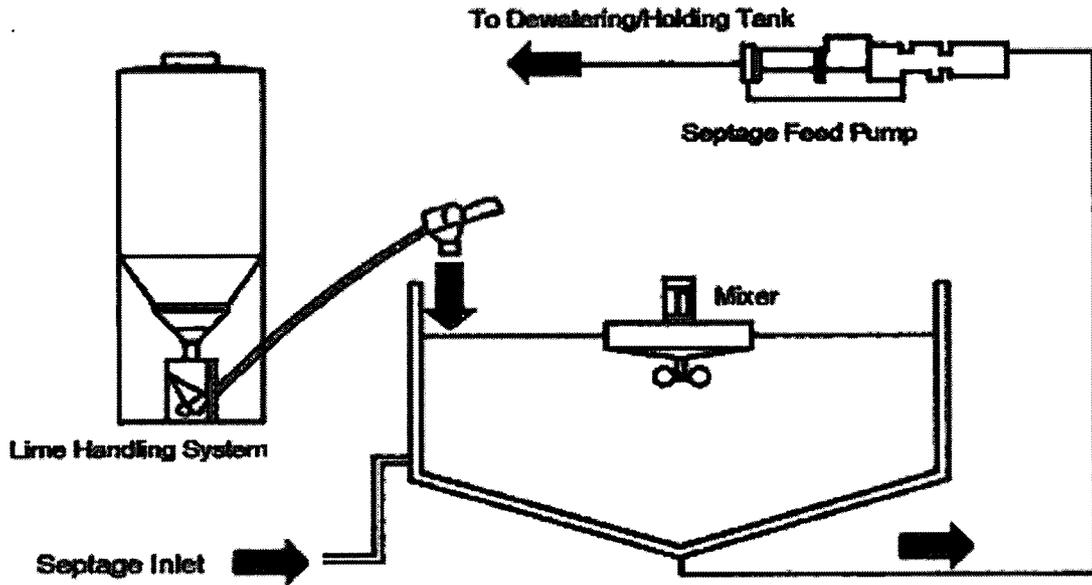
9.9.2 Septage Dewatering

The septage after lime dosing is pumped to screw press or any other mechanical dewatering machine. Polyelectrolyte is added to increase the dewatering efficiency of the machine.

The liquid residual / pressate / filtrate / supernatant from dewatering machine can be discharged for further biological treatment. The dewatered sludge can be send for further drying or composting prior to reuse as organic fertilizer. The typical mechanical septage dewatering system is shown in Figure 9.23 (overleaf)

Instead of Screw Press the options can be:

- i) Centrifuge
- ii) Belt Press
- iii) Filter Press



Supernatant to pH neutralization and dedicated STP
 Underflow to mechanical dewatering with polyelectrolyte

Figure 9.22 Lime stabilization of septage

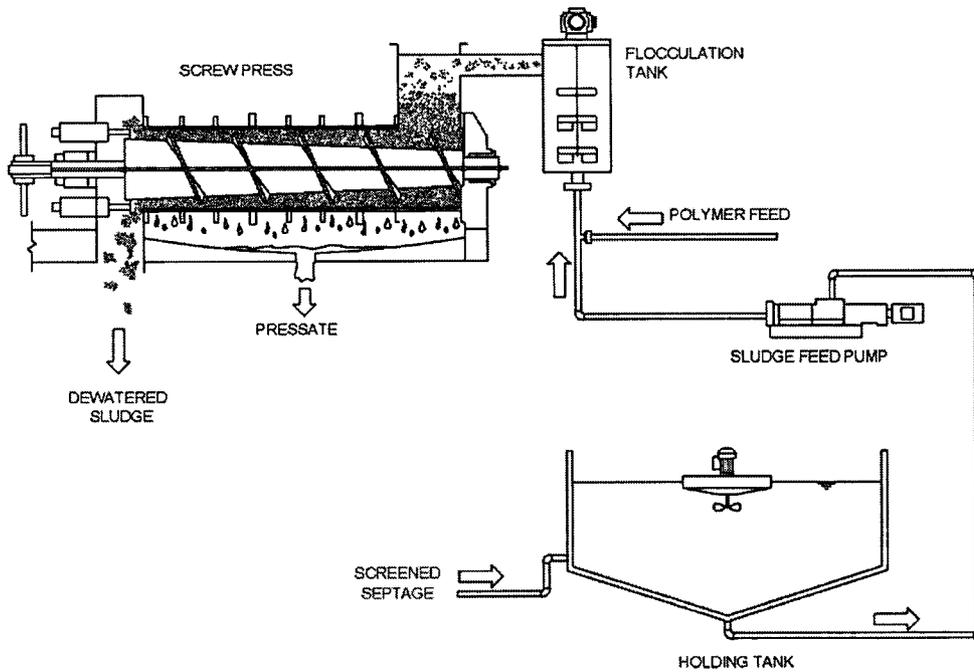


Figure 9.23 Typical Mechanical Septage Dewatering System

9.10 ADVANTAGES AND DISADVANTAGES OF THE SYSTEMS

Advantages and disadvantages of septage treatment at STPs and at independent septage treatment facility are given in Table 9.16 and Table 9.17, respectively.

Table 9-16 Advantages and disadvantages of septage treatment at sewage treatment plant

Method	Description	Advantages	Disadvantages
Treatment at STPs or Independent septage treatment facility in the vicinity of STPs	Septage is added to the pumping station, upstream manhole or sludge treatment process for co-treatment with sewage sludge. Septage volumes that can be accommodated depend on plant capacity and types of unit processes employed.	Most STPs in India are underutilized and are capable to handle some septage. As skilled personnel and laboratory facilities are available in STPs, easy to operate and maintain.	Potential for STP upset if plants are running at full capacity. Increased sludge treatment cost.

Table 9.17 Advantages and disadvantages of independent septage treatment facility

Method	Description	Advantages	Disadvantages
Treatment at independent septage treatment plants	A facility is constructed solely for the treatment of septage. Treatment generates residuals, i.e., dewatered sludge and filtrate which must be dried composted (dewatered sludge) and properly treated (filtrate) prior to being disposed off.	Provides regional solutions to the septage management.	High capital and operation and maintenance cost. Requires high skills of operation in case of mechanical dewatering.

9.11 COMPOSTING OF DEWATERED SEPTAGE OR SLUDGE

Another feasible option is composting where bulking agents are easily available. The humus is produced after composting that can be used as a soil conditioner. Composting is the stabilization of organic waste through aerobic biological decomposition. As described in more detail in Chapter 6, the process can be accomplished in various configurations. The different types of composting include two open-area methods: windrow and static pile composting and in-vessel mechanical composting. Operational parameters for septage composting are presented in Table 9-18 (overleaf) Compost products can be sold or given away.

Table 9.18 Operational parameters for dewatered septage composting

Parameter	Optimum range	Control mechanisms
Moisture content of compost mixture	40-60%	Dewatering of septage to 10 to 20% solids followed by addition of bulking material (amendments such as sawdust and woodchips), 3:1 by volume amendment: dewatered septage.
Oxygen	5-15%	Periodic turning (windrow), forced aeration (static pile), mechanical agitation with compressed air (mechanical).
Temperature (compost must reach)	55-65°C	Natural result of biological activity in piles. Too much aeration will reduce temperature.
pH	5-8	Septage is generally within this pH range, adjustments not normally necessary.
Carbon/nitrogen ratio	20:1 to 30:1	Addition of bulking material.

9.12 DEWATERED SEPTAGE SLUDGE REUSE

For dewatered septage/sludge agriculture application, it should satisfy the following criteria of Class A Biosolids of US EPA either by lime stabilization, solar drying and or composting.

- A faecal coliform density of less than 1,000 MPN/g total dry solids
- Salmonella sp. density of less than 3 MPN per 4 g of total dry solids (3 MPN/4 g TS)

Properly treated sludge can be reused to reclaim parched land by application as soil conditioner, and as a fertilizer in agriculture. Deteriorated land areas, which cannot support the plant vegetation due to lack of nutrients, soil organic matter, low pH and low water holding capacity, can be reclaimed and improved by the application of sludge.

Septage sludge has a pH buffering capacity resulting from lime addition that is beneficial in the reclamation of acidic sites, like acid mine spoils, and acidic coal refuse materials.

Sludge with a solid content of 30% or more handled with conventional end-loading equipment, and applied with agricultural manure spreaders. Liquid sludge, typically with solid content less than 6% managed and handled by normal hydraulic equipment.

Agricultural use of sludge matches best with priorities in waste management. Sewage sludge contains nutrients in considerable amounts, which can be used as discussed in Chapter 6 of the part A manual.

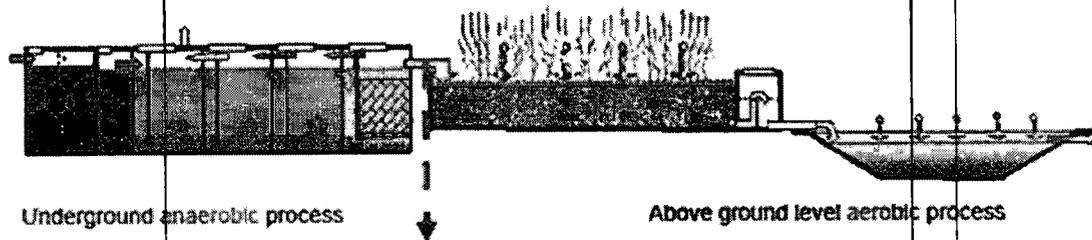
8.9 RECOMMENDATIONS

The decentralization concepts and technologies in sewage management need to be systematically investigated, with focus on its development and practical implementation in India. It may be borne in mind that the approach adopted for decentralized sewage management system (DSMS) is area specific and governed by number of issues and conditions prevailing, and also the methodology adopted and is influenced by (i) technical aspects as covered in this chapter and (ii) financial aspects, (iii) social aspects, (iv) environmental aspects, and (v) legal aspects that will be covered in the part C of the manual. It needs to be realized that this aspect and programme of decentralized sewerage is what the country needs urgently if the MDG is to be achieved especially in the peri-urban, rural and outlying areas and habitations. Accordingly, the following recommendations are brought up in deciding on implementing this.

- 1) As Incremental Sewerage - Decentralized Sewerage has an enormous significance by way of incremental sewerage and sanitation especially in newly developing peri-urban and rural settings, where conventional sewerage needs time to qualify itself physically and financially.
- 2) As a Combination of Collection System Options - It is the interim period from start of the layout to such time that underground conventional sewerage will qualify itself that is the bane of all environmental hazards of indiscriminate pollution. Ingenuity of a combination of decentralized collection systems and incremented treatment capacity of the STP are the remediations for the country as a whole.
- 3) Public Acceptance is the Key - However, with the mindset of the people that sewerage de facto implies only to the underground conventional sewerage, any deviation from a conventional system will require a public acceptance before implementation and as such, decentralized sewerage is not an exception. The Srirangam case study is an ideal example. Any attempt in starting a decentralized treatment there would have never seen the light of the day. This aspect must not be underestimated and hence, the public consultation process shall be announced well in advance in local media and repeated one more time giving notice of at least two weeks and making the venue as local marriage hall or public hall with adequate space and hired chairs and expenses being met by the local body. The technicalities are to be toned down and the benefits and costs alone need to be cited elaborately and the opinion elicited. Understandably, it will not be a full acceptance by all the habitation and there will be various cost recovery models thrown up for example, built-up area based on; number of families based, history of residence in terms of years, economically weaker sections, clusters, non-commercial Vs. commercial occupancies, etc., and these are to be debated to bring the issues on hand to a reasonable level of acceptance. The exercise needs to be repeated for a second time. At the end, if a consensus is reached, the project can be considered forward and if it still eludes, the best is pose a conventional sewerage system to JnNURM and await its turn.
- 4) Design of Collection System - With regard to design procedures of the collection systems, the Manning's formula holds good whether it be a circular conduit or a drain.
- 5) Design of Treatment Plants - With regard to treatment, the guidelines in Chapter 5 will however, apply as it becomes appropriate to each location.

8.8 DEWATS

This is an abbreviation of Decentralized Wastewater Treatment System (DEWATS) and has been assigned to a typical system of sewage treatment and resource utilization for greening in isolated habitations. The generalized treatment sequence is shown in Figure 8.14.



