Decentralized Wastewater Treatment System

Thesis submitted in partial fulfilment of the requirements for the degree

of

Master of Engineering in Water Resources & Hydraulics Engineering

Submitted By

Amir Sohel

Examination Roll No. – M4WRE22015
Registration No. -154655 of 2020-2021

Under guidance of

Prof. Dr. ARUNABHA MAJUMDER
Emeritus Professor
School of Water Resources Engineering, Jadavpur University

Dr. RAJIB DAS
Assistant Professor
School of Water Resources Engineering, Jadavpur University

School of Water Resources & Hydraulic Engineering

Faculty of Interdisciplinary Studies, Law & Management

Jadavpur University, Kolkata 700032

(2022)

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AND
COMPLIANCE OF ACADEMIC ETHICS

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Name-**Amir Sohel**
Examination Roll No. – M4WRE22015
Registration No. -154655 of 2020-2021

Thesis title- **Decentralised wastewater treatment systems**

Signature -

Date-

Faculty of Interdisciplinary Studies, Law & Management
Jadavpur University

CERTIFICATE OF RECOMMENDATION

This is to certify that the thesis entitled "**Decentralised wastewater treatment systems**" is a bonafide work carried out by **AMIR SOHEL** under our supervision and guidance for partial fulfillment of the requirement of Master of Engineering (Water Resources & Hydraulic Engineering) in School of Water Resources Engineering, during the academic session 2020-2022.

THESIS ADVISOR
Prof. Dr. ARUNABHA MAJUMDER
Emeritus Professor
School of water Resources Engineering
Jadavpur University, Kolkata-700032

THESIS ADVISOR
Dr. RAJIB DAS
Assistant Professor
School of water Resources Engineering
Jadavpur University, Kolkata-700032

Prof. Dr. Pankaj Kumar Roy
DIRECTOR
School of water Resources Engineering
Jadavpur University, Kolkata-700032

Prof. Subenoy Chakraborty
DEAN
Faculty of Interdisciplinary Studies, Law and Management
JadavpurUniversity,Kolkata-700032

Faculty of Interdisciplinary Studies, Law & Management

Jadavpur University

CERTIFICATE OF APPROVAL

This foregoing thesis entitled **“Decentralised wastewater treatment systems”** is hereby approved as a credible study of an engineering subject carried out and presented in a manner satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is understood that by this approval the undersigned do not endorse or approve any statement made, opinion expressed or conclusion drawn therein but approve the thesis only for the purpose for which it has been submitted.

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Date-

AMIR SOHEL

Examination Roll No. –M4WRE22015
Registration No. -154655 of 2020-2021

ABSTRACT

An increase in population, rapid urbanization and quick economic expansion are exerting pressure on the scarce water bodies globally. Untreated wastewater from human settlements reaches natural waterways and cause water pollution. Thus, affects the direct availability of freshwater for human consumption. The need to treat wastewater is important but how to treat the wastewater is to be discussed. Providing the most efficient and affordable wastewater treatment plant is the main challenge. Hence, selecting the right system should be considered along with many aspects such as financial investment, noise protection, operational costs and environmental issues. This paper describes about the wastewater management and decentralized wastewater management. This paper presents a number of technological options and considers their implication for decentralized wastewater systems.

Keywords: Wastewater treatment plant, DEWATS

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CHAPTER – 1
INTRODUCTION

1. Introduction:

Every community are responsible for the producing of liquid and solid waste and emissions of air. Almost 80% of the water used by the society becomes liquid waste. The water which is essentially supplied from the community after using in a variety of application is known as liquid waste, also called wastewater. From the perspective of the sources of generation, wastewater may be defined as a combination of the liquid and waste carried by liquid which are removed from the residences, institutions, commercial and industrial establishments.Sources of wastewater are from the household uses such as dishwashing, showering, laundry and most essentially flushing of toilets, from the industries where water is used for many purposes including processes, products, cleaning and rinsing of the parts and the solid waste such as sticks, rags, paper, plastic, cloths etc. are carried by the storm water.Due to a) extensive practice of septic tanks in residences without collection systems, b) absence of suitable treatment systems, c) Unavailability of auxiliary sullage management, d) absence of septic sewage management, especially in peri-urban areas where population density is relatively more, most of the surface water and shallow ground water sources are polluted by pathogens. More than 80% disease are due to inappropriate sanitation or insufficient hygienic conditions, so it is very essential to provide facilities and services for wastewater treatment. It is also calculated that 6.4% of Indian GDP has been lost due to improper sanitation. Wildlife and fisheries also get affected due to improper wastewater management. Discharge of wastewater directly into waterbodies also reduces the recreational amenities and quality life.

1.1 Wastewater management:

Wastewater management systems can be developed by either conventional centralized systems or decentralized system. Centralised systems usually large wastewater treatment plant which are designed and operated by government agencies. On the other hand, decentralized wastewater management (DWWM) systems are the small wastewater treatment systems which collects and treatwastewater close the origin from individual houses, small communities, cluster of houses, small blocks etc. Another wastewater treatment systems known as "on-site wastewater treatment (OSWT)" which partially treat wastewater directly collected without any sewerage systems from individual house or small cluster of houses. Small sewerage systems may exist in decentralized wastewater management. It is observed that overall sanitation will be possible in a city or town when it has treatment system combination of centralized, decentralized and onsite wastewater management systems.

A decision tree to choose wastewater management systems (centralized, decentralized, onsite) is given in the figure below-

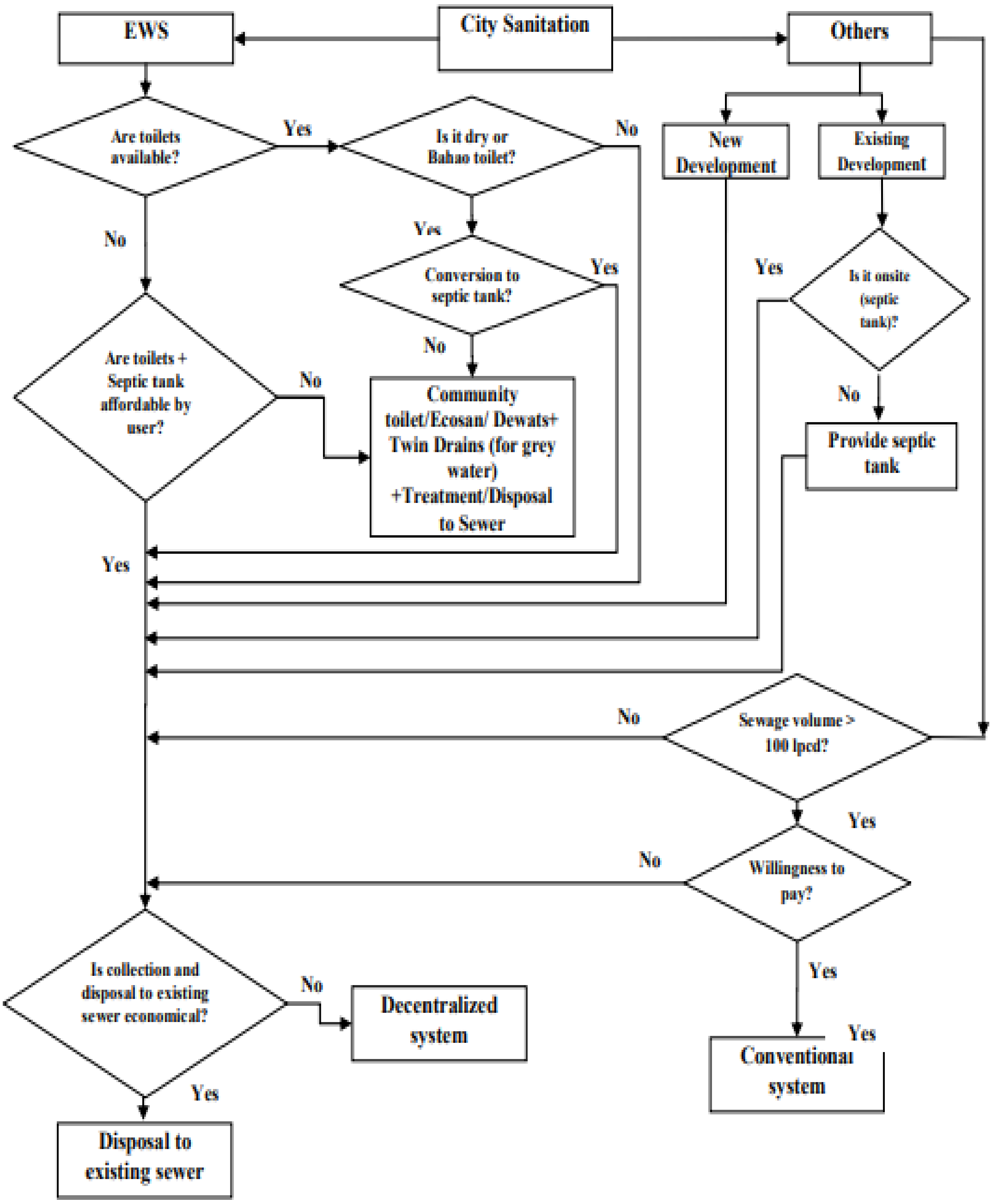


Figure 1: Decision tree to choose wastewater treatment systems

1.2 Decentralised wastewater management:

Decentralized wastewater management (DWWM) may be defined as "the collection, treatment, and disposal/reuse of wastewater from individual homes, clusters of homes, isolated communities, industries, or institutional facilities, as well as from portions of existing communities at or near the point of waste generation" (Tchobanoglous, 1995).

Typical example of decentralized wastewater treatment system is given in the figure below-

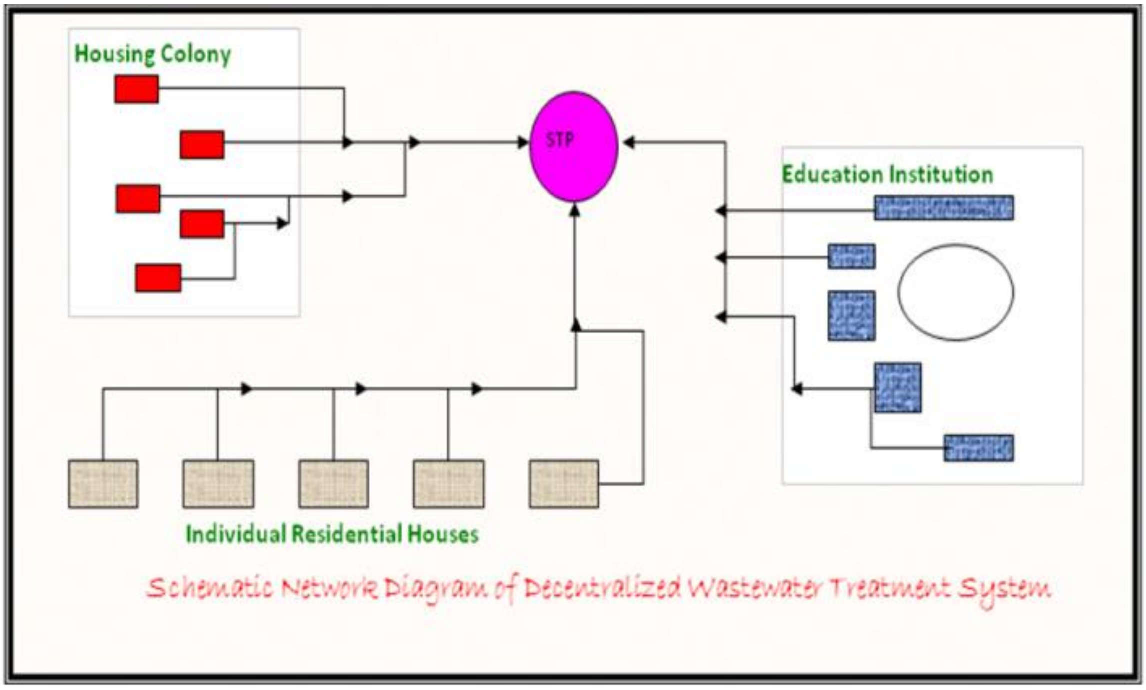


Figure 2 : Schematic Network Diagram of Decentralised wastewater treatment systems

1.3 Characteristics of wastewater:

Approximately 99.9% water is present in the domestic wastewater. The remaining part i.e. 0.1% which is a concern for water pollution includes organic, inorganic, suspended and dissolved solids with microorganism. The charactristics of wastewater is discussed below:

- **Hydraulic**:
  - Flow based
  - Each person disposes an average of 60 to 70 gallons per day(gpd) of wastewater. Taking into consider for industries and business, the average is 150 to 165 gpd per capita.

- **Chemical**:
  - Organic:
    - BOD (Biochemical Oxygen Demand)- is a measure of oxygen required by the aerobic bacteria to decompose organic matter.
    - COD (Chemical Oxygen Demand)- Similar to BOD, it is an important water quality parameter which gives an index to

assess the effect of discharged wastewater on receiving environment.

- Inorganic:

➢ **Physical**:

- Turbidity:
  - Due present of great variety of suspended solids, wastewater will have higher turbidity.

- Temperature:
  - Slightly more than drinking water.
  - Influences solubility of gas, viscosity of liquid and microbial activity.

- Color:
  - Slightly grey in fresh sewage.
  - In septic sewage it is dark grey or black.
- Odor:
  - Fresh sewage - musty, relatively unpleasant.
  - Septic sewage – become Rotten egg odor due to hydrogen sulphide and other decomposition by product.
  - Industrial Wastewater: Characteristics odor.

- Total Solids:
  - Floatable
  - Settleable
  - Suspended
  - Dissolved

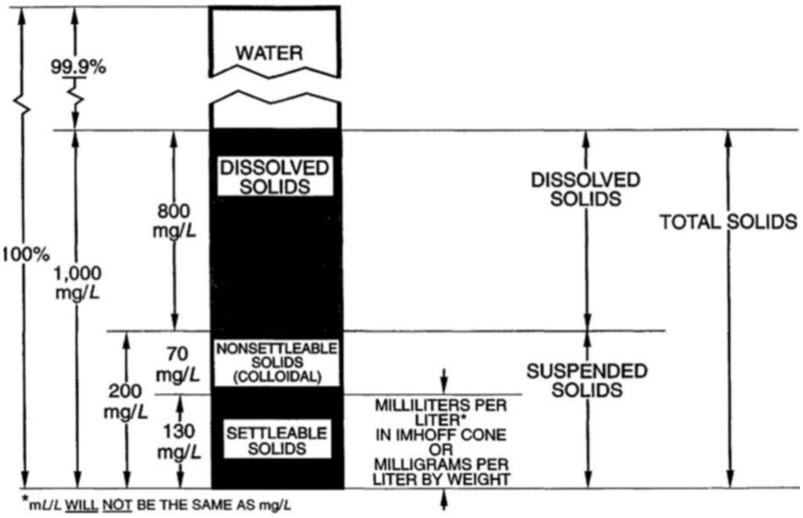


Figure 3: Phase Diagram of Physical Properties of Wastewater

➢ **Biological**:
- Aerobic
- Anaerobic
- Facultative
- Pathogenic
- Non-pathogenic

1.4 Current Status of Sewage generation and Sewage Treatment in India:

The main Sources of pollution of water bodies in India is disposal of domestic sewage from the cities and and towns.

According to population 2001 census, an estimated of 29129 MLD of sewage generated by all Class I and Class II cities in India. Against this, sewage treatment capacity of only 6190 MLD is installed. So, the gap between sewage generation and sewage treatment capacity is 22939 MLD which is 78.7 %. Another about 1743 MLD capacity of sewage treatment is on construction stage or under planning. Adding this with the existing capacity, gap will be 21196 MLD which is equal to 72.7% in sewage treatment capacity.

This clearly shows the dismal condition of sewage treatment, which is the biggest cause of pollution of waterbodies like rivers and lakes.

- **Table 1 shows Sewage generation and sewage treatment in Class I cities and Class II towns (2001 population basis)**

City category & population	Number of cities	Sewage generation (MLD)	Installed sewage treatment capacity (MLD)	Capacity gap in cities having STPs (A) (MLD)	Sewage generation cities having no STPs (B) (MLD)	Total capacity gap (A+B) (MLD)	Planned Treatment capacity (MLD)
Class I cities having more than 10 lac population	39	13503	4472 (In 29 cities)	6135	2896	9031	1549
Class I cities having 5 to 10 lac population	32	3836	485 (In 13 cities)	1293	2058	3351	123
Class I cities having 2 to 5 lac population	119	4807	768 (In 34 cities)	804	3235	4039	4
Class I cities having 1 to 2 lac	224	4018	322 (In 36 cities)	373	3323	3696	32.5

population							
All the above Class I cities together	414**	26164 (100%)	6047 (23.1%) (In 112 cities)	8605 (32.9%)	11512 (44%)	20117 (76.9%)	1708.5 (6.5%)
Class II towns having 0.5 to 1 lac population	489**	2965 (100%)	200 (>143*) (4.8%) (In 22 cities)	Nil	2822 (95.2%)	2822 (95.2%)	34.1 (1.15%)
All Class I cities & Class II towns	893**	29129 (100%)	6190 (21.3%)	8605 (29.5%)	14334 (49.2%)	22939 (78.7%)	1742.6 (6.0%)

*Estimated sewage of the cities having STPs
**Delhi being taken as one city.

1.5 Mode of disposal of wastewater/sewage:

- Indirectly to the lakes/ponds/rivers/creeks in 118 cities.
- On to the agricultural lands in 63 cities.
- Directly into the rivers in 41 cities.
- In 44 cities, it is discharged both into rivers and on agricultural lands.
- Around 25% of the total wastewater fall into estuaries, creeks, bays etc. in many of the coastal cities.

Figure 4: Mode of Disposal of Wastewater

1.6 Effects of Increasing Wastewater:

- It harms the river and marine life.
- It adversely affects the groundwater.
- It rises the pollution in the coastal area.
- Pollutes the soil.
- Creates scarcity of potable water.
- It affects the sources of water because of overabundance of harmful chemical, some of which is chronic.

- Its increases chronic health conditions related to toxic chemicals such as arsenic, lead and mercury in all living organisms.

1.7 How Wastewater Pollutes waterbodies:

- When water is used by our community, it becomes contaminated with the various types of pollutants. If we left these used water untreated and directly discharged into the nearby waterbodies like lake, ponds, river, it may kill the plants and animals that live in that water.Domestic waste water consists of microorganisms and organic matter (protein, fat, carbohydrates) and those microorganisms consume organic matter for their survival. The growth of the microorganisms depends on consumption of organic matter. Also, Microorganisms take oxygen from the water. So more the organic matter, more will be the growth of microorganism and more it will take the oxygen from the water and so less will be the availability of dissolved oxygen in the water. At the moment, when the concentration of dissolved oxygen is less than 4 mg/l, animals including fish will no longer can survive in that condition. And if the dissolved oxygen concentration is zero, water become black, in that case not a single plants and animals can live in that water.
- Nutrients like nitrogen, phosphorus including ammonia are essential elements for plant growth. So Present of excessive amounts of these nutrientsin the wastewater can lead to plentiful algal and plants growth in the lakes and river. Which is known as eutrophication. When discharged into the stream or lake, due to unwanted growth of algae, entire surface of the stream or lake is covered by the algal blooms. Which prevents the sunlight reaching other plant and affects photosynthesis process. Thus, plants die and oxygen in water is depleted. On the other hand, dead algae sink and deposits in the bottom level of the stream where they are decomposed by the bacteria consuming even more oxygen from the water. A point comes when hypoxic condition occurs at the bottom level of the stream due to overconsumption of oxygen, which leads to suffocation. In the end it leads to death of the larger life such as fish.

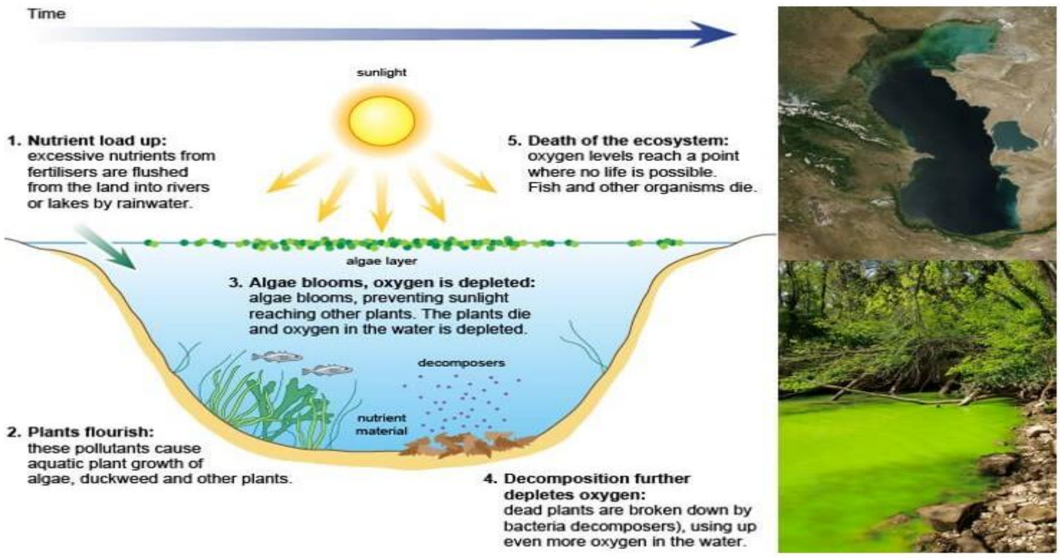


Figure 5: Process of Eutrophication in Pond

1.8 Paradigm Shift in the recent past:

- A paradigm shifts from 'use & throw' to a 'collect, treat and reuse' approach has gained a motivation focusing on resources recovery with minimal resource consumption.

- **Example: -**
  - "NEWater" Scheme in Singapore.
  - "Zero Discharge" norm for major industries.
  - "Recycled water" for domestic use.
  - Treated wastewater for groundwater and irrigation
  - Most recent, treated wastewater use in Thermal power plant.

1.9 Purpose of choosing decentralized option:

- To protect environment and human health from the disease caused by contaminated water by treating wastewater at small scale decentralised way.
- To provide facilities and services to a single household to community to a cluster of houses for proper sanitation.
- To minimize useable water scarcity by treating wastewater and reuse it. This treated water can be used for toilet flushing, car washing, gardening and irrigations purposes.
- To achieve more efficient quality of treatment than traditional centralised method.
- To maintain ecology of river and lakes by discharging better quality of treated water.
- To make wastewater treatment process cost effective. Decentralised wastewater treatment systems require lesser investment for sewer pipelines than conventional methods.
- To protect ground water from contamination, as in most of the rural areas, wastewater discharged directly on open ground, from where it infiltrates and mixed with ground water and pollute the ground water

1.10 How to resolve the issues of wastewater:

- Need to set up treatment plant at the various place at various situation
- Reuse of treated wastewater and recycle them.
- Need to analyses the life cycle of the wastewater treatment plant.

CHAPTER – 2
OVBJECTIVES AND SCOPE OF WORK

2. Objective and scope of work

2.1 Objectives:

The objectives of the study are-

- To describe about the technologies which are available options for treatment of wastewater in a decentralized way and discuss about their advantages and limitations as well as design criteria for domestic sewage treatment.
- To discuss about the selection of decentralized wastewater treatment systems as better option for wastewater treatment.
- To review and discuss about barriers and challenges on implementation of DEWAT systems.
- To review institutional, technical, financial policies on solution of wastewater treatment ad reuse in the country.

2.2 Scope of work:

- Preparation and detailed implementation plan in identified cities.
- Helping the Urban Local Bodiesin the implementationof the plan for decentralized wastewater management.
- Documentation and dissemination of the concepts and findings.

CHAPTER – 3

LITERATURE REVIEW

3. Literature review

- The collection and distribution systems in traditional centralized wastewater systems (CWATS) is outdated [Otterpohl 2006]. In the USA, 25% of the population is served by DWATS [UNEP, 2002]. In Germany, the centralized treatment expenses per person would cost around € 124 p.a. [wvgw, 2005], whereas for small scale treatment it ends up to € 600 – 1,500 p.a. for four persons [Fröhlich et al., 2005]. About 80-90% of capital costs in centralized systems are related to collection (including piping, pumps) for sewage [Libralato et al., 2012]. There are several drawbacks of conventional treatment such as controlling the peak flow, waste dilution, periodic maintenance of pipes and energy use for pumping. As per estimation, the decentralized system could save around 20% of total drinking water consumption by controlling source and differentiating water usage [Otterpohl et al.,2004]. Due to mixing of high rainfalls and industrial influence with sewer networks causes overflow and leads to high treated effluent discharge which has a higher probability for eutrophication compared to decentralized [Brown et al., 2010]. According to environmental compatibility and ecological favorability the decentralized system is always better than the centralized system. However, there is no clear understanding on assessment for overall advantages. Whether to install a system opposed to other vastly depends on local conditions and individual cases. Due to high expenses of total setup for centralized systems, a combined system with centralized and decentralized systems is recommended instead of a fully centralized system [Orth, 2007]. Measuring the greenhouse gases from wastewater treatment plants are gaining acute attention [Foley et al., 2010].

- Choosing of most sustainable wastewater treatment is under research and signifies for composite indicators to embrace the environmental, economic and social issues. To achieve a good ecological footprint, appropriate wastewater treatment in small settings should be focused, according to the Water Framework Directive (WFD) 2000/60/EC. Sludge production, reuse of wastewater and potential to recover products such as nitrogen (N), phosphorus (P) have been considered as environmental indicators. Some key factors for implementing a decentralized system are: odors, noise, visual impact, public acceptance, complexity of construction and operation [María et al., 2014]. Probability of mechanical failure in terms of effluent quality failure is also defined as an environmental indicator [Eisenberg et al., 2001]. Design tool, Environmental Decision Supports System (EDSS) is available to cope with the design and selection of wastewater treatment complexity. However, the efficiency studies have not been effectively noted in EDSS, compared with WFD for environmental planning, economic evaluation/ cost-benefit analysis of suitable methodological approaches. Internal and external impact of noise from treatment plants and economic feasibility should be surveyed. Membrane bioreactor (MBR) suits for treatment locally and deliver the best quality water for reuse but the installation costs are high. Constructed wetland is the cheapest option with almost no noise pollution than treating wastewater into an extended aeration system. So, for high loads MBR and moderate loads sequence batch reactors are economically acceptable [M. Molinos-Senante et al., 2012].

- The decentralized applications have been categorized into few classes like constructed wetland, improved aerobic and anaerobic biological systems [Singh et al., 2015]. If a decentralized system is properly designed and operated onsite by householders, equal public health could be generated for water reuse and nutrient recycling. In a centralized system, there is a high requirement of land for treatment as well as pumping and piping for collection [Ho et al., 2006]. Decentralized systems could enhance the source separation of micro pollutants (pharmaceutical products, personal care compounds) and result in materials recovery, eventually causing lesser environmental impact [Libralato et al., 2012]. As centralized systems have many known and undetermined problems, decentralization is quite effective for separating grey & black water, reducing water consumption (low flush toilet, vacuum) by spreading awareness, acceptance in institutional, public and administrative level [Capodaglio et al., 2017; Hamburg Wasser, 2017].
  Nutrients recovery by removing pollutants in CWATS is becoming obsolete to deal with recent population growth in cities. The innovative technologies and ideal circumstances could be provided in these existing plants to meet the circular economy and sustainable performance [Kehrein et al., 2020]. By adopting N recovery practices in wastewater treatment, 30 % of global N fertilizer could be achieved [Mulder, 2003]. More than 80% of used toilet papers pass into CWATS and increase the total suspended solids load [Ruiken et al., 2013]. Grey water is 65% of total wastewater flow from a household having high potential of pollutant removal for recycle and reuse [Ghaitidak et al., 2013]; further it can be increased up to 90% if vacuum toilets are installed [Hernández et al., 2011]. The emission rate can be reduced by separating the grey water from black water [Ghaitidak et al., 2013]. As the water is getting inaccessible and expensive, grey water separation and treatment at source is important to reduce the water stress [Morel et al., 2006].

- Due to urbanization, construction of small-scale decentralized is economically viable to tackle environmental protection. Therefore, these processes have to be compatible with operation reliability, possibility for future expansion, low operation & maintenance costs and economic feasibility. MBR is a reliable solution for small scale wastewater discharge in remote/small communities, urban and peri-urban areas with higher efficiency and very low environmental impacts, to be built depending on land availability and even constructed underground. As per ecology, local landscape and hydrology, the decentralized system also qualifies to serve small clusters of urban areas to develop local water reuse cycle, recycle of resources and energy recovery. Especially MBR requires low footprint, capabilities of handling high loading rate, immediate reuse of treated water after disinfection. The decentralized should be sustainable from several aspects including socially acceptable, economically affordable, environmentally suitable, technically reliable, and aesthetic appearance [Capodaglio et al., 2017]. Liability of existing online sensors which are prone to electrode fouling due to improper maintenance and inadequacy, not sufficient to interconnect into software to transmit the field operating parameters

[Carstensen et al., 1996]. Complicated monitoring and control of biological processes urge for automation of wastewater treatment with deterministic approach to show observed value and quick fault detection technique [Choi et al., 2001]. Potential benefits have been observed to produce energy (electricity, heat, biogas) by stream segregation of wastewater [Wenke et al., 2013; Hertel et al., 2015].

- The main effects of environmental noise are nuisance that has a negative impact on communication, recreation, and relaxation. Noise can causehealth problems, such as irritability, insomnia, headache, anxiety, severe cardiovascular diseases and hypertension, moreover, concentration in work and psychological well-being are also negatively affected by noise [Niemann et al., 2016, Danchenko N, 2016].

  Some areas which are not noise sensitive (such as commercial land, industrial area) suitable for installation of wastewater plants. Prolonged exposure to the environmental noise in silent zones like residential areas, hospitals, churches, and schools leads to the reduction of cognitive performance in children, ischemic heart diseases and premature deaths [European Environment Agency, n.d.]. The World Health Organization (WHO) and European Environment Agency (EEA) provided a variety of permissible noise levels based on location and activities.