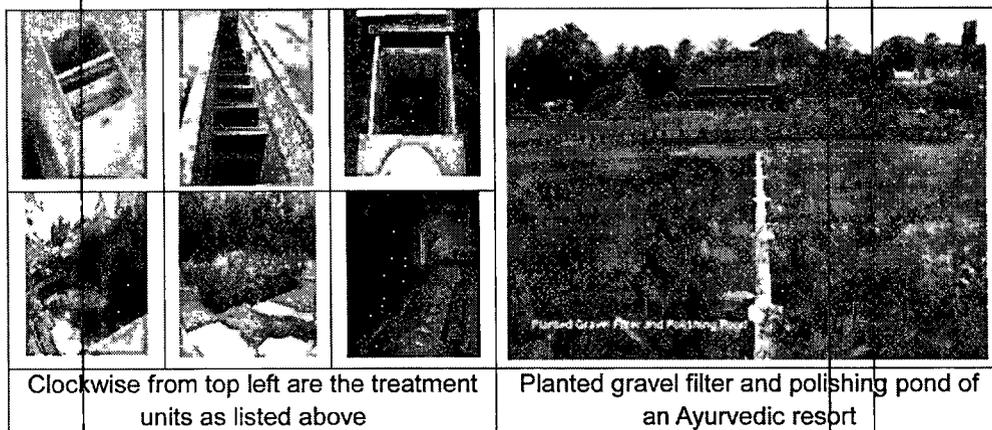
Source: ISPIRATION webpage

Figure 8.14 Schematic treatment process of DEWATS technology

This system is addressed to isolated habitations, where there is a need for non-mechanized and self-operating treatment technology given the premise that adequate land area is available and at reasonable distance from the habitation itself. Another aspect will be to group the toilets or at least bring the sewage from the various centres to the Dewats facility. The typical treatment units are:

- a) Pre-treatment settler: retention time of about 2 hours; BOD reduction by about 30%
- b) Anaerobic Baffled Tank Reactor: retention time of about 24 hours; BOD reduction by about 80%
- c) Anaerobic filter: retention time of about 8 hours; BOD reduction by about 90%
- d) Planted gravel filter: retention time of about 36 hours; BOD reduction by about 90%
- e) Polishing pond.

These have been installed and commissioned in quite a few habitations in India and a compilation of the facility at the earthquake ravaged place of Bhuj in Gujarat is shown in Figure 8.15. The treatment process has its advantage of not dependant on mechanized units but requires relatively large areas away from the habitation and vector propagation control in the planted gravel filters and ponds.



Source: ISPIRATION webpage

Figure 8.15 Typical DEWATS treatment plant components

5.8.4 Stabilization Ponds

5.8.4.1 General

Stabilization ponds are open, flow-through earthen basins designed and constructed to treat sewage and provide comparatively long detention periods extending from a few to several days. During this period the organic matter in sewage is stabilized in the pond through a symbiotic relationship as illustrated in Figure 5.3 earlier. Lightly loaded ponds are also used as a tertiary step in sewage treatment for polishing of secondary effluents and destruction of coliform organisms and are called maturation ponds. In warm climate countries, the pond systems are cheaper to construct and operate compared to conventional methods. They also do not require skilled operational staff and their performance does not fluctuate from day to day. The only disadvantage of pond systems is the relatively large land that they require, but this is sometimes over-emphasized. In addition, land on the outskirts of a growing city can be a worthwhile investment. Pond systems must be considered as an alternative when treatment of sewage or upgrading of existing facilities are planned and the life time costs of various other treatment system should be calculated and compared.

5.8.4.2 Classification

5.8.4.2.1 Aerobic

Aerobic ponds are designed to maintain completely aerobic conditions. The ponds are kept shallow with depth less than 0.5 m and BOD loadings are 40 to 120 kg/ha.d. The pond contents may be periodically mixed by float mounted paddle mixers. Ponds like these give rise to intense algal growth and have been used only on experimental basis

5.8.4.2.2 Anaerobic

Completely anaerobic ponds are used as pretreatment sometimes for municipal sewage. They are also used for digestion of STP sludge. Depending on temperature and waste characteristics, BOD load of 400 to 3000 kg/ha.d and 5 to 50 day detention period would result in 50 to 85% BOD reduction. Such ponds are constructed with a depth of 2.5 to 5 m to conserve heat and reduce land area. They have an odour problem due to sulphide gases.

5.8.4.2.3 Facultative

The facultative pond functions aerobically at the surface while anaerobic conditions prevail at the bottom. The aerobic upper layer oxidizes the sulphide gases and avoid the foul odours. The treatment effected is comparable to that of conventional secondary treatment processes. The facultative pond is suited and commonly used and further discussion in this chapter is therefore, confined to facultative ponds.

5.8.4.3 Mechanism of Purification

The physical, chemical and biological reactions in engineered pond systems are controlled by the design criteria. The functioning of a facultative stabilization pond and symbiotic relationship in the pond are shown schematically in Figure 5-3.

Sewage organics are stabilized by both aerobic and anaerobic reactions. In the top aerobic layer, where oxygen is supplied through algal photosynthesis, the non-settleable and dissolved organic matter in the incoming sewage is oxidized to carbon dioxide and water. In addition, some of the end products of partial anaerobic decomposition such as volatile acids and alcohols, which may permeate to upper layers, are also oxidized aerobically. The settled sludge mass originating from raw waste and microbial synthesis in the aerobic layer and dissolved and suspended organics in the bottom layers undergo stabilization through conversion to methane which escapes the pond in form of bubbles. For each kg of BOD-ultimate stabilized in this manner, 0.25 kg or 0.35 m³ of methane is formed. Another reaction which sometimes occurs in the anaerobic layers is conversion of hydrogen sulphide to sulphur by photo-synthetic bacteria; if present in sufficient numbers they give a distinct pink hue to the pond appearance.

5.8.4.3.1 Aerobic and Anaerobic Reactions

The depth of aerobic layer in a facultative pond is a function of solar radiation, waste characteristics, loading and temperature. As the organic loading is increased, oxygen production by algae falls short of the oxygen requirement and the depth of aerobic layer decreases. Oxygen diffusing from top layers is utilized quickly and completely. Further, there is a decrease in the photo-synthetic activity of algae because of greater turbidity and inhibitory effect of higher concentration of organic matter.

Gasification of organic matter to methane is carried out in distinct steps of acid production by acid forming bacteria and acid utilization by methane bacteria. Production of methane is fundamental to BOD reduction by anaerobic metabolism. If the second step does not proceed satisfactorily there is an accumulation of organic acids in the pond bottom which diffuses towards the top layers. Furthermore, under such conditions the pH of the bottom layers may go down. This would result in complete inhibition of methane bacteria and the pond may turn completely anaerobic due to accumulation of end products of partial anaerobic decomposition. Imbalance between the activities of the two sets of microorganisms in a pond may result from two possible reasons. The waste may contain inhibitory substances which would retard the activity of methane producing organisms and not affect the activity of acid producers to the same extent. In treatment of sewage such a condition, however, does not arise. The other reason for the imbalance may be a fall in the temperature of the pond. The activity of methane bacteria decreases much more rapidly with decreasing temperature as compared to the acid formers and gas production stops at temperatures lower than 15°C. Thus, year round warm temperatures and sunshine provide an ideal environment for operation of the facultative stabilization ponds.

5.8.4.3.2 Diurnal Variations

Both the dissolved oxygen and pH of the pond are subject to diurnal variation due to photosynthetic activity of algae which is related to incident solar radiation. A high dissolved oxygen concentration up to about 4 times the saturation value may be observed in the afternoon hours. Simultaneously, the pH value may reach a maximum of 9.0 or more due to the conversion of carbon dioxide to oxygen. Towards the evening or in the night, when photosynthetic activity decreases or ceases, there is a gradual decrease in both dissolved oxygen and pH.

In properly designed ponds, the dissolved oxygen does not completely disappear from the top layers at any time. The increase of pH is beneficial as it increases the die off rate of faecal bacteria like coliforms.

5.8.4.3.3 Odour Control

In a facultative pond, the nuisance associated with anaerobic reactions is eliminated due to the presence of oxygen in the top layers. The foul smelling end products of anaerobic degradation which permeate to the top layers are oxidized in an aerobic environment. Furthermore, due to a high pH in top layers, compounds such as organic acids and hydrogen sulphide, which would otherwise volatilize from the surface of the pond and cause odour problems are ionized and held back in solution.

5.8.4.3.4 Algae

In stabilization ponds, the significant algae are green which include *Chlorella*, *Scenedesmus*, *Hydrodictyon*, *Chlamydomonas* and *Ankistrodesmus* and blue-green algae which include *Oscillatoria*, *Spirulina*, *Merismopedia* and *Anacystis*. The *Chlorella*, *Scenedesmus* and *Hydrodictyon* possess relatively high oxygen donation capacity per unit weight. However, it is not practical to promote the growth of any particular type of algae in a pond which will depend on such factors as temperature, characteristics of the waste and intensity of sunlight. Concentration of algae in a stabilization pond is usually in the range of 100 to 200 mg/l which gives the pond effluent a typical green colour. Floating blue-green algae mats may develop in ponds during summer months. They are undesirable since they restrict penetration of sunlight leading to reduction in depth of aerobic layer. They also encourage insect breeding.

5.8.4.4 Design Considerations

The facultative pond system, though simple to operate, is a complex ecosystem. It is only by experience and understanding of the reactions that rational criteria are evolved. Appendix A.5.14 presents an illustrative design.

5.8.4.4.1 Areal Organic Loading

The permissible areal organic loading for the pond expressed as kg BOD₅/ha.d will depend on the minimum incidence of sunlight that can be expected at a location and on the percentage of the influent BOD that would have to be satisfied aerobically. Many different methods have been developed for determining the permissible area loading and two methods are discussed here, being

- (a) The BIS has related the permissible loading to the latitude of the pond location to aerobically stabilize the organic matter and keep the pond odour free (Refer IS: 5611) and
- (b) another based on field experience. The recommended loading rates are in Table 5.14 overleaf.

The values are applicable to towns at sea levels and locales where the sky is clear for nearly 75% of the days in a year.

Table 5.14 Permissible Organic Loadings at Different Latitudes

Latitude (N) degree	Organic loading Kg BOD/ha.d
36	150
32	175
28	200
24	225
20	250
16	275
12	300
8	325

Source: CPHEEO, 1993

The values of organic loading given in Table 5.14 may be modified for elevations above sea level by dividing by a factor of $(1+0.003 \text{ EL})$ where EL is the elevation of the pond site above MSL in hundred meters. An increase in the pond area has to be made when the sky is clear for less than 75% of the days. For every 10% decrease in the sky clearance factor below 75%, the pond area may be increased by 3%.

Another design approach, based on field experience in warm climates relates the permissible area BOD loading to the ambient temperature on the assumption that temperature would depend on solar radiation:

$$L_o = 20T - 120 \quad (5.36)$$

where

L_o = design organic load in kg BOD₅/ha/d and

T = average temperature during coldest month of the year in degree Celsius.

The designs based on the two methods given above, as well as other methods developed empirically, wherever possible should be checked against field experience in the region. When the ponds are intended to serve small communities or when they are located close to residences, it will be prudent to adopt lesser BOD loading to fully ensure absence of odours.

5.8.4.4.2 Detention Time and Hydraulic Flow Regimes

The flow of sewage through a pond can approximate either plug flow or complete mixing, which are two extreme or ideal conditions. If BOD exertion is described by a first order reaction, the pond efficiency is given by the equation in the next page:

For Plug flow

$$\frac{L_e}{L_i} = e^{-K_1 t} \quad (5.37)$$

For Complete Mixing

$$\frac{L_e}{L_i} = \frac{1}{1 + K_1 t} \quad (5.38)$$

where

L_i and L_e = influent and effluent BOD respectively,
 t = detention time,
 K_1 = BOD reaction rate constant.

The value of K_1 varies between 0.05 and 0.2 per day and is independent of temperatures above 15°C. The lower values were determined for secondary and tertiary ponds.