- The major noise in a CWATS is produced during construction, revetment upgrade, outfall construction, sewer construction, trench shaft and tunnelling works, sheet piling and associated construction traffic [Arklow WTPP, 2018]. Additionally, in a centralized treatment plant which comprises mechanical equipment (e.g. pumps, blowers, etc.) and aeration tanks that operate 24h daily stationary noise is produced. Moreover, there will be traffic noise from trucks that visit the site (onsite truck traffic) to deliver consumables (i.e. chemicals) or to remove solid waste material, besides an emergency generator will be tested bi-weekly, during daytime hours [Corey K. et al., 2016].

  The construction noise impacts are a function of the total length of sewer lines that would pass through or near residential and commercial areas. Noise levels and health impact of sewage construction are directly related to the number and type of construction equipment, and the distance from areas which would be affected [Jefferson, 1982]. Based on the different types of sewer construction equipment, the noise levels listed in Table 1 can be expected during construction of main sewers.

Table 2. Equipment Noise from the construction of sewer (USEPA, 1980).

Equipment	No. of Units	A-weighted sound level (dBA) at 50 feet	Usage Factor (a)
Backhoe	1	85	0.4
Truck	1	88	0.16
Air compressor	1	81	0.5 (estimated)
Paving Breaker	1	88	0.25
Crane Mobile	1	83	0.16
Welding	1	83 (loudest mode)	0.25 (Estimated)

Construction noise is always expected to exceed EPA recommended levels (Hearing Loss < 70 dBA) for the protection of public health and welfare. The exposure time of noise is short term but any one house or business could be expected to be impacted for two to three days. Newly improved Noise control techniques such as employing mufflers on machinery or limiting construction in work-day hours will reduce the severity of noise impacts. [Jefferson, 1982, USEPA, 1980].

Moreover, undesirable noise is produced from water supply and sewage system (plumbing noise) inside the building can disturb the residents of the apartment.However, with new construction and plumbing technologies such as use of insulation, double layers-gypsum and mineral wool insulation layer and double-layer wallscan be easily reduced or prevented [Danchenko, N, 2016].

The most common cause of the plumbing noise is from flushing WC. The use of the flush is the source of noise that travels through the construction elements and transmits to other rooms or lower apartments and it is annoying to the neighbors. In figure 1 the flush noise transmission to the neighboring flats is shown [Danchenko, N., 2016]. According to the Danchenko[2016], plumbing noise has different sources in water
supply and in water sewage systems such as faucets
noise, falling noise, flow noise, impact noise, water
hammer noise.

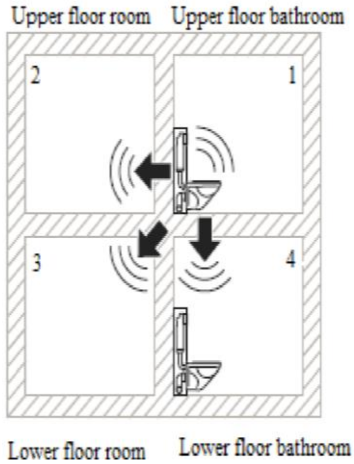


Figure 6. WC noise transmission [Danchenko, N., 2016]

- Aside from stationary noise sources of DWATS such as noise from vacuum toilets and septic tank evacuation, the transport of sludge will also increase the traffic noise pollution.

Nowadays the traffic noise especially road vehicles produce the majority of noise in residential and commercial areas, the flow of truck traffic through a residential area may be more offensive at night than a weekday [Sinha et al, n.d.], and if the waste from decentralized wastewater treatment installed systems is being transported together with household waste from these places it will lead to an increase in the number of trucks per day.

According to the Umweltbundesamt which is stated in Zannin et al. [2018], the household waste collection trucks generate sound power levels ranging from 105 dB(A) to 115 dB(A), which are strongly characteristic of impulse noise. Overall the operational noise of centralized and DWATS is negligible [CCNE, 2013] .

The introduction of the Environmental Noise Directive (END) in 2002 by EEA sought to monitor the effectiveness of EU noise emission and recommended the following measures to prevent noise pollution:

- Limit noisy construction works to 07.00 to 19.00 weekdays
- Utilise solid timber site hoardings where required to screen sensitive properties.

- Use modern, silenced and well-maintained equipment conforming to applicable EU directives.
- Shut down equipment when not in use, where practicable.
- Site semi-static equipment such as generators, mixers, and compressors as far away as possible from sensitive locations and ensure that the orientation is the optimum for low noise.
- Ensure that all workers are given training with respect to minimising noise and disturbance [EUR-Lex, 2002].

Van Afferden et al. (2015)

The focus of this research paper is to provide an approach in supporting of decision-making regarding the identifying proper development strategies and better finance schemes for decentralized wastewater infrastructure. The basic principles of this are to stand for an integrated perspective towards sustainable wastewater management. To operationalize these principles, a Geographic Information System (GIS) base approach 'Assessment of Local Lowest-Cost Wastewater Solution' – ALLOWS is developed. ALLOWS-GIS tool is introduced in this paper. The ALLOWS-GIS based assessment involves a geo-database provided with geographical, spatial, socio-economic, and statistical data of interested areas. ALLOWS creates financial indicators for different wastewater scenarios, thus it makes easy for the planners and decision makers which enables the comparative analysis to identify the best solution for the wastewater management problem.

M Anda et al. (2010)

This paper provides an overview of the results of five related research topics and reports the results of the exhibition projects of decentralized wastewater recycling in urban villages in Perth, Western Australia. The five research topics are: i) a new regulatory framework, ii) a technical element model (TEM), iii) a water balance and efficiency rating tool (named LaDeRS-H20), iv) mosquito monitoring in greywater wetlands, and v) a "Zero emissions nutrients" (ZEN) model for urban land developments.

M. Maurer et al. (2005)

In this paper estimation of cost of decentralized wastewater treatment plan has been shown and compare with the cost of conventional wastewater treatment plant. So, comprehensive cost of existing sewer system and conventional treatment plants is determined and on the basis of this cost a rough estimation has been calculated for the possible investment and maintenance cost not exceeding the cost of the centralized system and compare different the different conceptual alternatives. Costs of sewers and treatment plants, Replacement costs and investments, operation and maintenance costs is collected from various country of Europe and analyzed for the comparison.

Giovanni Libralato et al. (2012)

This paper discussed about the general review of recent trends regarding the role of centralisation and decentralisation in wastewater treatment. It is resulted priority has been given to both approaches on the basis of the specific required situation. This paper attempts to highlight the main aspects of decentralisation, pointing to the fact that it is not exact opposite of centralization, but a way to integrate the general effectiveness of wastewater treatment. But from this paper it is evident that in most cases in highly dense area with existing sewer system, a decentralised wastewater treatment approach is not stable alternative of centralised system because of high number condition factors such as social, economical and environmental. In this paper it is suggested to consider the possibility of a whole series of decentralized approaches of different levels of centralization and decentralization in WWTPs, which is currently showing a very realistic application, mainly in the case of large blocks (hospitals, shopping centers, schools, airports) and reformed urban areas, especially in relation to the recent tendency in treatment and reuse of treated wastewater.

J. Wolle et al. (2007)

In this paper some issues about monitoring and maintenance of decentralized wastewater treatments have been raised. The issues are the difficulty of maintenance by an expert from the far distance manually as it is not possible to present every plant at a time, because according to this paper these decentralised plants can not be run by an expert onsite. So, to mitigate this problem, the idea and development of a tool of an intelligent and information system has been discussed which enables the expert to oversee multiple systems by optimizing their processes and experimenting critical operating conditions remotely. Also, it helps to onsite staff by providing the basic process information for their efficient and secure performance.

DarjaIstenic et al. (2015)

The purpose of this paper is to put forward a survey on current status of wastewater treatment systems in 11 central and eastern (CEE) countries focused on rural small decentralized nature-based systems including treatment wetlands for settlement of less than 2000 people. This paper helped to evaluate and compare the nature-based wastewater treatment systems in each CEE countries. Also, some barriers such as lack of enough surface area and unavailability of flat surface in hilly or mountainous area have been discussed in this paper.

Andrea Arias et al. (2020)

In this paper, the study of comparison of carbon and water consumption for irrigation between the resident living in centralized wastewater area and the resident prefer to live in a decentralised wastewater treatment area has been presented. The study was conducted in the city of Santiago de Compostela in Spain. Within this framework two types of centralized configurations [i) a convention system with anaerobic digestion and ii) a conventional system without anaerobic digestion] were compared with two decentralized options [one with vacuum toilet and another is conventional toilet]. As a result, decentralized alternatives show 20-23% reduction in residential carbon footprint due to electricity generation. Also, reclaimed water from these systems can be used as irrigation purposes in nearby green areas, so no use additional tap water is required. The construction costs are more for decentralised systems and these are more complex but due to recovery products such as water and energy, the recovery time is less than the centralized systems.

Haddad M. et al. (2011)

In this paper, a test of hydroponic system is conducted as a decentralised wastewater treatment and reuse. Findings has shown that the hydroponic system is effective in reducing contaminant loads. The experiment is done in two ways, one is hydroponic barrels and another in hydroponic channels. Initially, both methods failed to produce an acceptable standards effluent, though it was effective in removing TSS and organics at high organic and loading rates. The test results obtained over a three of experiment. The initial design showed BOD removal of 21 to 30%, 45 to 71% COD removal, total nitrogen in the range of 13 to 47%, total phosphorus removal was relatively poor. But after modification of system to five consecutive treatments, the result strike 93-96% BOD removal, 80-89% COD removal and TN from 62-65%.

Ho G. et al. (2006)

This paper discussed about the comparison between centralized and decentralized wastewater system in view of economics, environmental and social factors. Considering these factors, it is concluded that the achievement of public health outcomes is same for both the onsite, small scale and decentralized wastewater systems and centralized systems and at almost same costs. But better environmentally sustainable outcomes can be achieved on a small-scale system than on a centralized system through recycling or reusing of water and nutrients. Extensive use of small-scale systems will only take place in the context of urban planning for sustainable cities. The social acceptability of small-scale systems requires time testing, but in order to enhance their sustainable features, exhibition projects should be facilitated by the government allowing changes in its policy and regulatory framework in the current situation of highly favorable centralized systems.

Orth H. (2007)

The objective of this paper is to select the right wastewater treatment system between centralized and decentralized method. Because choosing the wrong system can lead to catastrophic economic losses and result in inadequate sanitation. This hits specially the poorer countries where wastewater systems are just begun.So, the selection is very important. During selection, it is not justified in terms of ecological or cost-effectiveness to reject sewer system dogmatically or to denigrate the on-site plants because of the lower quality. Rather the benefit of the alternative systems depends on the conditions applicable to individual.

Li Z. H. et al. (2006)

The objectives of this study are to make assessment about the characteristics of aerobic granular sludge for the implementation of decentralized system sand to test the stability of aerobic granules as well as maintenance method. An experiment was conducted with a cylindrical column type reactor having working volume of 2L for cultivating aerobic granules. Sequencing Batch Reactor (SBR) was used as a reactor for the operation. After the operation of around 56 cycles, aerobic granules occurred in the reactor first time as a round shape, smooth surface and clear outline. At that time filamentous organism were observed at the surface of the aerobic granules. From the perspective of contaminates removal efficiencies, aerobic granular sludge is a highly promising technology for the decentralized wastewater treatment systems. To maintain outstanding settling property of aerobic granular sludge, the sludge volume index of short settling time such as 10 minutes is suggested.

Sharma A. K. et al. (2013)

The aim of this paper is to develop a generalised definition of the decentralized wastewater treatment systems for the acceptance across water sector. The definition encloses many different development scales where the decentralized systems are implemented and reflect the novel function and inherent characteristics of those systems. Various definitions of decentralized systems have been documented in the literature, in standards, code of practice and guidelines, which aims to provide guidance on design, installation and operations of wastewater systems to assure long term treatment facilities and protection of environment. From many definitions it is highlighted that the decentralized wastewater systems are the systems which are installed and operated close to the point of wastewater generation in semi urban development area. The main application of decentralized wastewater systems was to serve those area where it was not possible to develop centralized systems due technical or economical problem. After analysing 30 case studies, it is found that the most solid drivers for the adoption of decentralized systems is sustainability. The other drivers are difficulty of access of centralized systems and environmental protection.

Capodaglio, A.G et al. (2017)

This paper discussed about the merits and demerits of the many illustrated technologies, in terms of their sustainability potential. Various decentralized wastewater treatment methods and design parameters has been discussed. The methods are constructed wetlands, aerobic treatment systems: membrane biological reactors (MBR), Non-membrane biomass retention systems, anerobic treatment systems: upflow anaerobic sludge blankets (UASB). These all are nature-based systems. The main objectives of these methods are the protection of environment and human health by disintegrating the cycle of disease. Currently though the level of knowledge for implementation and performance is good at the level expert and scientist, it is still ineffective in technology transfer and have low awareness in the community about their benefits.

Tesfamariam E.H. (2018)

The topic of research in this paper is the technological efficacy of the concept of using effluent produced by the decentralized wastewater treatment systems (DEWATS) on agricultural land. A field experiment was conducted in a randomized complete block design (RCBD) with 2 treatments and 3 blocks. One treatment was DEWATS effluent irrigation and another was tap water with fertilizer. Experiment was done with Banana and taro crops using automated drip irrigation. The results show that irrigation with DEWATS effluent was comparable to tap water with fertilizer applied, especially for banana.

Alamgir M. et al. (2013)

The main objective of this paper the determination of the quality of wastewater at various stages of decentralized wastewater treatment systems (DEWATS) of the Panchtala colony at Kalishpur. For this, laboratory experiment was conducted collecting wastewater sample from 6 different points such as from inlet and outlet of settling tank, middle and outlet of anerobic center, outlet of planted filter, outlet of polishing pond of DEWATS at certain time interval. Test results show concentration of wastewater parameter such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), pH, Total dissolved solid (TDS), dissolved oxygen (DO), temperature, oil, grease, nitrate, phosphate, faecal coliform was gradually reduced to acceptable limit, which indicates that it is not harmful to discharge treated wastewater into natural water bodies or used for irrigation or reuse for toilet flushing and car washing.

Nayono S. et al. (2011)

This Paper present the results of the survey of the acceptance study by the community on decentralized sanitation options for rural karst area in Bribin's recharge area, conducted by KIT-ITAS and the faculty of geography, Gadjah Mada University in Yogyakarta, It was conducted by Indonesian-German joint research project IWRM in GunungKidul, Yogyakarta, Indonesia. The options that have been analysed includes: i) composting and urine diverted (UD) toilet, ii) Communal Bath-washing toilet facility, iii) anaerobic treatment for recovery of biogas, iv) reuse of grey water. Preliminary results of the survey show that the acceptance of existing systems (septic tank) is about 91.40% which is very high. But the concept of resources recovery is still very new to the community.

CHAPTER –4
METHODOLOGY

4. Methodology

4.1 Wastewater treatment plant: Technological options

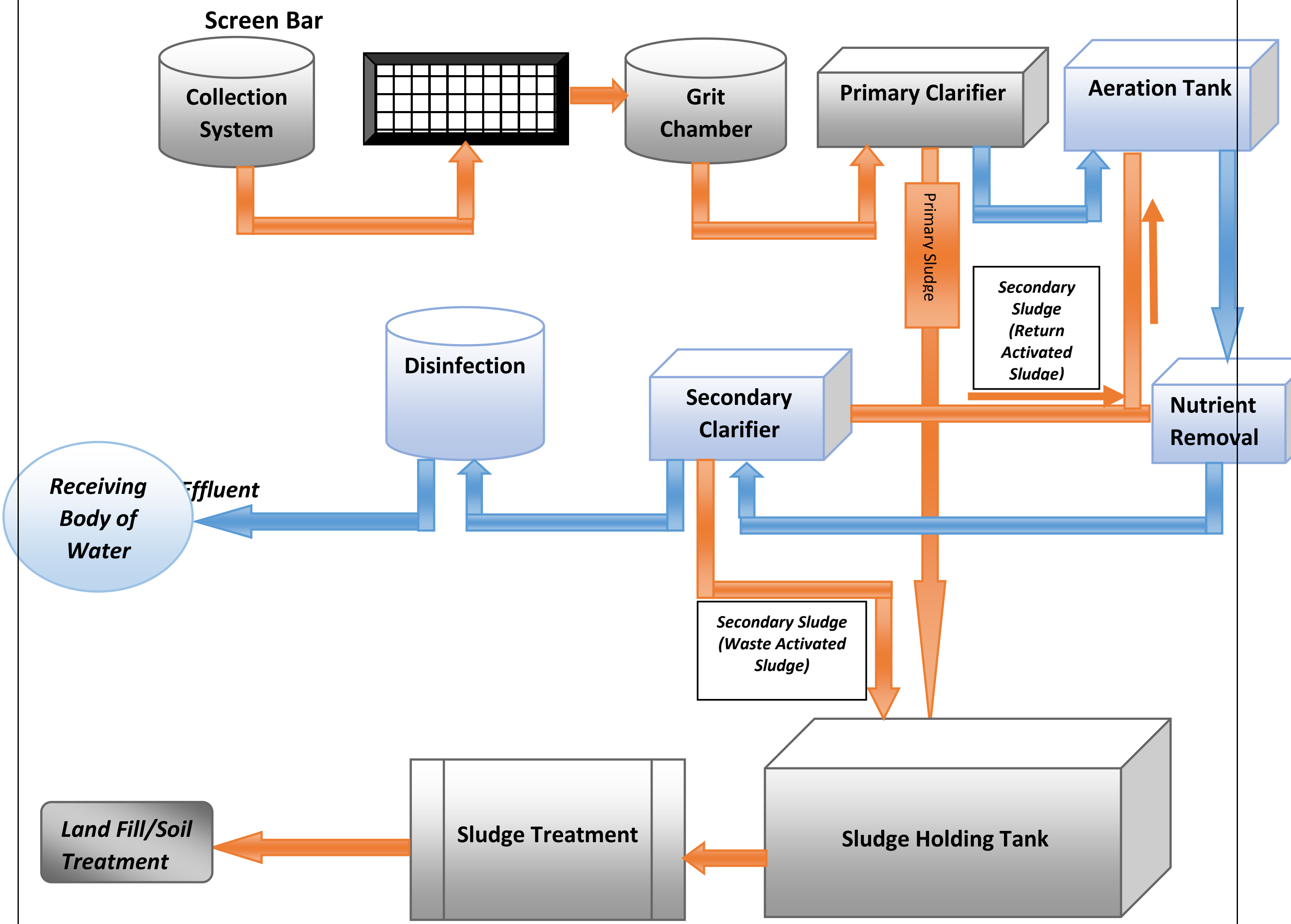
At present there are manytechnologicaloptions are available for wastewater treatments. These includes-

i. Activated Sludge Process (ASP)
ii. Aerated Lagoons
iii. Membrane Biological reactor
iv. Trickling Filters
v. Rotating Biological Contractors (RBC)
vi. Upflow anaerobic sludge blanket (UASB)
vii. Moving bed biofilm reactor (MBBR)
viii. Sequencing batch reactor (SBR)
ix. Waste Stabilisation Pond
x. Constructed Wetlands
xi. Phyto-remediation Systems
xii. Septic tanks
xiii. Root zone technology
xiv. Biofiltration and Sand Filters
xv. Bio-membrane Process
xvi. Bio-towers

4.2 Wastewater Treatment Systems:

- It is series of unit processes and unit operation that uses physical, chemical and biological processes.
- Designed to treat wastewater so that wastewater effluent does not harm the environment and human health.

4.3 Typical arrangements of wastewater treatment plant:



4.4 Activated Sludge Process:

The activated sludge process is now used regularly for biological treatment of municipal corporations and industrial waste water treatment. according to the definition, the basic activated sludge treatment process consists of the following three main components:

- A reactor where the microorganisms which are responsible for wastewater treatment are maintained in suspension and aerated.
- Separation of liquid solids, usually in a sediment tank
- A cyclic system where solids removed from the liquid-solids separation units can be returned to the reactor.

Types of reactors/aeration tank used in conventional activated sludge systems are

- Plug-flow reactor
- Complete mis activated sludge reactor

❖ Schematic diagram of the different reactors

a. Plug Flow Reactor

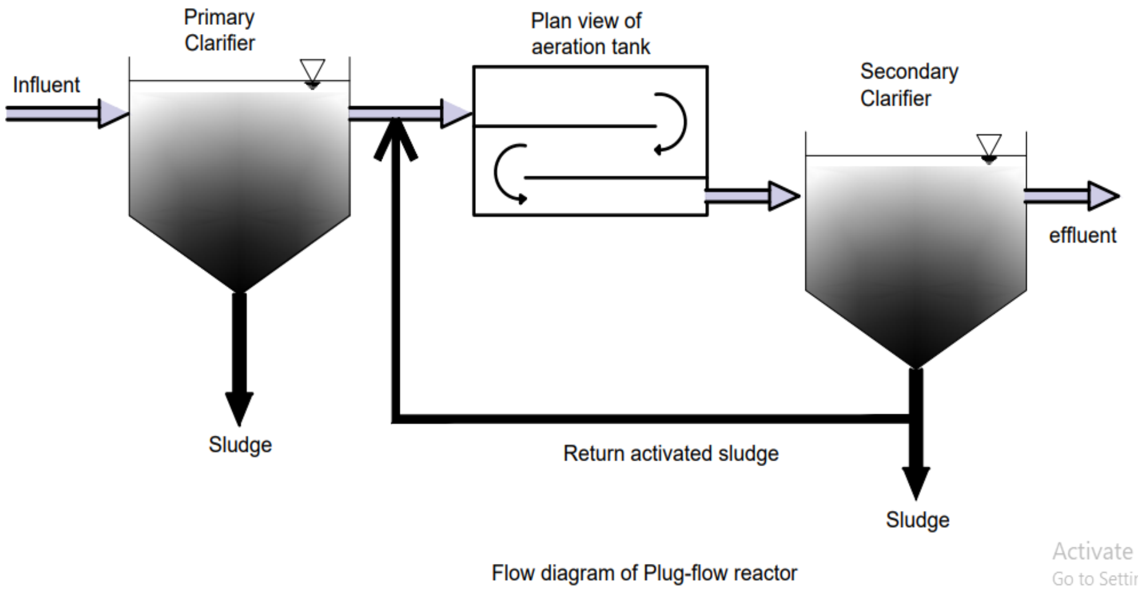


Figure 7: Flow Diagram of Plug-Flow reactor

b. Complete mixing sludge reactor

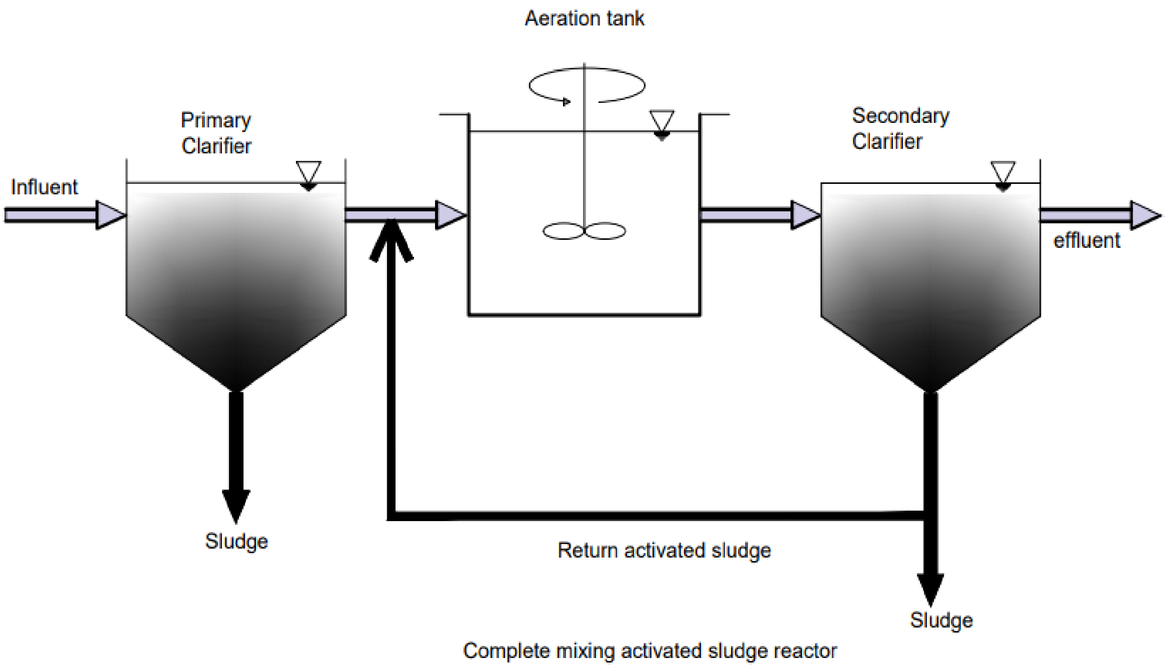


Figure 8: Flow Diagram of Complete mixing activated sludge reactor

- **Summary of general design criteria for treatment of domestic sewage in activated sludge**

Table 3

Sl. No.	Parameter	Conventional and complete mixing activated sludge process
1	Mean cell residence time, days	Warm: 4-5 Temperate: 5-10 Cold: 10-15
2	Food (F) to microorganisms (M) ratio, kg BOD_5/kg MLVSS	Warm: 0.6-0.9 Temperate: 0.4-0.6 Cold: 0.2-0.4
3	Hydraulic detention time, hour	3-8
4	MLSS, mg/l	2000-5000
5	Ratio of VSS and SS	0.70-0.85

6	Biodegradable fraction of VSS	0.55-0.70
7	BOD_5 of MLVSS (mg)/ Conc. Of MLVSS (mg)	0.55-0.70
8	SS in effluent, mg/l	10-30
9	Oxygen requirements, kg/kg of BOD_U removal	Without nitrification: 0.6-0.65 With nitrification: 0.80-1.20
10	Dissolved oxygen in aeration tank, mg/l	0.50-2.0
11	Expected removal efficiency	% of BOD_U :85-93 % of coliforms: 90-95
12	Kg phosphorus removed/100 kg BOD_U removal	0.40-1.0
13	Kg nitrogen removed/100 kg BOD_U removal	4-5

** MLSS – Mixed liquor suspended solids
VSS – Volatile suspended solids
SS – Suspended solids
MLVSS – Mixed liquor volatile suspended solids
BOD – Biochemical oxygen demand

4.5 Mechanically Aerated Lagoons:

Mechanically aerated lagoons are relatively shallow depth earthen basin generally 2 to 5 m deep. Mechanical aerators are installed on floats or fixed platform with aerated lagoon. Oxygen is provided by the mechanical aerators for biological treatment of wastewater and also mechanical aerators keep the organic solids into suspension.

Types of aerated lagoons:

Depending on the energy input per unit volume of lagoon and the provision of a recirculation arrangements, the solids are either settle or flow through or accumulate in the system. Thus, there are three principal types of aerated lagoons classified on the basis of the manner solids are handled. These are-

- Facultative aerated lagoons
- Aerobic, flow through
- Aerobic with solids recycling

- **Some general characteristics of different types of aerated lagoons for treatment of domestic sewage**

Table 4

Characteristics	**Facultative Lagoon**	**Aerobic, flow through**	**Aerobic with solids recycling**
Solids controls	None (Some settle and discharge with effluent)	Partial (Solids can not settle, all must discharge with effluent)	Full control (solids are recycle)
Suspended solids concentration in lagoon, mg/l	50-150	100-350	3000-5000
Ratio of volatile suspended solids (VSS) and suspended solids (SS)	50-80	70-80	50-80
Sludge age or mean cell residence time, days	High (because of settlement)	5	Warm: 10-20 Temperate: 20-30 Cold: more than 30
Overall BOD removal rate per day at 20^{o}C	0.6-0.8	1-1.5	20-30
Temperature Coefficients	1.035	1.035	1.01-1.05
Detention time,	3-12	2-5	0.5-2.0

days			
BOD removal efficiency, %	70-90	50-60	95-98
Coliform removal, %	60-99	60-90	60-90
Land requirement, m^2/person	Warm:0.30-0.40 Temperate: 0.45-0.90	Warm:0.30-0.40 Temperate: 0.35-0.70	Warm:0.15-0.25 Temperate: 0.25-0.55
Power requirement, kW/Person-year	12-15	12-14	18-24

❖ Schematic diagram of the different lagoons

a. Mechanically aerated facultative lagoon

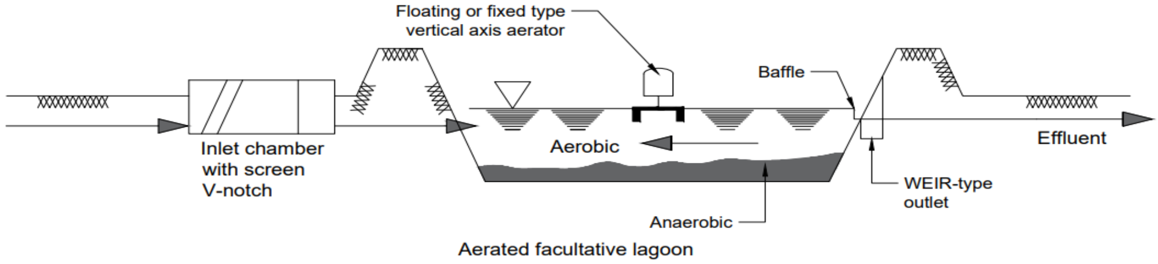


Figure 9: Schematic Diagram of Mechanically Aerated Facultative Lagoon

b. Mechanically aerated flow-through type lagoon

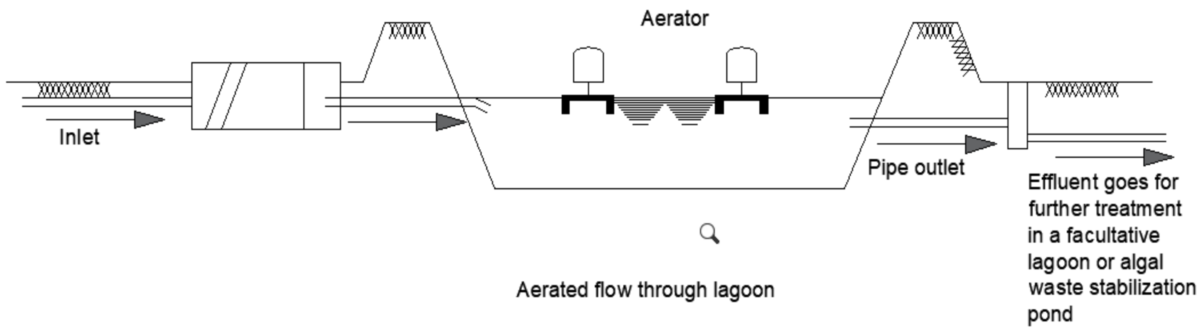


Figure 10: Schematic Diagram of Mechanically Aerated Flow-Through type Lagoon

4.6 Aerobic digestion Process:

Aerobic digestion can be used for the treatment of (a) only waste-activated sludge, (b) a mixture of primary sludge and waste-activated sludge or trickling filter sludge, (c) waste sludge of extended aeration plants. Recently aerobic digestion process has been introduced in larger wastewater treatment plants having capacity less than or equal to 2 m^3/s, but earlier it has been used in the plants of capacity less than 0.2 m^3/s.