In practice the hydraulics lies between the two regimes and is described as dispersed flow. The efficiency of treatment for different degrees of intermixing, characterized by dispersion numbers, can be determined as given in Section 5.8.1.7.12 for aerated lagoons. Dispersion numbers are determined by tracer studies. Dispersion numbers for stabilization ponds vary from 0.3 to 1.0. Choice of a larger value for dispersion number or assumption of complete mixing would give a conservative design and is recommended.

5.8.4.4.3 Depth

Shallow depths in facultative ponds will allow the growth of aquatic weeds in the ponds. The optimum range of depth for facultative ponds is 1.0 - 1.5 m. When depth determined from area and detention period works out lesser than 1.0 m, the depth should be increased to 1.0 m, keeping surface area unchanged.

5.8.4.4.4 Sludge Accumulation

The rate of sludge accumulation in facultative ponds depends primarily on the suspended solids concentration in the sewage. It varies from 0.05 to 0.10 m³/capita/year. A value of 0.07 m³/capita/year forms a reasonable assumption in design. In multiple cell ponds operated in series, most of the sludge accumulation will be in the primary cells. Continued sludge accumulation in ponds over many years will cause (i) sludge carryover into the effluent, (ii) development of aquatic weeds, and (iii) reduction in pond efficiency due to reduction in the detention period. Facultative ponds therefore require periodical desludging at intervals ranging from 6 to 12 years.

5.8.4.4.5 Bacterial Reduction

Bacterial reduction in ponds is similar to BOD reduction except the BOD reduction rate constant is replaced by bacterial die off constant, K_b and inputs and outputs are in terms of bacterial concentrations N_i and N_e , respectively.

It is customary to use completely mixed conditions when calculating bacterial reduction. This gives a conservative design. Overall bacterial reduction in 'n' ponds of equal detention time 't' in series is given by

$$\frac{N_e}{N_i} = \frac{1}{(1 - K_b t)^n} \tag{5.39}$$

A commonly used value of K_b for faecal bacteria at 20°C is 2.0 per day. The value of K_b at other temperatures may be calculated by

$$K_{b(T)} = K_{b(20)} (1.19)^{(T-20)} \tag{5.40}$$

where,

$K_{b(T)}$ and $K_{b(20)}$ are values of the constant at T and at 20°C respectively.

5.8.4.4.6 Mosquito Aspects

It is popularly believed that ponds will promote the growth of mosquitoes. This is not true. The stages of growth of mosquitoes are shown in Figure 5.43.

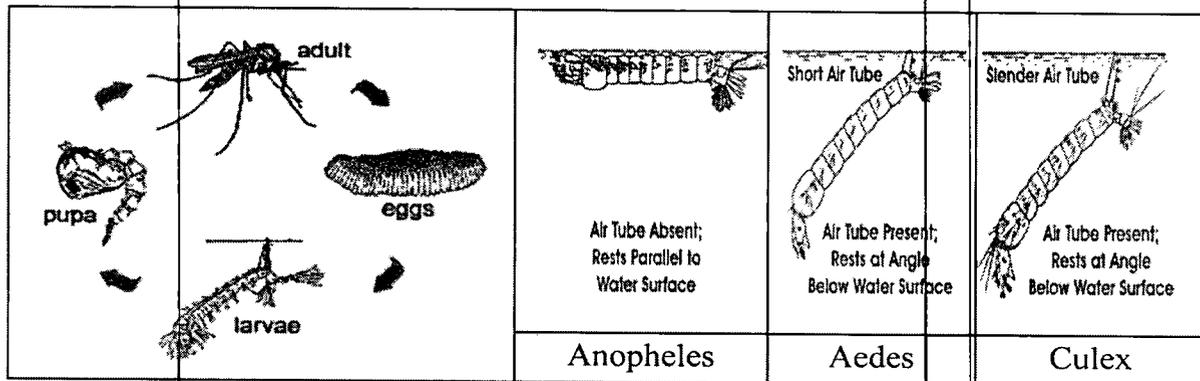


Figure 5.43 Stages of Mosquito growth and Larvae Stage Breathing near Water Surface

It may be seen that the mosquito eggs becomes larvae and they must breathe air to survive. This is why the larvae generally remain just beneath the surface of the water. There are three broad types of mosquito larvae like this. These are Anopheles, Aedes and Culex. The Anopheles lay parallel to the water's surface in order to get a supply of oxygen through a breathing opening. The other two types have siphon tubes and lay beneath the water surface and the siphon pipe punctures the water and protrudes into the air. After some days in the larval stage they grow to pupa and then adults. In a well operated pond free of any weeds, the wind causes the water surface to be continuously oscillating non-stop. Due to this, raw sewage gets into the breathing system of the larvae and chokes them. Thus the ponds do not promote mosquitoes. Hence, the pond shall be free of weeds which will otherwise prevent the oscillation of the water surface.

5.8.4.5 Construction Details

5.8.4.5.1 Site Selection

Facultative pond sites should be located as far away as practicable (at least 200 m) from habitations or from any area likely to be built up within a reasonable future period. If practicable the pond should be located such that the direction of prevailing wind is towards uninhabited areas. The pond location should be downhill of ground water supply source to avoid their chemical or bacterial pollution. Special attention is required in this regard and in porous soils and in fissured rock formations. The pond site should not be liable to flooding and the elevation of the site should permit the pond to discharge the effluent by gravity to the receiving streams. The site should preferably allow an unobstructed sweep of wind across the pond and open to the sun. Trees should not be grown in the bunds and for an annular distance of 10 m from the toe of the bunds. Advantages should be taken of natural depressions while locating the ponds.

5.8.4.5.2 Pre-treatment

Medium screens and grit removal devices shall be provided before facultative ponds.

5.8.4.5.3 Construction in Stages

In cases where the design flow will occur only after a long time, it is important to design facultative ponds in multiple cells and construct the cells in stages. Otherwise, the small flows in the initial years may not be able to maintain satisfactory water levels in the ponds. This will cause objectionable weed growths. The weeds will prevent the water surface from oscillation by wind. Hence mosquitoes can breed and multiply. Construction in stages will also reduce initial costs and help in planning future stages based on the performance data of the first stage.

5.8.4.5.4 Multiple Units

Multiple cells are recommended for all except small installations (0.5 ha or less). Multiple cells in parallel facilitate maintenance as any one unit can be taken out of operation temporarily for desludging or repairs without upsetting the entire treatment process. The parallel system also provides better distribution of settled solids. Multiple cells in series decrease dispersion number and enable better BOD and coliform removal and reduced algal concentration in the effluent. The series system implies a high BOD loading in the primary cells and to avoid anaerobic conditions in these cells, they should have 65% to 70% of the total surface area requirements. A parallel series system possesses the advantages of both parallel and series operations. A convenient arrangement for this system consists of three cells of equal area, of which two are in parallel and serve as primary ponds and the third serves as secondary pond in series. Individual cell should not exceed 20 ha in area.

5.8.4.5.5 Pond Shape

The shape should be such that there are no narrow or elongated portions. Rectangular ponds with length not exceeding three times the width are to be preferred. Maximum basin length of 750 m is generally adopted. The comers should always be rounded to minimize accumulations of floating matter and to avoid dead pockets.

5.8.4.5.6 Embankment

Ponds are usually constructed partly in excavation and partly in embankment. The volume of cutting and the volume of embankment should be balanced to the maximum extent possible in order to economize construction costs. Embankment materials usually consist of material excavated from the pond site. The material should be fairly impervious and free of vegetation and debris. The embankment should be compacted sufficiently. The top, width of the embankment should be at least 1.5 m to facilitate inspection and maintenance. The free board should be at least 0.5 m in ponds less than 0.5 ha in area. In larger installations, the free board should be designed for the probable wave heights and should be at least 1.0 m. Embankment slopes should be designed based on the nature of soil, height of embankment and protection proposed against erosion. Outer slopes are generally 2.0 to 2.5 horizontal to 1 vertical. Inner slopes are made 1.0 to 1.5 when the face is fully pitched and flatter and 2.0 to 3.0, when the face is unprotected. Inner slopes should not exceed 4 as flatter slopes create shallow areas conducive to the growth of aquatic weeds. The outer faces of the embankments should be protected against erosion by turfing. The inner faces should preferably be completely pitched to eliminate problems of erosion and growth of marginal vegetation. Pitching may be by rough stone revetment or with plain concrete slabs or flat stones with adequate gravel backing. When complete pitching is not possible, at least partial pitching from a height 0.3 m above water line to 0.3 m below water line is necessary and the face above the line of pitching should be turfed to the top of embankment. A properly constructed pond is shown in Figure 8.10 in this manual.

5.8.4.5.7 Pond Bottom

The pond bottom should be level, with finished elevations not more than 0.10 m from the average elevation. The bottom should be cleared of all vegetation and debris. The soil formation of the bottom should be relatively impervious to avoid excessive liquid losses due to seepage. Where the soil is loose, it should be well compacted. Gravel and fractured rock areas must be avoided.

5.8.4.5.8 Pond Inlets

The pipeline conveying raw sewage to the pond, whether by gravity or by pumping, should be terminated in a flow measuring chamber located close to the pond. There should be sufficient fall from the measuring chamber to the pond surface so that the measuring weir may not be submerged. If the pond installation is in multiple parallel cells, the measuring chamber should have flow splitting provision and there should be separate pipeline to each cell. The size of the pipeline may be designed to maintain an average velocity of 0.3 m/s. The pipeline should be semi-flexible and should be properly supported inside the pond. In case the pond cell is large, multiple inlets should be provided along the inlet side of the pond at the rate of one for every 0.5 to 1.0 hectare of pond area. This requirement applies also to outlets. In case the pond is small, a single inlet and a single outlet will be sufficient. The inlets in the pond shall be so located as to avoid short-circuiting of flow to the outlets. The inlets should not be upwind of the outlets and should be extended into the pond for one-third to one-fourth the pond length or 15 to 20 m, whichever is less. The discharge may be horizontal and at half depth. A concrete apron of adequate size should be provided under the discharge to prevent erosion of pond bottom, especially when the pond is being filled up.

5.8.4.5.9 Pond Outlets

Multiple outlets are desirable except in small ponds and may be provided at the same rate as for inlets, one for every 0.5 ha pond area. The outlets should be so located with reference to the inlets as to avoid short-circuiting. The outlet structures may consist either of pipes projecting into the ponds or weir boxes. In the former case vertical tees and in the latter case hanging baffles submerged to a depth of 0.25 m below the water surface should be provided to ensure that floating algal scum is not drawn along with the effluent. When the outlet structure is a weir box, it is desirable to provide adjustable weir plates so that the operating depth in the pond can be altered if required. Where the pond effluent is to be used for farming and involves pumping, the outlet pipe should be led to a sump of adequate capacity (30 minutes at the rate of pumping). All piping should be provided with suitable valves to facilitate operation and maintenance.

5.8.4.5.10 Pond Interconnections

Pond interconnections are required when ponds are designed in multiple cells in series. These interconnections should be such that the effluent from one cell withdrawn from the aerobic zone can be introduced at the bottom of the next cell. Simple interconnections may be formed by pipes laid through the separating embankments. At their upstream ends, the interconnecting pipes should be submerged about 0.25 m below the water level. The downstream ends may be provided with a bend, facing downward, to avoid short-circuiting by thermal stratification, care being taken to prevent erosion of the embankment.

5.8.4.5.11 Other Aspects

Provision should be made for flow measurement both at inlet and outlet of the ponds, wherever practicable, facilities should be available to drain out the pond completely by gravity through a sluice arrangement. The pond site should be fenced to prevent entry of cattle and discourage trespassing. Public warning boards should also be put up near the ponds clearly indicating that the pond is a sewage treatment facility.

5.8.4.6 Performance

The algae in the pond effluent will exert BOD in the standard laboratory BOD test involving darkroom incubation and will give high SS values. The BOD and SS values may each be in the range of 50 to 100 mg/l. However, the effluent will not cause nuisance when disposed of on land or discharged into receiving waters because the algal cells do not readily decompose or exert oxygen demand under natural conditions, in fact, the algae increases the oxygen levels in the receiving water by continued photosynthesis.

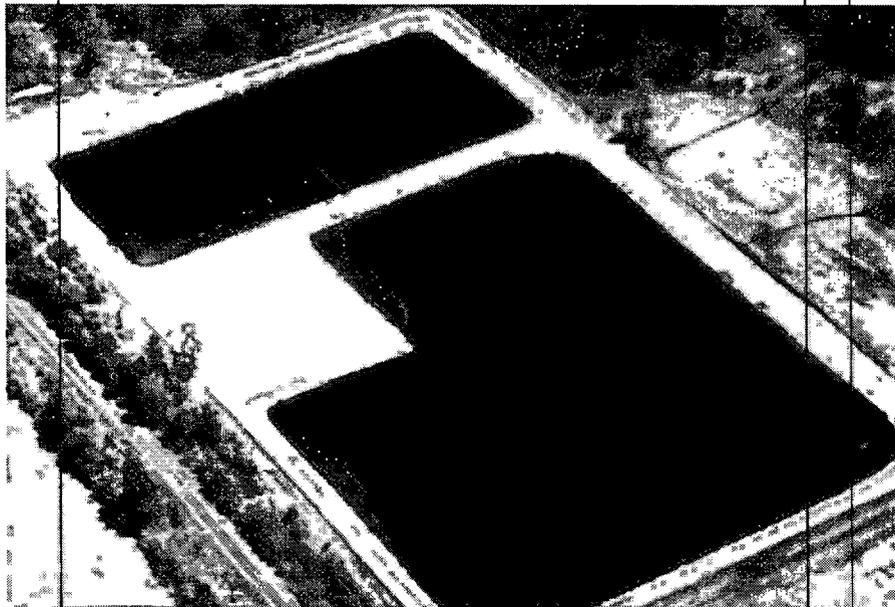
Because of the above reasons, the standard BOD and SS tests are not considered useful for evaluating the quality of facultative pond effluents.

The quality is usually assessed based on the BOD_5 of the filtered effluent, the assumption being that the suspended solids in the effluent are all algae. The filtration procedure adopted for the test is the same as for the suspended solids test.

Well designed facultative ponds give about 80% to 90% BOD reduction based on the filtered BOD₅ of the effluent. Facultative ponds also effect high bacterial reduction, the efficiency being particularly high in multi cell ponds operated in series. Coliform and faecal streptococci removals are as high as 99.99%. Intestinal pathogens belonging to Salmonella and Shigella groups are reportedly eliminated in stabilization ponds. Cysts of Entamoeba Histolytica and Helminthic larvae are also eliminated.

5.8.4.7 Construction for Filtering Out Algae

The algae flowing out of the pond need not be removed when the treated sewage is used for crop irrigation. The most appropriate technique for this is a rock filter, which consists of a submerged porous rock bed within which algae settle out as the effluent flows through. The algae decompose releasing nutrients which are utilized by bacteria growing on the surface of the rocks. In addition to algal removal, significant ammonia removal may also take place through the activity of nitrifying bacteria growing on the surface of the filter medium. The performance depends on loading rate, temperature and rock size and shape. The permissible loading increases with temperature and in general an application rate of 1.0 m³ of pond effluent per m³ rock bed per day should be used. Rock size is important, as surface area for microbial film formation increases with decreasing rock size but, if the rocks are too small, then problems can occur with clogging. Rock size is normally 75 to 100 mm, with a bed depth of 1.5 to 2.0 m. A typical rock filter is shown in Figure 5.44.



Source. Duncan Mara

Figure 5.44 Rock Filter Installed in the Corner of a Pond at Veneta, Oregon, USA

The effluent should be introduced just below the surface layer because odour problems are sometimes encountered with cyanobacterial films developing on wet surface rocks exposed to the light. Construction costs are low and very little maintenance is required, although periodic cleaning to remove accumulated humus is necessary, but this can be carried out during the cooler months when algal concentrations are lowest.

ALTERNATIVE TREATMENT TECHNOLOGIES FOR WASTEWATER TREATMENT IN DRAINS

In Compliance to Direction of Hon'ble NGT in the Matter of OA No. 06/2012

Titled Manoj Mishra Vs Union of India & ORS



February, 2020

CENTRAL POLLUTION CONTROL BOARD, DELHI

7. CHALLENGES WITH APPLICATION OF ALTERNATIVE BIOLOGICAL TREATMENT TECHNOLOGY

- Application of any *in-situ* bioremediation of wastewater requires obstruction wall (check dam / weir) to slow down the velocity of flowing water. Any flowing wastewater in storm water drains carry huge volume of floating material (solid waste, plastic waste etc.) and silt. Such obstruction to slow down of the velocity of wastewater results in trapping of floating material and deposition of silt.
- Siltation of drains will result in ponding of wastewater in upstream of such structures that may also result in flooding of upstream areas. Therefore, provisions must be made for regular removal and proper disposal of deposited silt. Floating matter collected also need to be disposed off in scientific manner.
- Spacing between the gabions need to be cleaned on regular basis as it may get choked with silt and floating materials.
- Efficiency decrease in monsoon due to high flow.
- It needs regular harvest of biomass and cleaning of physical filters.
- Difficult to operate when depth of water in drain is more than three feet.
- Slow process as compared to conventional treatment.
- Not effective in backwater, flood water from river on high tides.

8. CASE STUDIES ON DIFFERENT ALTERNATIVE TREATMENT TECHNOLOGIES

Case studies of some of the wastewater interception, diversion and treatment facilities based on alternative treatment technologies namely constructed wetland, soil biotechnology, oxidation pond, trickling filter and aerated lagoon are as under:

8.1 Constructed Wetland

- a) Constructed wetland has been established at Neela Hauz lake near Sanjay Van by Centre for Environmental Management of Degraded Ecosystems (CEMDE), Delhi University in collaboration with DDA. The lake is fed by discharge from drain having 01 MLD flow. The constructed wetland effectively results in 90% reduction in BOD and has resulted in restoration of the Neela Hauz lake which was practically dead due to high pollution load. The project was started in November, 2016 and is currently in operation; it was constructed at a cost of Rs. 10 lakhs and requires annual harvest of dead biomass and annual cleaning of physical filters and removal of sludge from oxidation ponds.
- b) In-situ constructed wetland system at Rajokari water body was installed by Irrigation and Flood Control Department, Delhi with a project cost of Rs. 77.19 lakhs. The water body is fed by a drain having flow of 600 KLD. There is 84% reduction in BOD in the water body post construction of the wetland. The wetland is currently in operation.
- c) Ex-situ remediation for water body rejuvenation through Phytoid technology developed by CSIR-NEERI. This project has been implemented Pan India in 300 sites and is currently in operation in all the sites. The cost of the project was Rs 2.2 crore per

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Urban water resource management: experience from the revival of Rajokri lake in Delhi

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**Research article****Urban water resource management: experience from the revival of Rajokri lake in Delhi****Ankit Srivastava¹, Prathna T.C.^{2,*}**¹ Delhi Jal Board, Government of the National Capital Territory of Delhi, New Delhi, India² Department of Irrigation and Flood Control, Government of the National Capital Territory of Delhi, New Delhi, India* **Correspondence:** Email: prathna.tc@gmail.com.

Abstract: Water bodies are critical in maintaining and sustaining ecosystems. However, urban water bodies are often ignored during development projects, and comprehensive plans for their revival and rejuvenation are not seen as priorities. This paper describes the rejuvenation project for a dry water body at Rajokri, Delhi, India. A “scientific wetland with active biodigester” (SWAB) system was developed to treat domestic wastewater, which was then used to fill the lake. The SWAB effectively removed about 89% removal of oil and grease, 86% biological oxygen demand (BOD), 85% chemical oxygen demand (COD) and 86% of total suspended solids (TSS) when the respective inlet concentrations were 18 ± 1.14 mg/L, 124 ± 2.9 mg/L, 480 ± 11.9 mg/L and 116 ± 1.82 from the raw wastewater. The SWAB system provides completely natural treatment with zero electrical consumption. The revival of the water body using a decentralized wastewater treatment system has immensely helped in management of urban wastewater, ground water recharge and enhanced ecosystem and biodiversity values. The project demonstrates the integration of socio-cultural, societal, ecological, ecosystem and technological aspects for the revival of the lake.

Keywords: revival; water body; wastewater; rainwater; water quality; ground water

Abbreviations: SWAB: Scientific Wetland with Active Biodigester; WWTP: Wastewater treatment plant; MLD: Million litres per day; BOD: Biological oxygen demand; HRT: Hydraulic retention time; COD: Chemical oxygen demand; TSS: Total suspended solids; TDS: Total dissolved solids; MSW: Municipal solid waste; C&D: Construction and demolition

1. Introduction

Freshwater bodies such as ponds, lakes and reservoirs have always dotted the landscape of India and, historically, met the population's water supply demands. However, factors like rapid urbanization, population explosion and improper water resource management have caused water bodies to dry up, leading to water crises in many major cities [1]. Urbanization affects the hydrologic cycle by causing (i) increased water scarcity; (ii) urban flooding due to concretization; (iii) water pollution, and (iv) changes in surface water as well as groundwater recharge [2,3]. This problem is acute in most developing nations due to either the absence of guidelines or failure to implement laws safeguarding urban water bodies strictly. Over the years, major cities in India – e.g., Delhi, Chennai, Hyderabad, and Bengaluru – have recorded the disappearance of water bodies due to encroachments and delays in restoration [4,5]. The situation elsewhere in the developing world is no different. China has lost nearly 25% of its urban lakes in the last decade [6] while Indonesia has lost 10 to 20% of its urban lakes over the years due to issues like illegal encroachment, garbage dumping, changing land use patterns and landfilling [7].

Awareness has been increasing among governments, non-government organizations, public-private partnerships, and local stakeholders in developing countries of the need to safeguard and revive existing water bodies. However, water body revival and long-term conservation are complex, and involve thorough knowledge of the water body, its water sources, the effective cost and time required for its revival, and the management plan for its conservation [8]. Every water body is unique and requires a specific revival plan based on its existing condition, hence the need for a framework for water body restoration. While an advisory on urban water body conservation and restoration is available from the Indian Government's Ministry of Housing and Urban Affairs [8], a water body restoration framework is still lacking in India as in many other developing countries.

Untreated domestic wastewater discharging into water bodies is a reality in urban societies of the developing world. In many instances, not all parts of the city, especially in middle- and lower-income countries, may be connected to the sewer network. For example, only 1% of the urban population in Uganda is connected to sewers while <10% of total wastewater generated in Vietnam, Indonesia and Philippines is conveyed to wastewater treatment plants (WWTPs) for treatment [9]. Bringing all localities into the sewer network for centralized wastewater treatment may not be technically or economically feasible for most countries in the lower and middle-income developing world [10].

Decentralized wastewater treatment technologies provide advantages in terms of cost, land availability, ease of installation and operation as compared to centralized wastewater treatment. Some of the commonly used decentralized wastewater treatment technologies in the developing world include DEWATS (Open Source Constructed Wetland Technology) and Phytoid [11]. These systems utilize constructed wetlands coupled with a host of other physical and biological treatment technologies. The selection of appropriate technical configuration in DEWATS depends on factors such as volume and quality of wastewater, cost, local conditions, social acceptance and end use of the treated water. Phytoid, on the other hand, is based on re-engineered wetland systems to solve wastewater quality issues. However, both these technologies may not be feasible when the land availability is limited [11]. Therefore, use of other appropriate technologies for decentralized wastewater treatment and their use for revival of water bodies was explored in the current study. Scientific wetland with active biodigester (SWAB) is a model developed as a sustainable alternative to conventional wastewater treatment.

The major objective of this work is to describe the revival of a water body at Rajokri in Delhi, India, and propose a framework for such efforts. The scientific wetland with active biodigester discussed is a natural and sustainable treatment system implemented by the Government of Delhi to revive water bodies, and offers particular benefits when limited land is available. The multifold goal of the project was to create a lake that could efficiently treat all the sewage water flowing in, while also containing clean water throughout the year. Additionally, the revival of the lake was supposed to serve as an inclusive community centre and a natural ecosystem.