- **Advantages of aerobic digestion process:**
  - The reduction of volatile solids in a well operated aerobic digester is almost same to that of the obtained from anaerobic digester.
  - Generates supernatant liquid of low BOD and nutrient concentration.
  - Produce nuisance odourfree, humuslike, organic stable end product.
  - Recover high basic fertizer in sludges.
  - Relatively easy operation.
  - Construction is simple.
  - Capital cost is low.
  - Suitable for high nutrient biosolids digestion.

- **Disadvantages of aerobic digestion process:**

  The major disadvantages are-
  - Energy intensive high for consuming oxygen.
  - The sludges produced from the aerobic digestion is not dewaterable mechanically.
  - The process is seriously affected by temperature, geometry of tank, feed solids concntration, type of aeration or mixing device, tank material and location.
  - Methane which is useful byproduct can not be recovered.

- **Design parameter for aerobic digesters:**

Table 5

Parameter	**Units**	**Value**
Sludge retention time	Day	At 20°C: 40 At 15°C: 60
Volatile solids loading	$Kg/m^3.d$	1.6-4.8
Oxygen requirements	Kg O_2/kg VSS	Approx. 2.3
Energy requirements for mixing	Mechanical aerator: $kW/10^3\ m^3$ Diffused air mixing: $m^3/m^3.min$	20-40 0.02-0.40
Dissolved oxygen residual in liquid	Mg/l	1-2
Reduction of volatile suspended solids	%	38-50

4.7 Membrane biological reactorsprocess (MBRs):

Membrane biological reactor (MBRs) is combination of microfiltration membrane having pore size 0.1-0.4 micrometer with a biological reactor with suspended microorganisms. First MBR were developed commercially by Dorr-Oliver in the late 1960s, consisting ultrafiltration with a conventional activated sludge process for the application of ship board sewage treatment. Microfiltration membrane separate the treated wastewater from active biomass. Recently it is widely used for the treatment of municipal as well as industrial wastewater treatment.

- **Types of membrane bioreactor:**

a. Side-stream MBR with external membrane filtration

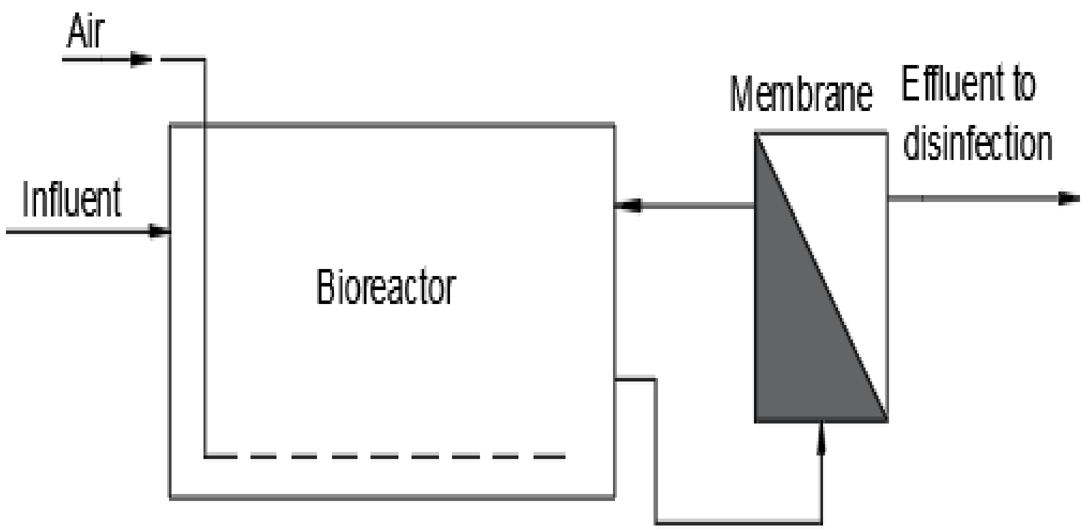


Figure 11: Schematic Diagram of Side-Stream MBR with external Membrane Filtration

b. Submerged MBR with internal membrane filtration

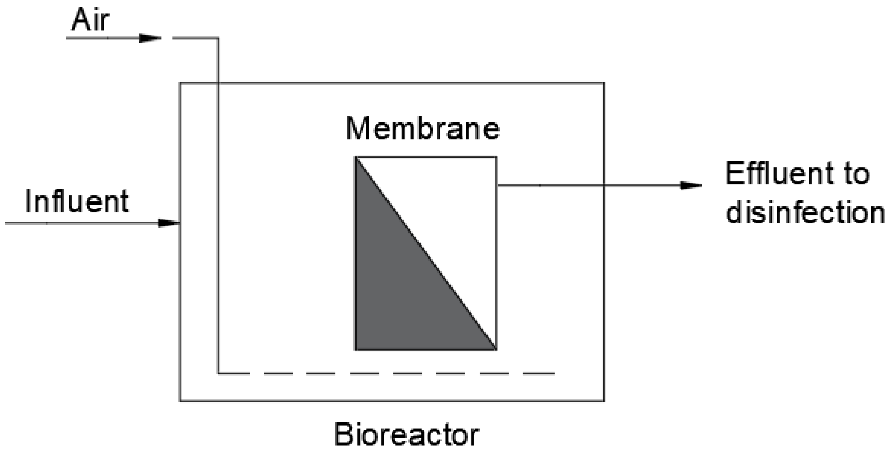


Figure 12: Schematic Diagram of Submerged MBR with internal Membrane Filtration

- **Process flow diagram**

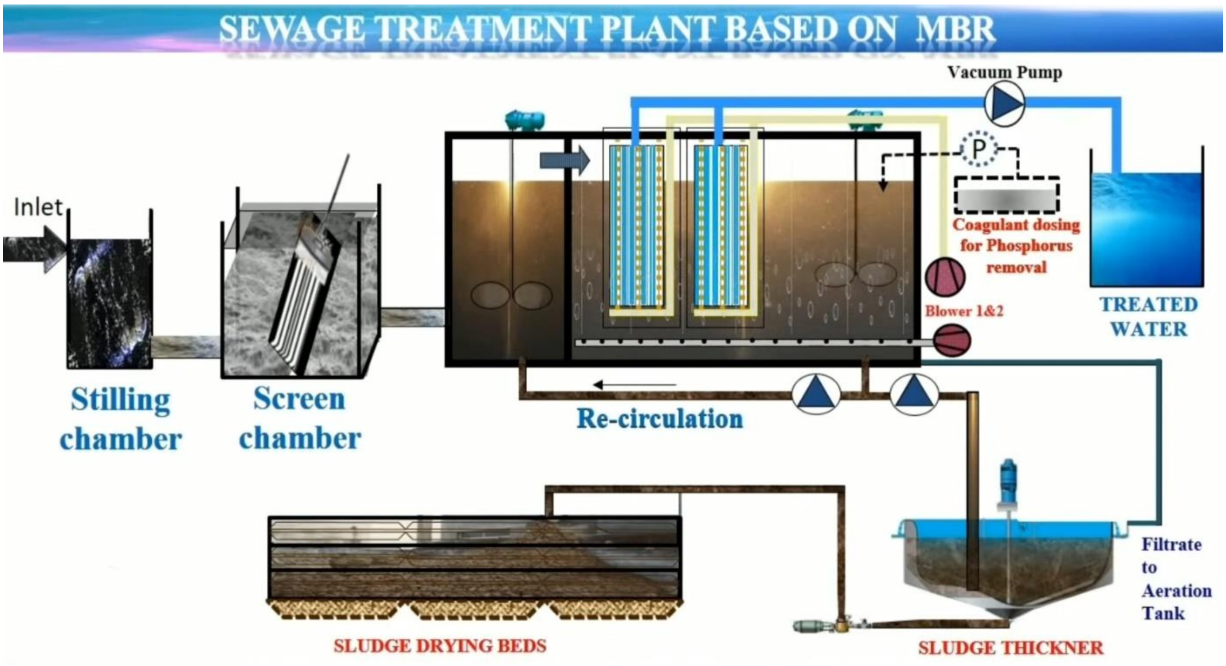


Figure 13: Diagram of Sewage Treatment plant Based on MBR

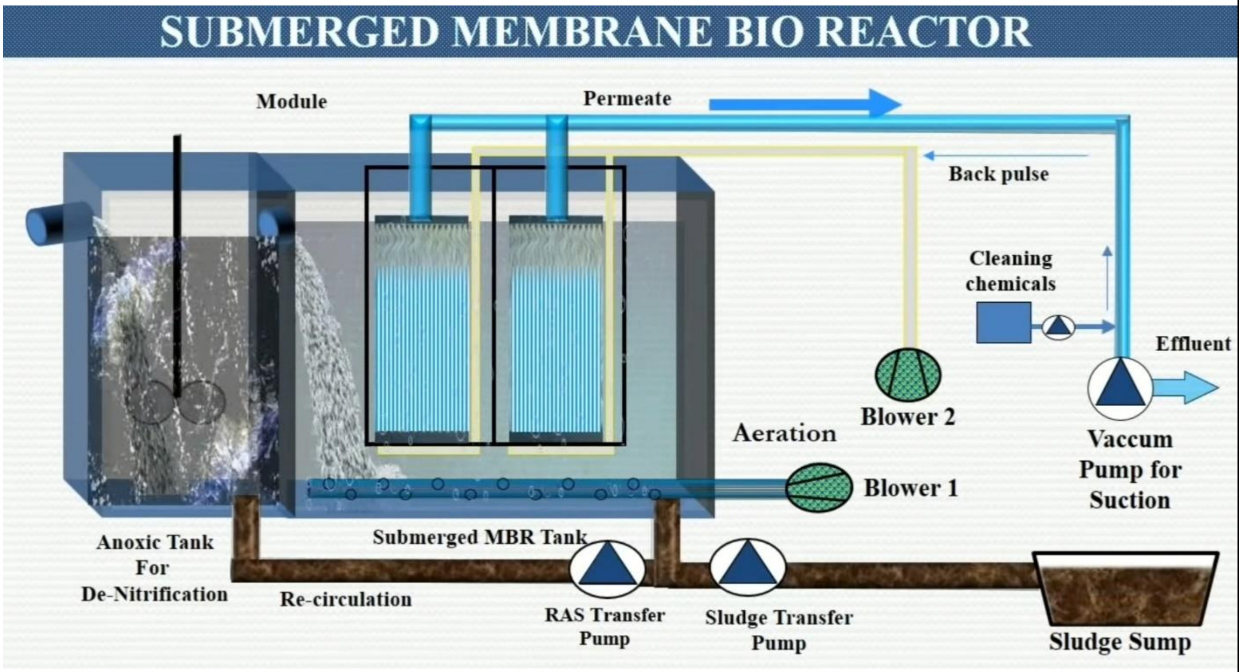


Figure 14: Process Flow Diagram of Submerged MBR with internal Membrane Filtration

Blower1 is for aeration for BOD removal in tank, will turn during operation and it will be off at the time of cleaning.
Blower2 is for back pulse of air during physical cleaning of membrane to avoid blockage, thus during operation of MBR, it will be in off mode and during cleaning it will be on mode.
**Chemical enhanced backwash is required in every 1-2 weeks for avoiding residual fouling and chemical cleaning for irreversible fouling is required in every 6-12 months,

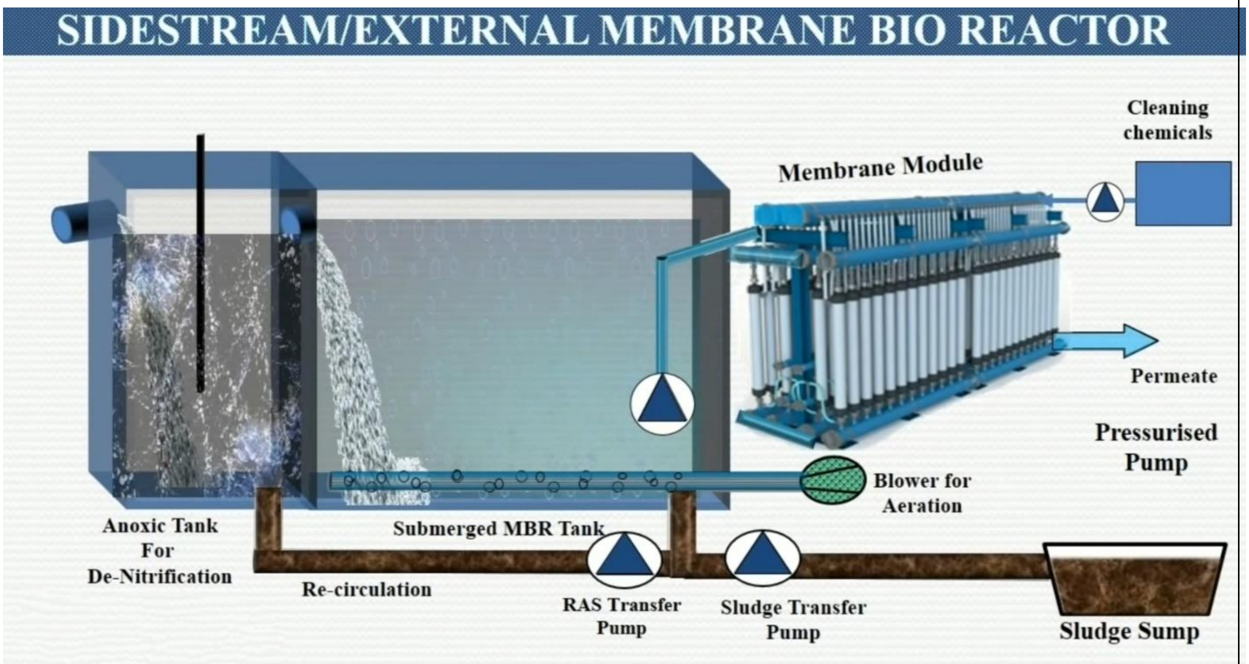


Figure 15: Process Flow Diagram of Side-Stream MBR with external Membrane Filtration

- **General operational & Performance data of a Membrane reactor:**

Operational data **Table 6**

Parameter	**Unit**	**Values**
COD loading	Kg/m^3. d	1.2-3.2
MLSS	mg/l	5000-20000
MLVSS	mg/l	4000-16000
Food to microorganism ratio	g COD/g MLVSS-d	0.1-0.4
Sludge retention time	Day	5-20
Flux	L/m^2. d	600-1100
Applied vacuum	kPa	4-35
Dissolved oxygen	mg/l	0.5-1.0

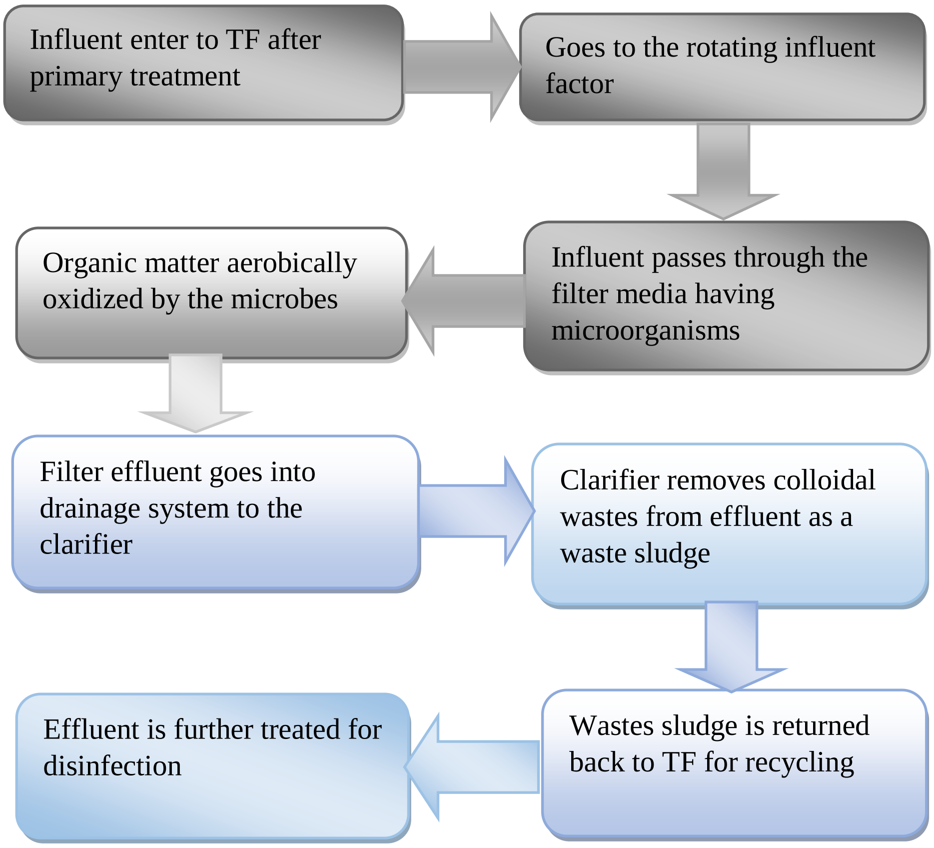
Performance data

Effluent BOD	mg/l	<5
Effluent COD	mg/l	<30
Effluent NH_3	mg/l	<1
Effluent TN	mg/l	<10
Effluent turbidity	NTU	<1

4.8 Trickling Filter (TF):

Trickling filters is the one type of aerobic wastewater treatment system having fixed film bioreactor which is a section of secondary wastewater treatment system. Trickling filter pursues attached growth system. In this system, microorganisms are attached to a medium which are responsible to degrade and remove the maximum biological and inorganic waste from the wastewater.

- **Process**



- **Applicability**

After primary treatment wastewater influent passes through the filter media. At that time organic material of the wastewater is adsorbed by the population of microorganisms which are attached to the medium as a bio-film or slime layer (thickness: approx. 0.10 to 0.20 mm). During passing through the filter media, microorganisms present in the wastewater gradually attached with the filter materials like slag, rock or plastic packing surface and form a film. In the outer part of the slime layer, organic matters are degraded by aerobic microbes. Thickness of slime layer increases due microorganism growth and because of this oxygen can not penetrate the full depth of the slime layer, hence anaerobic environment develops near the packing surface. Microorganism in the layer start endogenous respiration and lose the ability to cling with packing medium. Then slime layer washed out from packing medium by the liquid and slime layer again begins to grow. The process of falling the slime layer is known as sloughing. The sloughed solids go to the underdrain system and then clarifier to remove from wastewater.

- **Advantages**
  - Easy and reliable secondary wastewater treatment unit.
  - Small area requires for construction, so suitable where the large area is not available.
  - Effective treatment of high concentration of organic matters based on the medium used.
  - Produce BOD, COD, nutrients, colloids free effluent.
  - Less power needed.
  - Diligent nitrification unit.

- **Disadvantages**
  - Requires high capital cost for designing.
  - Additional treatment by chemical disinfectant requires to meet standard level.
  - Possible accumulation of excessive biomass which can not maintain aerobic condition may hamper TF performance.
  - Occurrence of clogging is high.
  - Flies breading and odor problem.
  - Regular operator attention requires.
- **Types of trickling filter**

  Based on the hydraulic and organic load, trickling filters can be classified into two categories. These are-
  - Low rate trickling filters
  - High rate trickling filters.

- **Design characteristics of trickling filters treating domestic wastewater**

Table 7

Parameter	**Low rate filters**	**High rate (stone media) filters**	**High rate (plastic media) filters**	**Roughing filters**
Hydraulic load, $m^3/m^2/day$	1-4	10-30	40-90	60-80
Organic load, kg $BOD_5/m^3/day$	0.10-0.30	0.30-1.2	1.2-3.0	2.0-6.0
Re-circulation ratio	Nil	0.5-3.0	1.0-4.0	1.0-4.0
Depth, m	1.8-3.0	1.0-3.0	4.0-12.0	4.0-12.0
Filter media	Rock, gravel	Rock, gravel	Plastics	Plastics
Removal efficiency, %	80-85	65-85	65-85	40-65
Nitrification	Well	Limited	Limited	Nil

4.9 Rotating biological contactors (RBC):

RBC was first installed in 1960 in West Germany and after that in the United State (US). Rotating biological reactor is a fixed bed reactor. It consists of stacks ofdiscs mounted on a rotating horizontal shaft. Discs are partially immersed (about 40%) into the flowing wastewater and slowly rotates at about 1 to 6 rpm. RBC unit is used as a secondary wastewater treatment unit in conventional wastewater treatment process after the primary treatment of wastewater. The rotation of discs helps the population of microorganisms to expose alternatively to the atmosphere and wastewater and keeps wastewater tank aerated and assimilated to degrade dissolved organic matters and nutrients.

- **Advantages**
  - Contact time is high.
  - Effluent quality is high (reduce both BOD and nutrients)
  - Processing stability is high and resists shock hydraulic and organic loads.
  - Space requirement is less.
  - Comparatively silent process.
  - Risk of channeling is nil.

- ➢ Requirements of power is less.
- ➢ Excess sludge production is low.
- ➢ Broad active surface.

- **Disadvantages**
    - ➢ Investment as well as maintenance cost is high.
    - ➢ Needs weather protection (sunlight, rain, wind and cold climate).
    - ➢ Odor problems.
    - ➢ For operation and maintenance, skilled permanent technical labor is required.

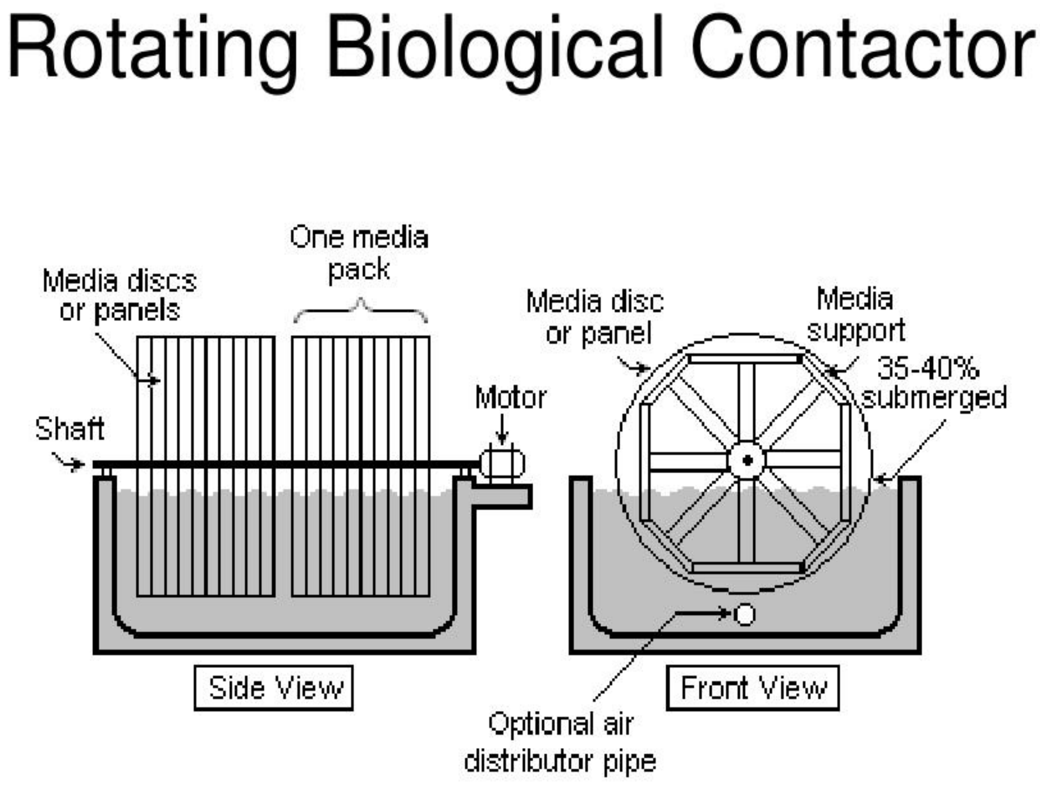
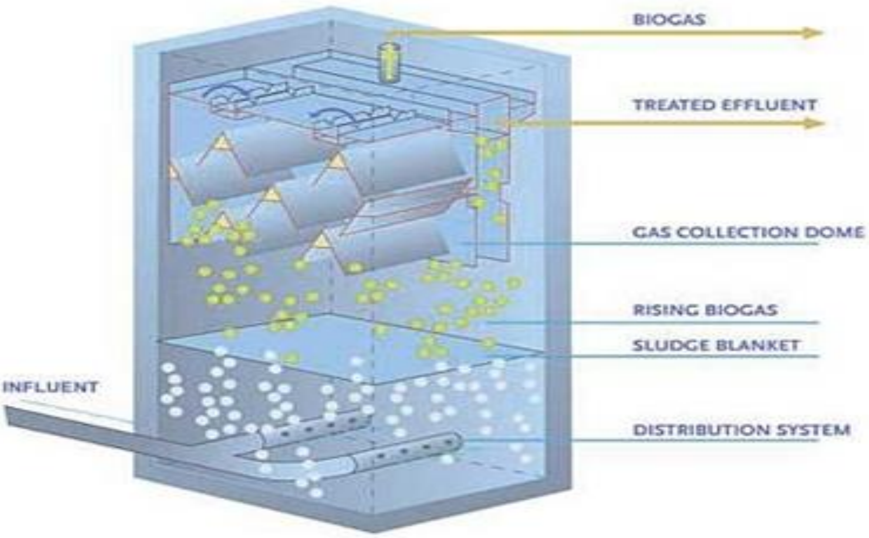


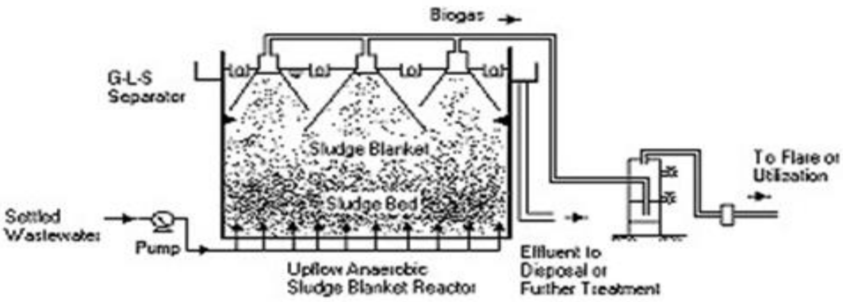
Figure 16: Schematic Diagram of Rotating Biological Contactor

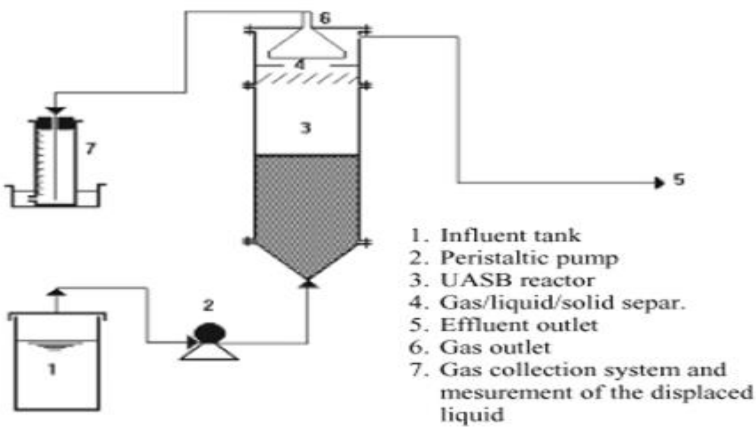
4.10 Up flow anaerobic Sludge blanket (UASB):

Up flow anaerobic sludge blanket technique is also called as UASB reactor. It was developed in 1970s by Prof. GatzeLettinga, in Netherland. UASB reactor is used in the principal of anaerobic process.It is a methane producing reactor.

- **Concept and process**

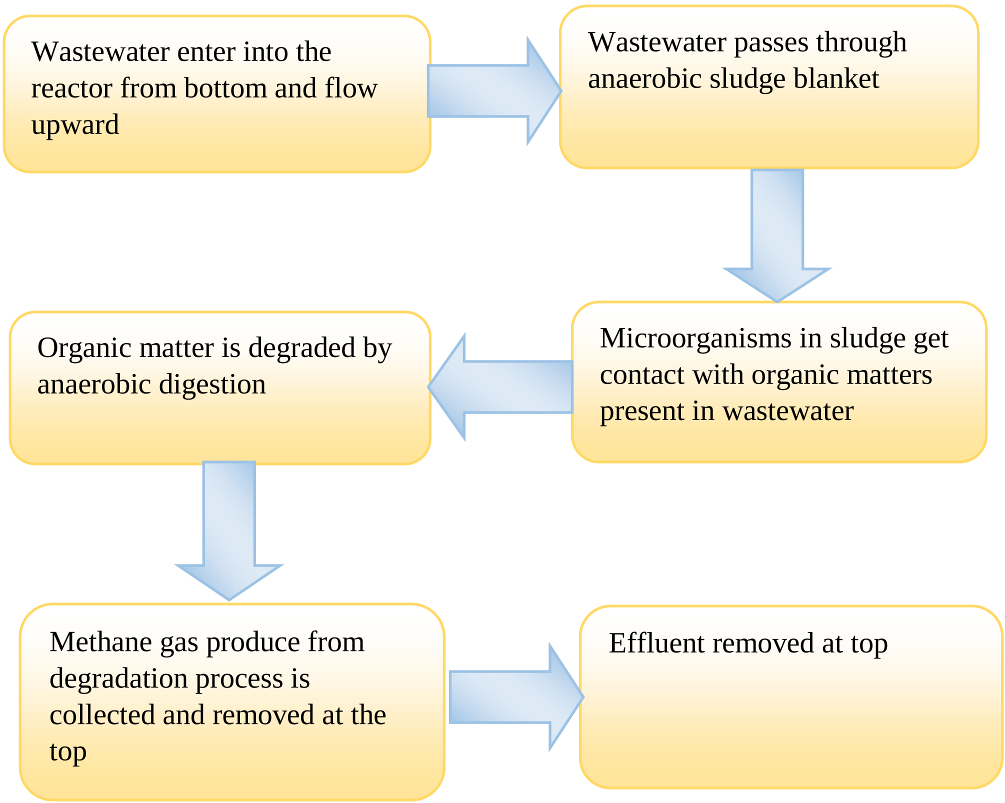






Schematic diagram of the laboratory UASB reaction system.