2. Methodology

2.1. Study area

Rajokri Lake (28°30'44.92" N 77°07'10.28" E) is in Rajokri village, near Delhi (India) and covers a little less than 9500 m². The region is in the sub-tropical zone with mild winters alternating with extremely hot summers with average temperatures ranging between 40–45 °C in summers and 4–5 °C in winters [12]. The location of the study area is shown in Figure 1.

2.2. Study design

2.2.1. Discharge of domestic wastewater

Until 2017, domestic wastewater from the adjoining semi-urban settlements of Rajokri village were channelled through open drains into the lake, which became a breeding ground for communicable diseases.

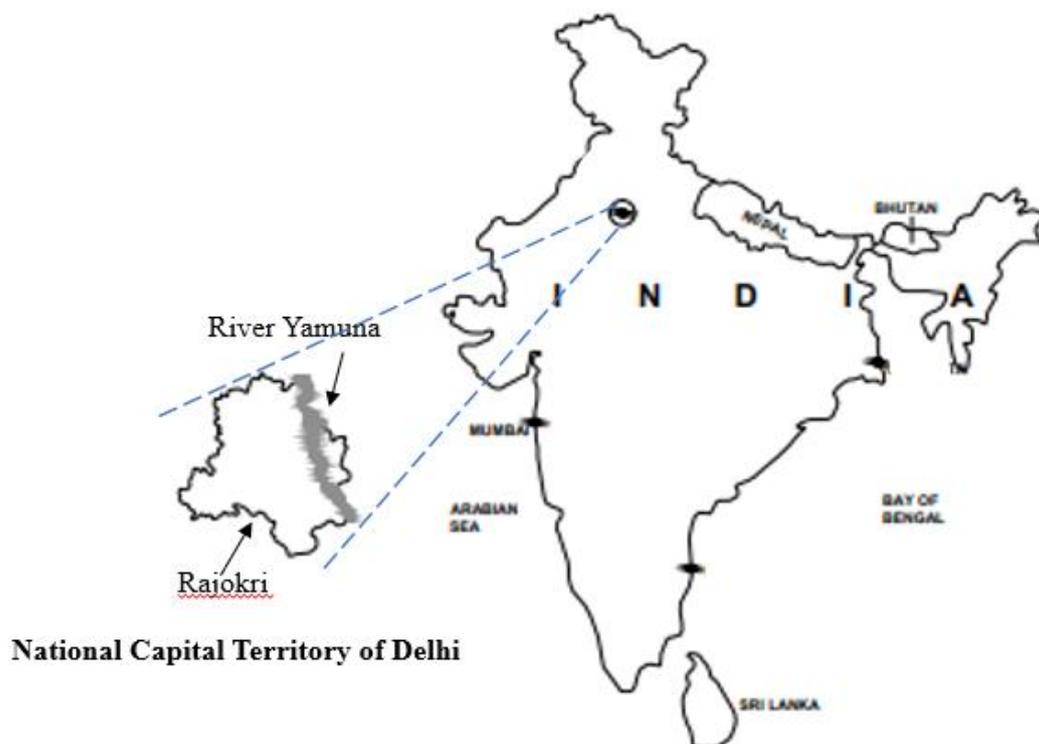


Figure 1. Location of the study area.

2.2.2. Construction of a wastewater treatment plant (WWTP)

The design capacity of the WWTP is based largely on the flow-through volume – i.e., the amount of water required to fill and maintain the water body throughout the year. Of the total area available, the water spread area - i.e., the area of land covered by water – was determined as about 2000 m², using government records and Google Earth Pro. Wastewater from the surrounding areas was channeled through a single inlet and a 0.6 million litres per day (MLD) WWTP was designed.

2.2.3 WWTP Components

The influent wastewater has high biological oxygen demand (BOD) levels. Since limited land was available for the WWTP, a SWAB-based natural system was used. This has two components: a sedimentation tank and a gravel bed.

Sedimentation-cum-biodigester tank

The influent wastewater to the WWTP was channelled to a collection tank with 6-hour hydraulic retention time (HRT), enough to handle the peaks flows. The wastewater passes through 25 mm pass size mesh filters, which remove large solids and plastic, and then to a 0.76 ML sedimentation-cum-biodigester tank containing baffle wall partitions with an HRT of 16 hours. There are five baffle walls with alternate slots top and bottom, partitioning the tank into six compartments. The tank functions both to remove relatively large particles by sedimentation and initiate anaerobic digestion as it contains a mix of microorganisms isolated from centralized WWTPs. The partially treated water flows on to a gravel bed for further treatment.

Gravel bed

Solar-powered pumps lifted the partially treated wastewater from the sedimentation tank to the gravel bed (wetland system), which has 15 chambers. These are 2.5 m deep on average and contain pebbles that vary in size between 80 and 300 mm. The HRT is 24 hours. The pebbles in the gravel bed increase in size from top to bottom. *Cyperus alternifolius* (commonly known as Umbrella Papyrus) and *Canna indica* pre-treated with natural auxins to enhance their bioremediation efficiency were obtained from National Environmental Engineering Research Institute (NEERI), India. These wetland plants are grown in the gravel bed to provide further treatment. Figure 2 shows the lake management plan developed for Rajokri.

2.3. Water quality analysis

Parameters including pH, total suspended solids (TSS), total dissolved solids (TDS), oil and grease, BOD, COD, dissolved oxygen and total coliforms were measured using the APHA protocols [13]. Measurements were conducted every alternate day in January 2020 (one during peak and the other during off-peak hours) and statistical analysis was performed. The average influent parameters of the wastewater were with a pH of 6.3 ± 0.05 , oil and grease of 18 ± 1.14 mg/L, biological oxygen demand (BOD) of 124 ± 2.9 mg/L, chemical oxygen demand (COD) of 480 ± 11.9 mg/L, total suspended solids (TSS) of 116 ± 1.82 and total coliforms of 1.1×10^7 .



Figure 2. Rajokri lake development plan.

3. Results and discussion

3.1. Clearing the lake premises

The lake site was a municipal solid waste (MSW) dumping ground for some years. At the start of the revival project, the flow of domestic wastewater into the lake was stopped, and the MSW and

residual wastewater were cleared from it. The water was discharged onto forestland nearby. The accumulated sludge and solid waste were then cleared from the lake bottom to promote groundwater recharge and increase the lake's capacity. Many dry water bodies serve as dumping grounds for or are encroached upon by all types of wastes, the commonest being construction and demolition (C&D) waste, MSW and domestic wastewater. C&D waste is a major concern in cities worldwide, particularly in developing countries. Beijing, for example, generated 40 million tonnes of C&D waste in 2014, less than 5% of which was recycled [14]. On the other hand, Japan recycles nearly 95% of its C&D waste [15]. The situation in India is the same as in other countries with rapid urbanization. The floods in Chennai in 2015 were caused by the storm water drains clogging due to indiscriminate dumping of MSW and C&D waste [16]. Many countries have introduced landfill taxes to promote C&D waste recycling [17]. MSW that finds its way into water bodies can damage ecosystems and its disposal should be controlled by local authorities.

Silt often finds its way into water bodies after rainfall and soil erosion. Static water bodies need desilting regularly to promote groundwater recharge and maintain water storage capacity. Desilting guidelines are provided in the draft, Indian sediment management policy [18].

3.2. Water source

India receives most of its rainfall during the monsoon - July and September - with a small proportion being brought about by cyclones and convectional rainfall. Delhi receives nearly 90% of its 740 mm annual rainfall in these monsoon months. Owing to the limited annual rainfall received by the city, it was not feasible to depend on conventional methods of water-body rejuvenation, which often involves cleaning the polluted water bodies and letting it get recharged with rainwater. It is important, therefore, to ensure that other water sources are available. The situation concerning the need for other sources is similar in most parts of the world [19,20].

Taking rainfall as the primary water source, other sources were identified in the study including, for instance drains, treated water from WWTPs, sewers and stormwater. In 2019, Delhi generated nearly 3270 MLD of sewage much of which went to WWTPs [21]. About 410 MLD of the treated effluent is used for non-potable purposes including horticulture and cooling plants and is still a less explored water resource [22]. However, it was not economically and technically feasible to divert treated water from nearby WWTPs to fill Rajokri lake since the area is located uphill. At Rajokri, untreated wastewater from drains was available throughout the year for use as an alternative source. Pipelines were put in place to ensure raw wastewater from the drains was channelized to a large drain, which in turn entered the WWTP for treatment. The wastewater in the large drain initially passed through mesh filters to remove plastic and other large solid material.

3.3. Assessing WWTP capacity

Water is lost from lakes, etc, largely by evaporation and percolation, and this must be taken into account when calculating the water body's volume. The amount lost daily is effectively "consumed" as it is lost from the system [23]. The evaporation rate from water bodies in Delhi is taken as 2.5 m/a [24]. The rate of percolation from the lake will be affected mainly by the area of the lake bed, depth of the water above the bed and the soil type. Lighter texture soils for example provide greater opportunity for more rapid soil water movement which is reflected in more rapid rates of percolation than heavier texture soils. The Central Groundwater Board of India (CGWB) reports that soils in the

Delhi area are mostly light with some of medium texture [25] with the Sewerage Master Plan of Delhi confirming the presence of newer alluvium (mixture of clay, sand and silt) at Rajokri. The area of Rajokri lake is about 2000 m², and its depth between 1.5 and 1.8 m at the deepest, so its maximum holding capacity is about 3600 m³ (assuming that the lake's sides are almost vertical below the water surface). The capacity of the WWTP was ascertained after taking into account daily water losses from the lake and availability of raw wastewater. The capacity of the WWTP was assessed to be 600 m³ which consisted of two major components- a biodigester and gravel bed.

The lake occupied 2000 m² of the total 9500 m² land area available. The WWTP's footprint was 600 m² and the remaining area was landscaped with an amphitheater, open gym, walkway and space for cultural activities. The purpose of landscaping in this project was to both enhance the landscape of the area and also benefit the people on a long-term basis.

3.4. SWAB based natural treatment system to revive the lake

The type of treatment system used depends on issues including wastewater quality, intended end use and land available. A WWTP consisting of both physico-chemical and biological components was installed at Rajokri because the aim was to fill and recharge the lake. Table 1 is a comparison of the commonest forms of constructed wetland used in India [11].

Table 1. Commonly used wetland technologies for wastewater treatment in India.

Requirement for 1 MLD with DEWATS [26]	Phytoid [27]	SWAB (present study)
250 to 20 mg-BOD/L		
Footprint (m ²)	4000–5000	~2000
Gravel bed depth (m)	1–1.5	2–2.5
Carbon removal	Oxidized to carbon dioxide	Converted to methane in the absence of oxygen
		Converted to methane which is oxidized to carbon dioxide through biological processes

The major purpose of the biodigester is to break down organic matter, and activated sludge from conventional WWTPs may be used in it to contribute the active culture required for biodigestion. The biodigester has a second role in removing finer solids, which settle as sludge containing significant amounts of BOD. On average, 30 to 40% BOD and 50% suspended solids can be removed using a digester with 48-hour HRT [28]. At Rajokri, BOD and TSS removal in the digester were 53 and 65% of influent concentrations of 124 ± 2.9 and 116 ± 1.82 mg/L respectively.

The partially treated wastewater flows from the digester to the gravel bed (Figure 3). The gravel bed incorporates wetland plants that have extended root systems as a stress response to toxic metals in the wastewater [29]. The rhizosphere around the roots provides a suitable environment for microbes to degrade and assimilate contaminants. Phytohormone treatment of wetland plants has been studied to increase biomass, lengthen lifespan, speed root growth and improve stress responses to metal toxicity [29]. The plants used in any system should be selected on the basis of local availability and influent water quality. *Canna indica* and *Cyperus* sp. treated with indole 3-acetic acid were procured externally and used at Rajokri to improve the bioremediation potential. The role of exogenous phyto auxin treatment in enhancing root growth and thereby bioremediation efficacy has been studied extensively [30]. An aerial image of the location of the biodigester system and the construction wetland system is shown in Figure 4.



Figure 3. Gravel bed with wetland plants to treat biodigester effluent.