Figure 17: Schematic Diagram of The Laboratory UASB reaction Systems



- **Advantages:**
  - High BOD reduction.
  - Resists high hydraulic and organic loads.
  - No need of frequent desludging as sludge production rate is low.
  - Produced biogas can be utilized as a source of energy.
  - Energy consumption is less as no aeration system is required.
  - Nutrients rich effluent can be used for agricultural irrigation.
  - Low land area required, can be constructed in underground.
  - Produce less CH_4 and CO_2 than other anaerobic process.
- **Disadvantages**
  - Requires Skilled person for operation and maintenance.
  - Requires constant source of electricity.
  - Requires further treatment of effluent and sludges.
  - Not suitable for cold regions.
  - Unstable for varying organics and hydraulic loads.

- **Design Characteristics of Upflow anaerobic sludge blanket (UASB) reactor**

Table 8

Parameter	**Value**
Depth, m	4.5-5 for sewage
Sludge blanket depth, m	2 to 2.5 for sewage, more for stronger or industrial wastewater.
Upflow velocity, m/hr	0.5 to 1.2
Volumetric organic load, kg COD/m^3/day	For domestic: 1 to 3 For agro-industrial: 10-15
Sludge production, kg TSS/m^3 treated sewage	0.15-0.25
Hydraulic retention time (HRT), hr	8-10
Solids retention time (SRT), day	30-50
BOD and COD removal efficiency, %	BOD: 75-85 COD: 74-78
Nitrogen and phosphorus removal, %	5-10
Gas production, m^3/kg COD Removed	0.38

❖ Decentralised Methods:

4.11 Waste Stabilization Pond:

- ✓ Waste stabilization ponds (WSPs) are the simplest biological techniques for the treatment of wastewater.
- ✓ It is most appropriate when high quality effluent is not required and there is a large area available for the treatment.
- ✓ It a natural process, so no requirement of operating skills and equipment.
- ✓ Highly recommended for warm climate regions.

- **Types of WSPs**

  Based on their depth and biological reaction occur in the pond, stabilization pond can be classified in three types. They are-
  - Anaerobic waste stabilization ponds
  - Facultative waste stabilization ponds
  - Maturation ponds

- ✓ Generally, ponds are constructed in the earthwork having relatively very small in depth compared to their large surface areas.
- ✓ It can be utilized individually or in a series to improve treatment quality.
- ✓ To increase treatment effectiveness, WSPs should be linked in a series of three or more ponds where effluent will flow from anaerobic pond to facultative pond and at last, to the maturation pond.

- **Anaerobic ponds**
  - Depth of these ponds are generally kept in the range of 2.5 to 5.0 m.
  - Anaerobic conditions prevail throughout the depth of the ponds except few centimeters of surface zone.
  - A layer of scum forms at the surface of the ponds, which helps to maintain the anaerobic conditions throughout the whole depth as Scum layer prevents the penetration of sunlight inside the ponds and thus prevents the photosynthesis action.
  - Stabilization of sludge involves decomposition of organic matters into CO_2, H_2S and CH_4 through anaerobic digestion and their precipitation.

- **Facultative ponds**
  - Depth of these ponds are varying in the range of 1.5 to 2 m.
  - There are three zones exists throughout the depth of the ponds. Aerobic zones at the top surface, At the bottom there is anaerobic zone and facultative zone at the middle of the pond.
  - As the sunlight helps in photosynthesis, the oxygen level is highest during the day and drop at night and thus, during day, facultative zones are predominantly aerobic.

- In the upper part of the top and intermediate layers, the soluble organic matters are oxidized the microorganisms present in the wastewater under aerobic and facultative condition using the oxygen supplied by the photosynthesis metabolism of algae present in the pond.
- The solids settled at the bottom and anaerobic bacteria decomposed them to a stable end product.

- **Maturation ponds**
  - These ponds are generally 1 to 1.5 m in depth (for sunlight penetration and mixing)
  - Hydraulic retention time is 3 to 10 days/
  - Aerobic conditions exist throughout the depth.
  - The main objective of this pond is to achieve natural die-off of bacterial at the desired level.

- **Layout out of waste stabilization pond systems**

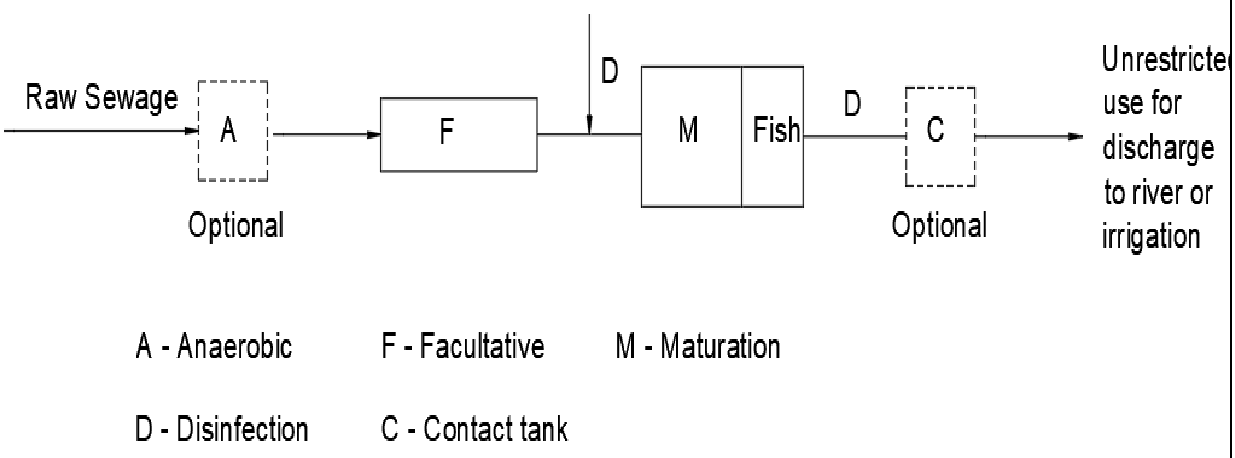


Figure 18: Layout of Waste Stabilisation Pond Systems

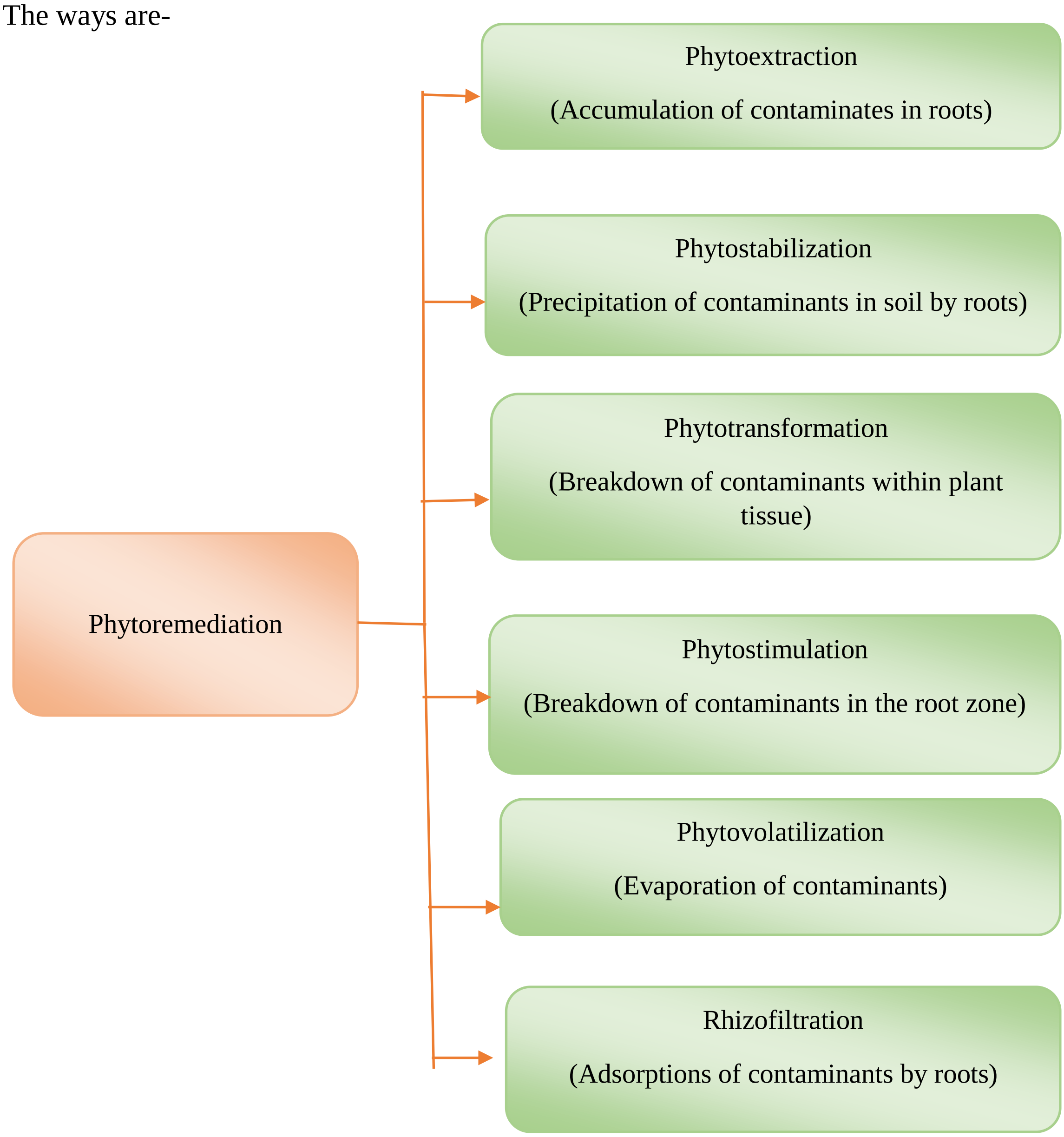
4.12 Phyto-remediation systems:

Phytoremediation is the technology by which contaminants of wastewater can be removed naturally by using plants and their co-existing microbes.

- **Mechanisms of phytoremediation**

Depending upon the types of contaminants, bioavailability and soil properties, there are many ways contaminants can be cleaned up by the plants.
Root systems have a large surface area which absorbs and accumulates water and essential nutrients need for plant growth. The emergence of contaminants occurs primarily in the root systems.

The ways are-



❖ Schematic diagram of different approaches of phytoremediation

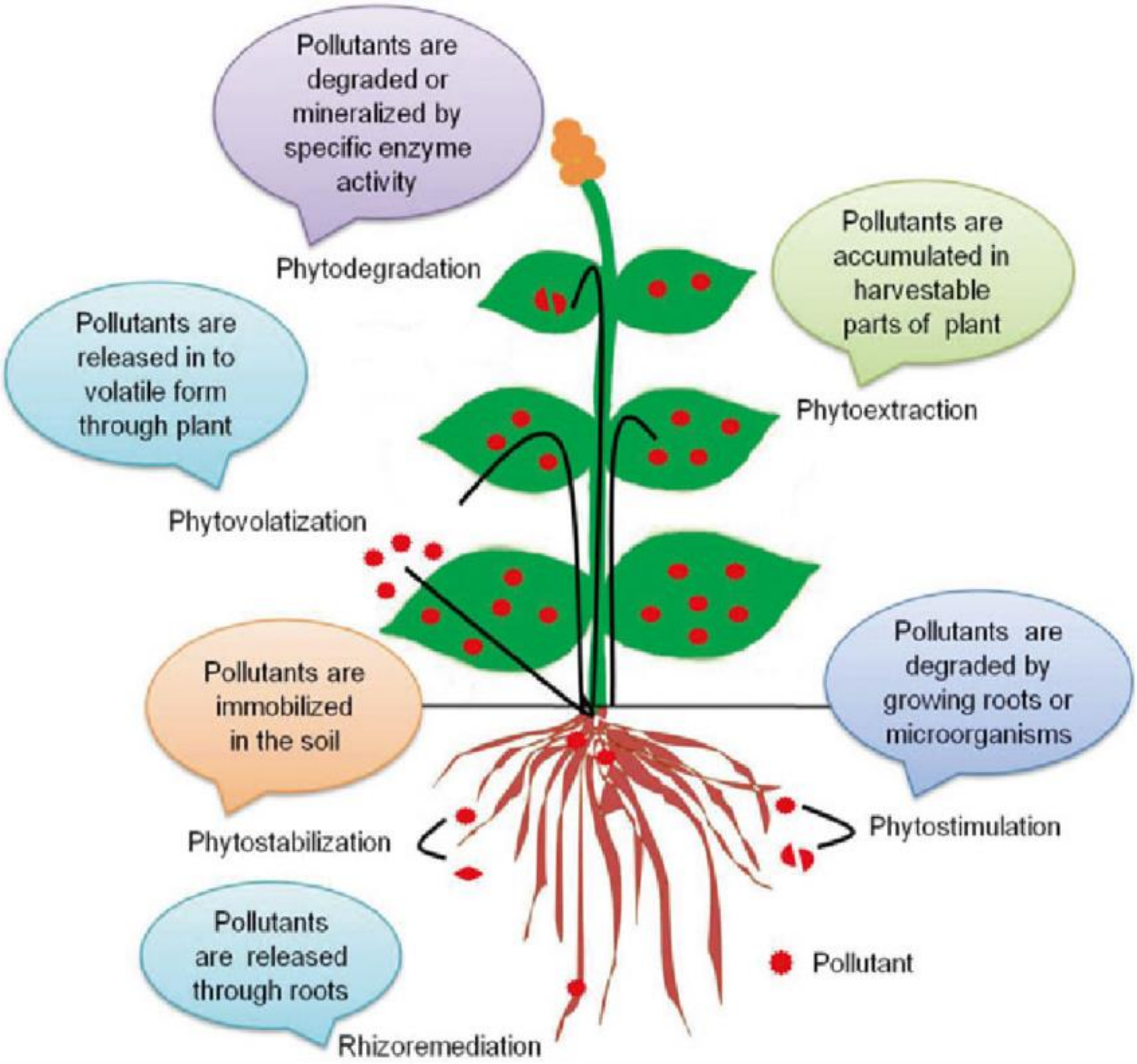


Figure 19: Schematic diagram of different approaches of phytoremediation

- ## Advantages
  - ➢ Cost effective compared to the conventional method of wastewater treatment.
  - ➢ Natural method, aesthetically more pleasant.
  - ➢ Need minimum land area.
  - ➢ Same plant can remove multiple contaminants.
  - ➢ Least harmful method.
  - ➢ Possible to recover and reuse of usable metal.
  - ➢ Reduce the potential spread of contaminants via air and water.