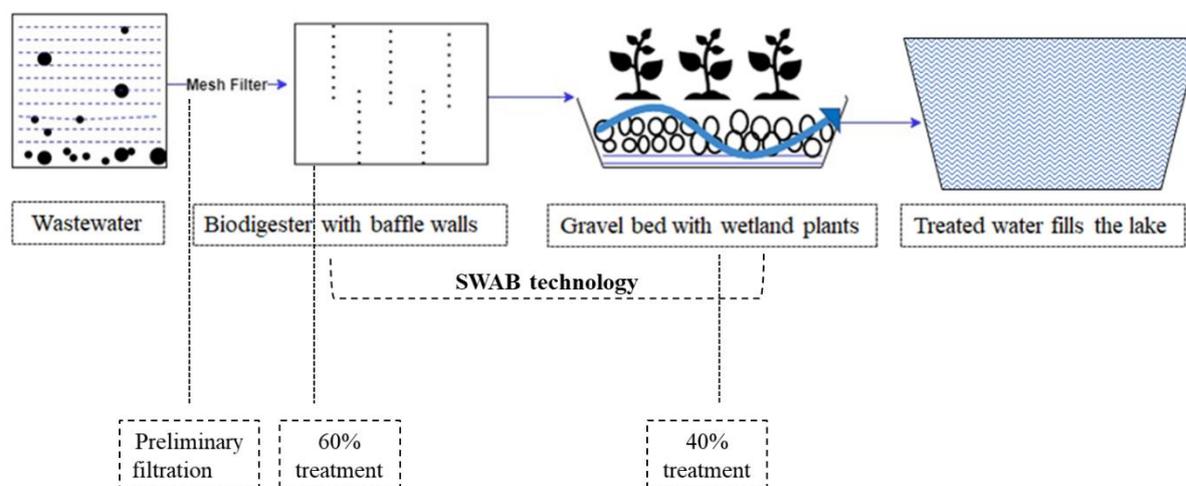
Figure 4. Aerial image of the SWAB system (1) Biodigester (2) Scientific Wetland and (3) Floating wetlands.

Wetland systems are effective in removing TSS and BOD, and nutrients like nitrogen and phosphorus, as well as pathogens and trace pollutants. The influent and effluent water quality parameters for Rajokri are shown in Table 2.

Table 2. Influent and effluent water quality at Rajokri Lake, after revival.

Parameter	Water Quality	
	Influent	Effluent
pH	6.3 ± 0.05	6.5 ± 0.09
Oil and grease (mg/L)	18 ± 1.14	2 ± 0.36
BOD (mg/L)	124 ± 2.9	17 ± 0.9
COD (mg/L)	480 ± 11.9	71 ± 3.28
TSS (mg/L)	116 ± 1.82	16 ± 0.61
Total Coliforms	1.1 x 10 ⁷	6 x 10 ³

About 89% of the influent oil and grease, 86% of BOD, 85% of COD and 86% of TSS were removed from initial concentrations of 18 ± 1.14 mg/L, 124 ± 2.9 mg-BOD/L, 480 ± 11.9 mg-COD/L and 116 ± 1.82 mg-TSS/L respectively. Random grab samples were collected approximately monthly from the biodigester and the constructed wetland system, and determined for water quality parameters. Slightly better BOD removal efficiency was observed in summer, and corresponded to increased nitrogen and phosphorus removal. However, no significant seasonal changes in COD or TSS removal were observed. This is in line with the findings of Varma *et al* [31]. Rajokri is in the sub-tropical zone and experiences mild winters, and the wetland plants were locally sourced and could therefore withstand the seasonal variations. A schematic showing the decentralized wastewater treatment system (SWAB technology) used to rejuvenate the lake is shown in Figure 5.

**Figure 5.** Schematic showing SWAB technology used to rejuvenate Rajokri lake.

Treated water from the WWTP was used to refill the lake, where many floating wetland plants help further in filtering and polishing the water. Floating wetlands were constructed using rafts made of PVC tube and wire mesh. The area surrounding the lake was landscaped with native trees and grasses, with minimum use of construction material, to enhance groundwater percolation. Figure 6 is an aerial view of Rajokri Lake after revival.



Figure 6. Aerial view of the revived lake at Rajokri.

3.5. Cost analysis

The basic capital costs for constructed wetlands include those of the land, site investigation, labor for earthworks and construction, construction and other materials, and media and vegetation, etc [32]. Operating and maintenance costs are comparatively lower for constructed wetlands than conventional wastewater treatment systems. Maintenance may include cleaning the screens/grit chambers, pumping water, etc [32]. The capital cost of the SWAB system at Rajokri was approximately 105,000 USD. Sludge from the biodigester can be removed annually as part of maintenance, while the constructed wetland system might require cleaning once every four years and has negligible maintenance costs. Flow in the treatment system is driven mainly by gravity, with only transfer from the biodigester to the gravel bed requiring a pump. The pump uses solar energy and operating costs are low. The cost of treatment is less than 0.014 USD/KL which is cheaper than the conventional cost of wastewater treatment. The environmental accrued from the project need to be considered while evaluating the cost benefit considerations.

3.6. Concerns and challenges

The main constraints pertaining on water body revival, based on experience at Rajokri, are:

- (a) Siltation: silt and fine minerals settle in the water body over time, impeding percolation and inhibiting recharge, so regular desilting is needed. The bund around Rajokri Lake was strengthened with native plants to reduce erosion of silt and minerals significantly.
- (b) Sewage: Raw sewage from local unsewered areas often finds its way into the lake, increasing the BOD and lowering the DO. It is important, therefore, to try to stop such flows. At Rajokri, prior to intervention, wastewater from surrounding areas was discharged directly to the lake. During restoration, wastewater was channeled into a common inlet tank for the WWTP. Enforcement of regulations and monitoring of the site is required to ensure no discharge reaches the lake untreated.
- (c) Encroachment: Indiscriminate dumping of MSW in the water body, which destroys the ecosystem, often arises from local settlements near/around it. Rajokri Lake was encroached by illegal

settlements with solid, liquid and cattle waste finding its way into the water body. Encroachers were obstructive and hostile during the initial phase of the project and transporting waste using excavators was a challenge due to local resistance. Enforcement of regulation and clear demarcation of boundaries initially delayed the initiation of the project.

(d) Community engagement: Community participation is critical to the success of any project. Local authorities and government agencies need to work to generate a sense of responsibility among the public – e.g., by providing new public spaces. One of the major challenges while working on this project was to tackle heavy encroachment. In addition, the site was a hub for several anti-social elements making it quite unsafe. The positive sociological impact of the project on the community, especially women, was realized during execution based on feedback received from women in the community. While restoring the lake, the area around it was landscaped to create a public space. This included walkways, an open gym and an amphitheater for social activities. Chhatt Puja is a socio-religious activity performed by the local community and so, on the basis of feedback from the community, a Chhatt Ghat (place to perform the socio-religious activities) was developed. The community had a psychological barrier in using treated sewage water for religious purposes though they had no inhibitions using raw sewage water for the rituals prior to restoration. Respecting the local sentiments, a sandstone embankment between the main water body and the amphitheater was created to function as a Chhatt Ghat. This has strengthened community participation in safeguarding the site and inhibiting encroachment. Public resistance during the initial stages of the project changed with regular engagement of the community through awareness campaigns and community workshops. It encouraged the local people to put forth their needs for the creation of the socio-religious space. Following the inauguration of the completed project, there has been a regular congregation of the community for Chhatt Puja every year with nearly 2000 people attending the religious festival every year.

3.7. Project benefits

The revival of Rajokri Lake has had several benefits:

(i) Groundwater recharge

A revived water body can recharge groundwater effectively. This is critical in countries like India with rapidly falling groundwater levels. The project at Rajokri is immensely helping in improving the falling water table levels in the area. In addition to reviving the lake, bioswales have been created in the area surrounding the lake with percolation pores for water retention, groundwater recharge and also regulating the flow of rainwater into the lake. These bioswale systems function as an alternative to storm sewers and remove pollution and debris from rainwater and divert it to the lake.

(ii) Aesthetics

Water body revival increases human contact, so water quality should be maintained at the highest level. Water bodies serve as socio-cultural sites worldwide and their revival can help to rejuvenate socio-cultural practices. The revived Rajokri Lake serves as a community space for religious and other activities, with an amphitheater, open gym and walking space [33]. In addition, the project ticks the boxes of biodiversity enhancement through plantation of native tree species in the premises of the lake.

Prior to the project, the lake was a sewage sink and a source of communicable diseases. With no stagnant raw sewage present, the threat of mosquito breeding has been eliminated. The lake no longer has an unbearable stench and at least 15 species of birds have returned to the locality. The decentralized treatment system provides aesthetics with the treatment of wastewater occurring below ground.

(iii) Inhibiting flooding

Water bodies can play an important role in urban flood management [20]. Proper revival strategy planning can ensure that excess water, e.g., from local roads, finds its way into the water body and is not lost. Chennai was badly affected by floods in 2015 and suffered extensive damage [34]. A major reason for the severity of the damage in Chennai was that floodwaters could not find their way into water bodies so the roads were flooded. This can be attributed largely to poor urban planning and management [35]. Landscaping at Rajokri has been designed in such a way to prevent flooding. Rain gardens on two ends of the lake ensure that water drains into the lake. Now that it has been revived, Rajokri Lake can play an important role in inhibiting flooding in the Delhi region.

4. Summary and conclusions

The revival of Rajokri lake is a stellar example of innovation meeting grassroots level social development. The revival of Rajokri Lake scores well economically, environmentally and socially. The project is sustainable, and has negligible operating and maintenance costs. The wastewater treatment system is basically natural and refills the dry lake. Moreover, the cost of treatment of wastewater is less than 0.014 USD/KL which is cheaper than the conventional treatment of wastewater. The Rajokri model includes space for socio-religious activities and therefore involves community participation in safeguarding the revived water body. The SWAB-based treatment system effectively removed ~89% of oil and grease, 86% BOD, 85% COD and 86% of TSS from the influent, when the initial concentrations were 18 ± 1.14 , 124 ± 2.9 , 480 ± 11.9 and 116 ± 1.82 mg/L respectively.

Conflicts of Interest

All authors declare no conflicts of interest in this paper.

References

1. Kookana RS, Drechsel P, Jamwal P, et al. (2020) Urbanisation and emerging economies: Issues and potential solutions for water and food security. *Sci Total Environ* 732: 139057.
2. Strohschon R, Wiethoff K, Baier K, et al. (2013) Land use and water quality in Guangzhou, China: A survey of ecological and Social vulnerability in four urban units of the rapidly developing megacity. *Int J Environ Res* 7: 343–358.
3. Wakode HB, Baier K, Jha R, et al. (2018) Impact of urbanization on groundwater recharge and urban water balance for the city of Hyderabad, India. *Int Soil Water Conserv Res* 6: 51–62.
4. Jamwal N. Disappearing Lakes. Published in Deccan Herald, 2015. Available from: <https://www.deccanherald.com/content/506003/disappearing-lakes.html>.
5. Rashid I, Romshoo SA, Amin M, et al. (2017). Linking human-biophysical interactions with the trophic status of Dal Lake, Kashmir Himalaya, India. *Limnologica* 62: 84–96.

6. Xie C, Huang X, Wang L, et al. (2018) Spatiotemporal change patterns of urban lakes in China's major cities between 1990 and 2015. *Int J Digital Earth* 11: 1085–1102.
7. Henny C, Meutia AA (2014) Urban Lakes in Megacity Jakarta: Risk and Management Plan for Future Sustainability. *Procedia Environ Sci* 20: 737–746.
8. CPHEEO. Advisory on Conservation and Restoration of Water Bodies in Urban Areas, 2013 Available at: <http://mohua.gov.in/upload/uploadfiles/files/Advisory%20on%20Urban%20Water%20Bodies.pdf>.
9. World Bank Group-Water and Sanitation Program (2015) Improving On-site Sanitation and Connections to Sewers in Southeast Asia- Insights from Indonesia and Vietnam. Available from: <https://www.wsp.org/sites/wsp/files/publications/WSP-Improving-On-site-Sanitation-Connections-to-Sewers-Southeast-Asia.pdf>.
10. De Gisi S, Petta L, Wendland C (2014) History and technology of Terra Preta sanitation. *Sustainability* 6: 1328–1345
11. Srivastava A (2020) Constructed Wetlands. *Environ Ecol Biodivers* 61: 21–23.
12. Agarwal N, Koti SR, Saran S, et al. (2018) Data mining techniques for predicting dengue outbreak in geospatial domain using weather parameters for New Delhi, India. *Curr Sci* 114: 2281–2291.
13. APHA (2017) Standard methods for the examination of water and wastewater 23rd Edition Washington D.C., United States
14. Huang B, Wang X, Kua H (2018) Construction and demolition waste management in China through the 3R principle. *Resour Conserv Recy* 129: 36–44
15. Duan H, Miller TR, Liu G, et al. (2019) Construction debris becomes growing concern of growing cities. *Waste Manage* 83: 1–5.
16. Narasimhan B, Bhallamudi SM, Mondal A, et al. (2016) Chennai Floods 2015: A Rapid Assessment. IIT Madras, IIT Bombay, and IISc Bangalore. Available from: <http://itra.medialabasia.in/img/Chennai%20Floods-Rapid%20Assessment%20Report-May%202023,%202016.pdf>.
17. Kulkarni BN (2020) Environmental sustainability assessment of land disposal of municipal solid waste generated in Indian cities – A review. *Environ Dev* 33: 100490.
18. Ministry of Water Resources, Govt. of India Draft Policy on Sediment Management, 2017. Available from: http://mowr.gov.in/sites/default/files/Draft_Policy_on_Sediment_Mgmt-June2017.pdf
19. Samuel MP, Mathew AC (2008) Rejuvenation of Water Bodies by Adopting Rainwater Harvesting and Groundwater Recharging Practices in Catchment Area- A Case Study. *Proceedings of Taal2007: The 12th World Lake Conference* 766–776.
20. Bindu CA, Mohamed AR (2016) Water bodies as a catalyst to growth and development- The case of Kodungallur town, Kerala. *Procedia Technol* 24: 1790–1800.
21. National Green Tribunal Monitoring Committee for the River Yamuna (2019). Sewage Management in Delhi. Available from: <https://yamuna-revival.nic.in/wp-content/uploads/2019/02/Sewage-Management-in-Delhi.pdf> (accessed 9 July 2021)

22. National Green Tribunal (2020). Final Report of the Yamuna Monitoring Committee. Available from:
https://greentribunal.gov.in/sites/default/files/news_updates/Final%20Report%20by%20Yamuna%20Monitoring%20Committee%20in%20OA%20No.%2006%20of%202012.pdf (accessed 9 July 2021)
23. Kohli A, Frenken K Evaporation from artificial lakes and reservoirs. FAO AQUASTAT Reports, 2015. Available from: <http://www.fao.org/3/a-bc814e.pdf> (accessed 25 May 2020).
24. Sewerage Master Plan for Delhi- 2031 Final Report, 2014. Available from: http://www.indiaenvironmentportal.org.in/files/file/Sewerage_Master_Plan%20for%20Delhi%202031.pdf.
25. CGWB 2016. Aquifer mapping and ground water management plan of NCT Delhi, New Delhi, India
26. Gutterer B, Sasse L, Panzerbieter T, et al. (2015) Decentralised Wastewater Treatment Systems (DEWATS). Water, Engineering and Development Centre, United Kingdom. Available from: https://sswm.info/sites/default/files/reference_attachments/DEWATS_Guidebook_small.pdf
27. NEERI (2015) Phytoid technology for treatment of sewage. Available from: https://www.cseindia.org/static/mount/recommended_readings_mount/19-Phytoid-Wastewater-Treatment-Technology.pdf
28. CPCB and DBT Manual on Constructed Wetland as an Alternative technology for sewage management in India, 2019. Available from: <http://www.dbtindia.gov.in/latest-announcement/manual-constructed-wetland-alternative-technology-sewage-management-india>.
29. Tassi E, Pouget J, Petruzzelli G, et al. (2008) The effects of exogenous plant growth regulators in the phytoextraction of heavy metals. *Chemosphere* 71: 66–73.
30. Tandon SA, Kumar R, Parsana S (2015) Auxin treatment of wetland and non-wetland plant species to enhance their phytoremediation efficiency to treat municipal wastewater. *J Sci Ind Res* 74: 702–707.
31. Varma M, Gupta AK, Ghosal PS, et al. (2021) A review on performance of constructed wetlands in tropical and cold climate: Insights of mechanism, role of influencing factors, and system modification in low temperature. *Sci Total Environ* 755: 142540.
32. Vymazal J (2014) Constructed wetlands for treatment of industrial wastewaters: a review. *Ecol Eng* 73: 724–751
33. Consortium for DEWATS Dissemination Society. 2019. Waterbody Rejuvenation - A Compendium of Case Studies. Bengaluru.
34. Joerin J, Steinberger F, Krishnamurthy RR, et al. (2018) Disaster recovery processes: Analysing the interplay between communities and authorities in Chennai, India. *Procedia Eng* 212: 643–650.
35. Devi NN, Sridharan B, Kuiry SN (2019) Impact of urban sprawl on future flooding in Chennai city, India. *J Hydrol* 574: 486–496.



SHORT FEATURE

MONIKA JAGGI

Neela Hauz Biodiversity Park

From Barren to Beautiful



Neela Hauz Lake before and after restoration

“Nature is not a place to visit.
It is home.”

- Gary Snyder

THIS quote does not hold true in today's time as the stench of apathy and greed is polluting our environment every day. Even with environmentalists crying their hearts out, the environment is turning dry and dirty.

Water bodies are important components of the natural water cycle on which an entire ecosystem is dependent. Once these natural catchments and reservoirs are destroyed, the cycle is disturbed. Water bodies also contribute to keeping up a healthy groundwater table that has gone very low in India.

Delhi is already grappling with a serious water shortage. An environment department survey by Delhi government in 2014 revealed a sad state of water bodies in the capital. Out of 611 water bodies, 274 have already dried up, while the rest 337 that still have water are in a terrible state.

The Neela Hauz Lake was also going the same way. Once a beautiful fresh water lake (covering around 2.5 hectares), which fed the plethora of flora and fauna, it turned in to a dumping ground for debris and raw sewage from the surroundings. But with the concerted efforts of local residents, environmentalists and the Delhi Development Authority

(DDA), the lake is now the symbol of environmental regeneration at the Neela Hauz Biodiversity Park. The regeneration model has proved so successful that officials have submitted the concept to the Delhi Jal Board for implementation in other water bodies across Delhi.

Neela Hauz is a mini biodiversity park and includes the Neela Hauz Lake fringing the undulating landscape terrain abutting the Sanjay Van Forest. It is being developed on the south central ridge located near Vasant Kunj. It is spread over an area of 10 acres. According to folklore, Neela Hauz was the main water source for the Rajput city of Qila Rai Pithora and also a halt on the trade route to Delhi. Studies have shown that Neela Hauz was part of a much larger watershed that drained this part of the Aravallis and, through a system of nallahs, reached the River Yamuna. It was the biggest natural water body in South Delhi and used to be a major fresh water source for the entire South Delhi.

Initially, the catchment area of this lake was covered with the dense forests of Sanjay Van. Later a part of it was removed to make an institutional area. The forest was also invaded by keekar (*Prosopis*) and other acacia species, which the British had introduced, leading to the loss of native species. For a period of time, the lake was encroached upon – while some part of it was filled with debris, the central portion was

sedimented, and untreated sewage water was thrown in because of which the lake was completely silted and covered with water hyacinth (*Eichhornia*). About a decade ago, the lake was completely filled with debris during the construction of a flyover over it.

Back from the Dead

In response to a petition filed by local residents in Delhi's High Court, Neela Hauz was handed over to DDA under its Delhi Biodiversity Foundation. The revival process started immediately in collaboration with the Centre for Environmental Management of Degraded Ecosystems (University of Delhi).

The DDA took responsibility to revive the dead lake through a Constructed Wetland System (CWS). The lake is critical to maintain water levels in south Delhi, especially the Mehrauli block, where the water table has fallen drastically.

So the question arose, where to get water from since much of its catchment had been taken up by institutions, rainwater flows into the Neela Hauz had been substantially reduced and natural drains had been blocked by encroachment. It was decided to use raw sewage mixed with STP-treated water to maintain water levels in the lake since it is otherwise dependent solely on rainwater. The lake was desilted and the silted material was used for landscaping its embankments. The raw sewage and STP-treated water (designated as waste water) passed through a constructed wetland system before it enters into the lake. The storage capacity of the lake is enhanced by constructing a mini run-off river check dam in order to attract aquatic birds.

CWS involves both physical and biological processes with zero energy input. CWS constitutes of two oxidation points and four physical channels/tanks.

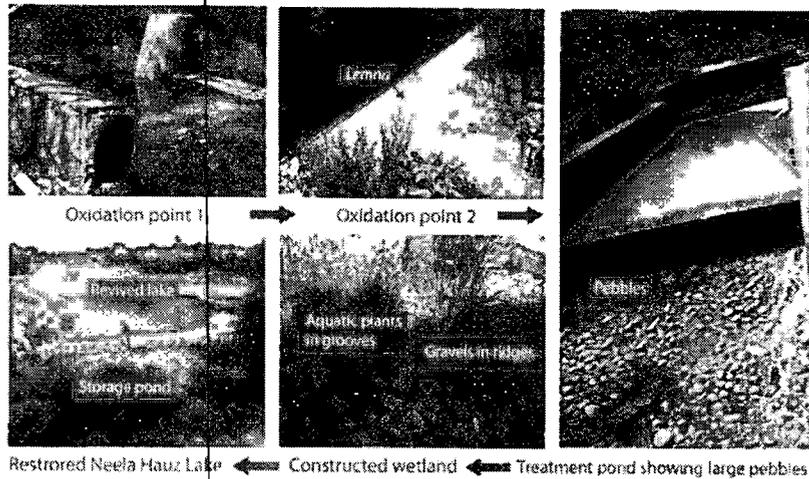


Figure showing treatment of sewage water by Constructed Wetland System

In the first oxidation step, sewage is stored and retained in a large surface area for 24-48 hours so that atmospheric oxygen can break down all organic material by natural microbes (aerobic bacteria).

In the second step, water is stored in a pond where aquatic plants like lemna absorb nitrates and phosphates from water, further improving quality. The lake's Biological Oxygen Demand (BOD) levels, along with the level of phosphates and nitrates, fell sharply. These nitrate and phosphate-rich lemna are also used as fertilisers after collecting them from the water. After passing through these two oxidation points, the biodegradable material gets oxidized and the bacterial biomass (particulate organic matter) and other silt gets settled.

Then, the water is passed through various physical channels or treatment points. First, the water passes through a channel having river bed pebbles of large size which filters the waste water by

removing large sized particulate organic matter. This water then passes through three tanks – Tank I has smaller pebbles; Tank II has still smaller pebbles; and Tank III has the smallest pebbles. These three tanks remove particulate organic matter of all sizes.

In the next step, water flows past a series of alternating ridges and furrows. The former has gravels while the latter has 20 different aquatic plants species (e.g. *Typha*, *Phragmites*, *Alternanthera*, *Ipomoea*, *Solanum*, etc.). The microbes present in the rhizosphere of these aquatic plants cleansed the water of biotoxins, while sludge and fine particulates were removed via a gradual process of passing the water through a cascade which also harbours some aquatic plants and finally enters into another pond with floating aquatic plants. The purpose of this pond is to get any left out fine particulate organic matter sedimented. Different gradient levels of pebbles as well as microbes from these plants naturally

improve the quality of water before it enters the lake.

The lake water has DO of more than 4 mg/l and BOD less than 4 mg/l and COD less than 0.7 mg/l and pH around 7.2 and the sulphates and chlorides are less than permissible standard. The lake has many aquatic birds. A total of 100 species of birds have been recorded.

According to Prof. C.R. Babu (Project Incharge of the Biodiversity Parks Programme of Delhi Development Authority), "No energy is being consumed in the process. We are only using physical materials such as river bed pebbles and gravel and aquatic plants with special properties to clean the water. Sewage treatment plants in Delhi are not as efficient as the constructed wetland system in improving the treated water quality. We have successfully treated sewage and STP-treated water to the level that the treated water has the same quality as that of river water by an all-natural process".

The water body at Neela Hauz now treats close to a million liters of water every day through natural processes.

The Neela Hauz Biodiversity Park was dedicated to the Nation by the former Lt. Governor of Delhi, Dr. Najeeb Jung in November 2016. More than 15,000 saplings of native trees and shrubs belonging to six biological communities have been planted. These saplings belong to more than 75 species.

Within two years the Neela Hauz Biodiversity Park will become a paradise for bird lovers and for nature lovers. Since its revival, 70 bird species have been sighted at Neela Hauz. Migratory birds have started to visit the lake again. Walking trails have also been developed around the lake with proper sitting areas at regular intervals. Submerged, free floating and rooted water plants and phytoplankton and zooplankton have been introduced in the water body. Grasses such as *Chrysopogon*, *Heteropogon* and *Cenchrus* have been planted to stabilize slopes around the water body.

Water analysis

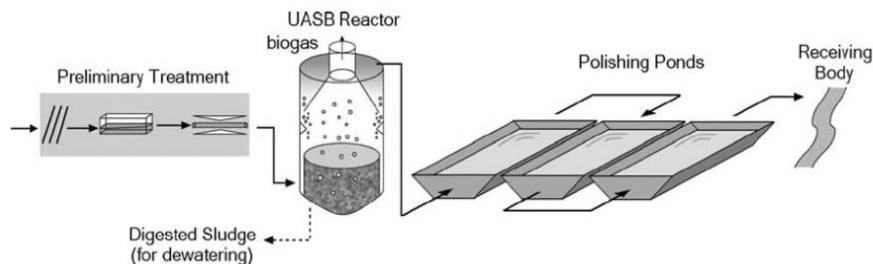
Parameter	Before CWS	After CWS
Acidity level (pH)	7.8	6.78
Biochemical Oxygen Demand (BOD)	40	4.0
Chemical Oxygen Demand (BOD)	80	0.7
Dissolved Oxygen	0	3.4
Phosphates	103	14
Total Dissolved Solids (TDS)	600	298

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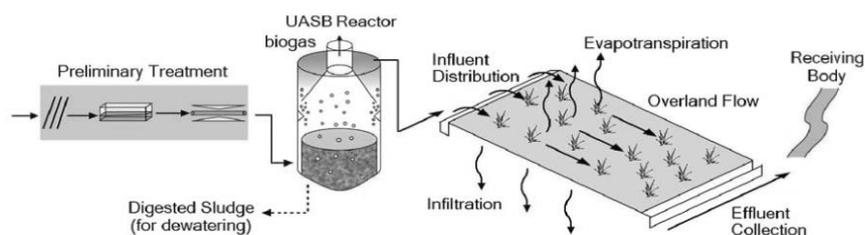
Annexure-V

The major organic load of the used water can be treated (60-70 % of inflow) anaerobically in the secondary stage, which will reduce the pressure, and increase the efficiency of the post treatment units. These combination of the anaerobic with nature based post treatment options can reduce the BOD upto 80-90 % of the inflow and can meet the general discharge standards of 1986. Anaerobic treatment (UASB, High rate anaerobic reactors, ABR etc) is much influenced by climate, and easily work in warm climate regions like India, Brazil etc. The above mentioned options are as follows:

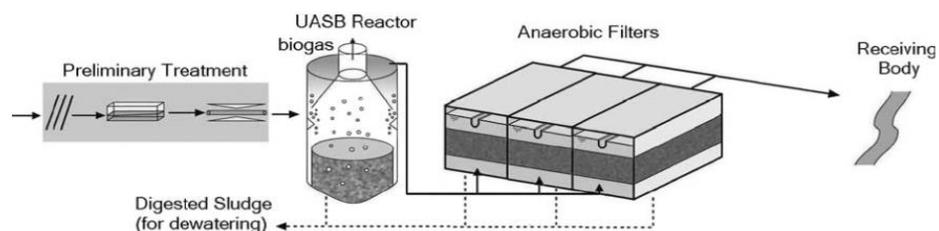
- High-rate anaerobic reactors/ UASB/ABR + Polishing ponds



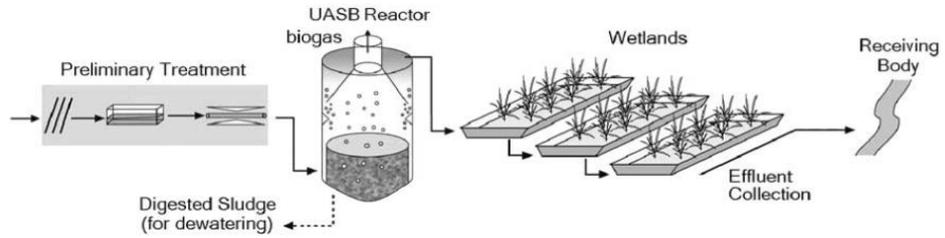
- High-rate anaerobic reactors /UASB/ABR + Overland flow systems



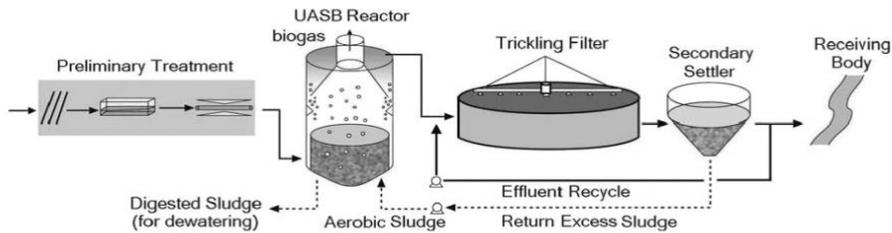
- High-rate anaerobic reactors /UASB/ABR + Anaerobic Filters



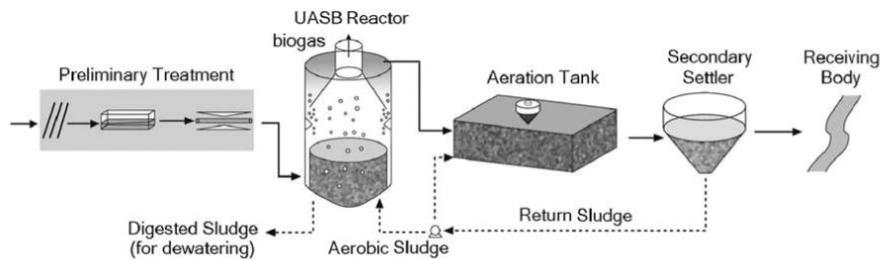
- High-rate anaerobic reactors /UASB/ABR + Constructed Wetlands



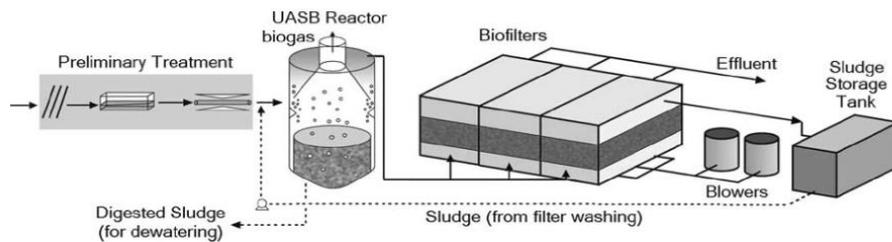
- High-rate anaerobic reactors/ UASB/ ABR + Trickling Filter



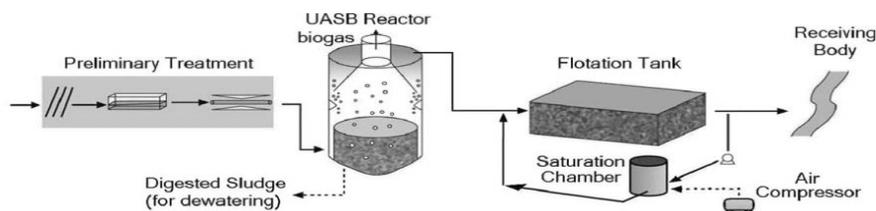
- High-rate anaerobic reactors/ UASB/ ABR + Activated Sludge



- High-rate anaerobic reactors/ UASB/ ABR + Submerged aerated biofilter



- High-rate anaerobic reactors/ UASB/ABR + Dissolved air flotation



Annexure-VI

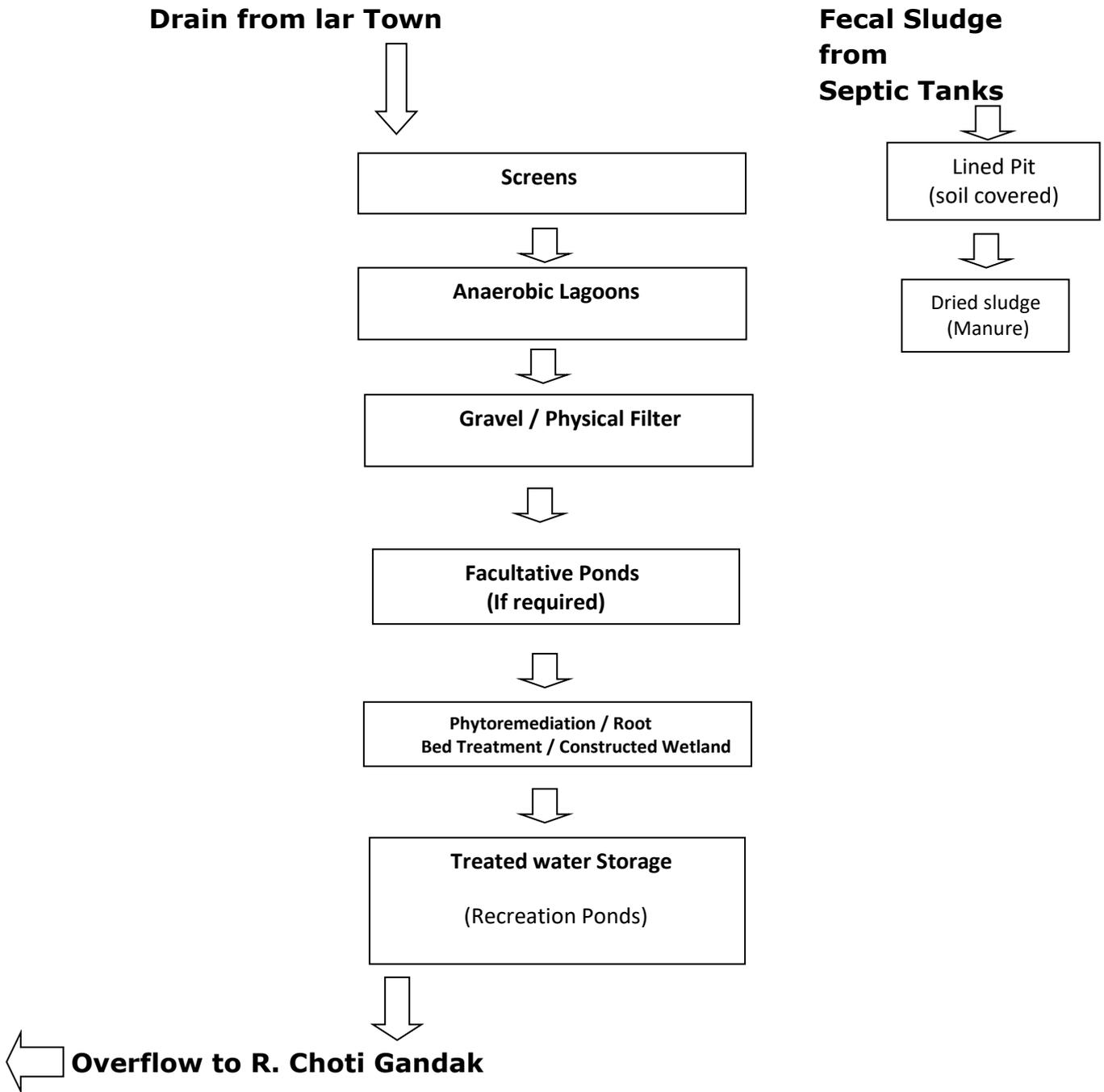


Fig: 01 Conceptual Plan for Sewage / Septage Management, Lar, Deoria