- **Disadvantages**
  - Decontamination rate is slow.
  - Not easy to achieve acceptable level of treated wastewater.
  - Possibility of spreading contaminants by the fallen leaves.
  - Care requires for trees and plants.
  - Trees might be killed by contaminants.
  - Not effective for wastewater having high contaminants.

❖ **Treatment wetland describing by phytoremediation process**

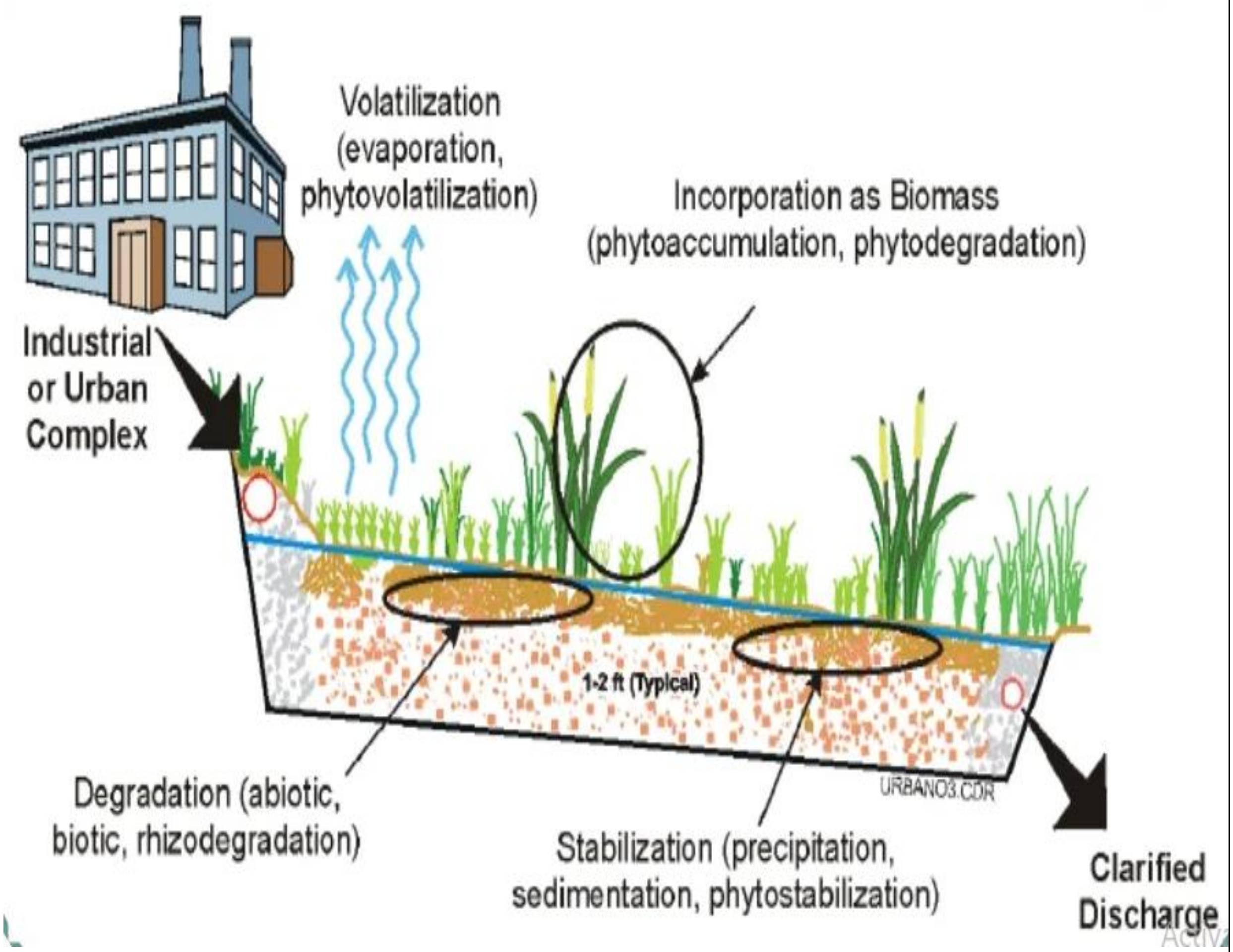


Figure 20: Diagram of Treatment Wetland describing by Phyto-remediation Process

4.13 Constructed wetlands:

Constructed wetland is one of the efficient nature-based technology for treating wastewater. It can effectively remove various types of pollutants from wastewater. It is a well-designed engineering technology developed to optimize the natural process found in the environment and so this process is considered as environmentally friendly and sustainable for wastewater treatment. Operation and maintenance cost of this process is lower than other nature-based decentralized wastewater systems.

- **Types of constructed wetlands**

This is divided into Free surface flow (FSW) and subsurface flow. Depending on the direction of water flow, sub-surface flow can be subdivided into horizontal flow (HF) and Vertical flow (VF).

❖ **Horizontal Flow (HF) wetland**

- Wastewater flows horizontally through a filter media having sand or grave as a filter medium and the water level is kept below the surface.
- Anaerobic degradation process prevails due to water saturated conditions.
- Clogging may be the one issue, so primary treatment must need to remove particulate materials to prevent clogging.
- EmergentMacrophytes are used.
- Preferable for secondary or tertiary treatment due to clogging problem.

❖ **Vertical flow (VF) wetland**

- Water is sometimes loaded on filter media surface and vertically percolates through the media.
- Air enters into the pores of the filter during reloading of water. So aerobic degradation process prevails.
- Emergent macrophytes are used.
- Preferable for secondary or tertiary treatment due to clogging problem.

❖ **Free Surface flow**

- It is look like natural wetland.
- Large area required.
- Generally, lightly loaded.
- Different plant genus can be used. a) emergent: Typha, Phragmites, Scirpus, (b) submerged: Potamogeon, Elodea, etc, (c) floating: Eichornia (water hyacinth), Lemna (duckweed).
- Preferable for tertiary treatment.

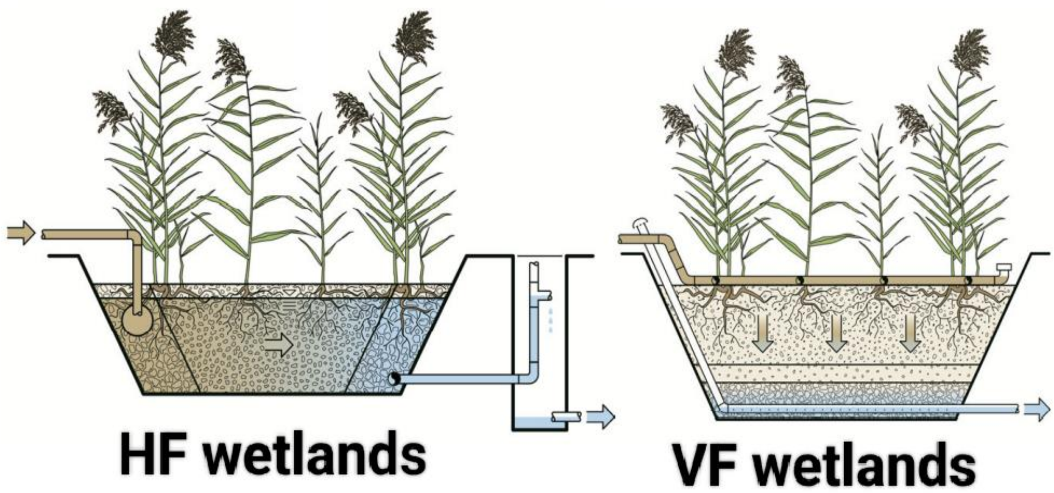


Figure 21: Flow Diagram of Horizontal & Vertical Flow Wetlands

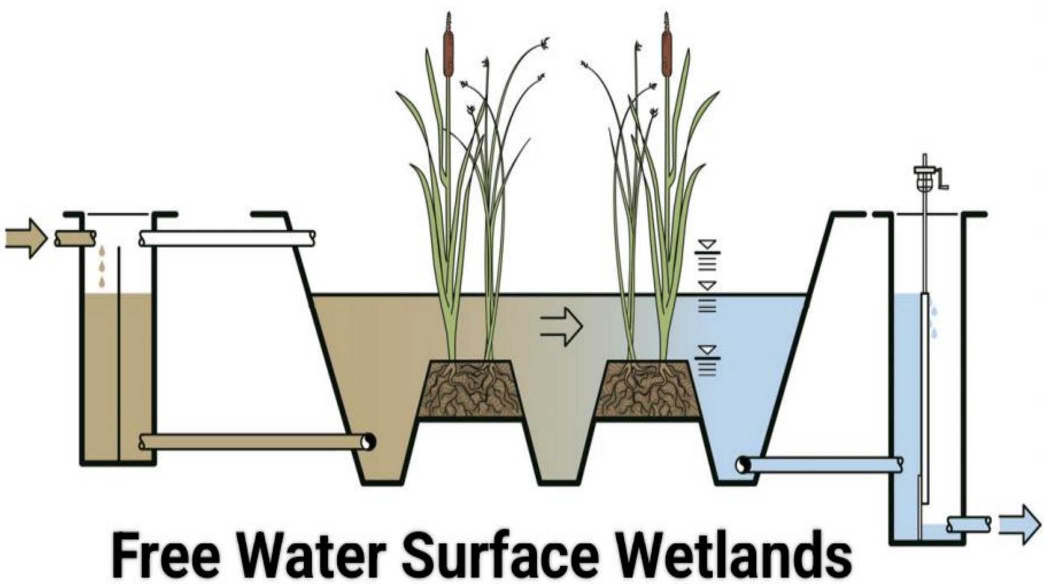


Figure 22: Flow Diagram of Free Water Surface Flow Wetlands

- **Removal efficiency of Constructed wetlands**

Table 9

Parameter	**Horizontal flow**	**Vertical flow**	**Free water surface flow**
Main application	Secondary	Secondary	Tertiary
Total suspended solids	>80%	>90%	>80%
Organic matter (measured as oxygen demand)	>80%	>90%	>80%
Ammonia nitrogen	20-30%	>90%	80%
Total nitrogen	30-50%	<20%	30-50%
Total phosphorus (long-term)	10-20%	10-20%	10-20%
Coliforms	$2\log_{10}$	$2\text{-}4 \log_{10}$	Log_{10}

4.14 Septic Tank:

Septic tank is an on-site wastewater treatment system, can be used for a single house. It is a watertight enclosed structure having one or more compartmentsconstructed below the ground level. Septic tank collects wastewater the house and separate solids from water.

- **Function of septic tank**

➢ It receives blackwater or excreta from the toilet.

➢ Large and heavy solids settle at the bottom of the tank and decomposed by the anaerobic bacteria.

➢ The decomposed sludge stored at the bottom.

➢ Gasses like, methane, carbon-di-oxide, hydrogen sulphide produced during anaerobic decomposition, can be released through vent pipe to the atmosphere.

➢ Lighter particles such as grease, hair, shampoo packet floats on the surface.

➢ The septic tank has to clean once in two or four years to remove accumulated sludge.

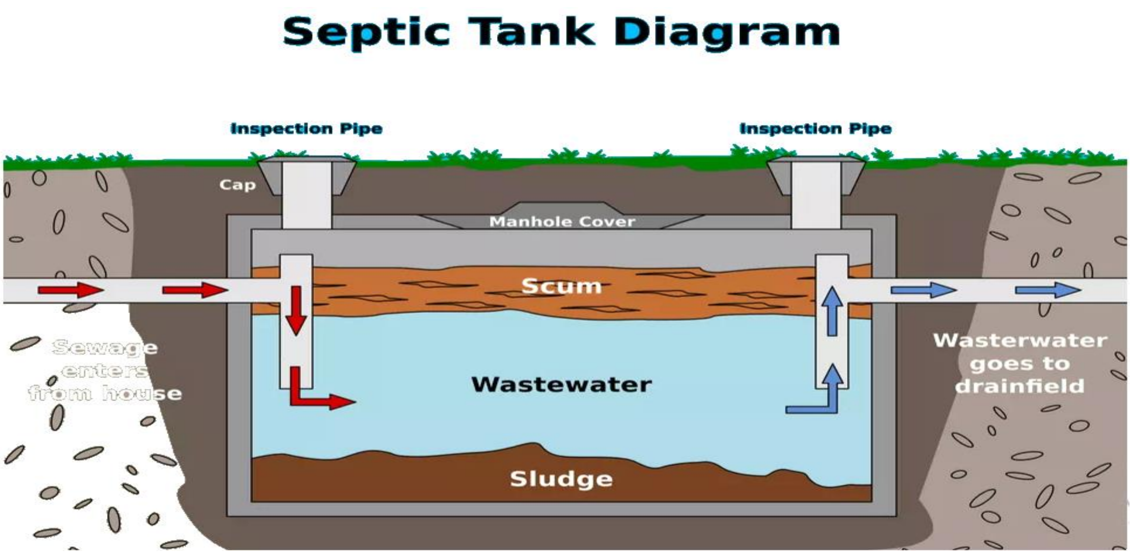


Figure 23: Flow Diagram of Septic Tank

- **Design criteria for septic tank**

Table 10

Parameter	**Value**
Discharge from each unit	10 Lpm at peak hours
Surface area for sedimentation	1 m^2/10 lpm of peak discharge
Minimum depth for sedimentation	30 cm
Minimum detention time	24 hours
Volume of fresh sludge	0.0005 m^3/capita/day
Digestion period	45 days
Digested sludge	0.03-0.07 m^3/capita/annum
Minimum total volume of tank	Two times daily design flow
Cleaning period	2 to 4 years
Length to width ratio	2 to 3:1

CHAPTER – 5
DISCUSSION

5. Discussion

5.1 Decentralised wastewater systems: Its issues and challenges

There are several issues andchallengesexperienced while implementing decentralised wastewater treatment systems. These are-

5.1.1 Lack of management expertise

It is a major issue to implementdecentralizedsystems. Evenwhen policy makersaccept the validity of decentralised approach, a lack of capacity to plan, design, implement and operate decentralised wastewater treatment systems is likely to severe barriers on effort to ensure its wide adaptations.

5.1.2 Institutional constraints

In the majority of the countries there is a lack of suitable institutional arrangements for managing decentralised wastewater systems and a Lack of suitable policy framework that encourages a decentralised approach, so there is a danger that decentralization will lead to fragmentation and a failure to address all overproblems adequately. So, without technical assistanceand other capacity buildingmeasures, a problem of institutional capacity that existed under centralised operations are simply passed to the new structure without a formalinstitutionalframeworkwithin which it canbe located efforts to introduce decentralised management are likely to be unreliable from the professional point of view.

5.1.3 Economic Issues

Decentralised systems may reduce the cost of investment required for wastewater management. But the majority of the local governmentagenciesanddepartmentslack the resources to invest innewinfrastructure. Actually, many developing countries lack the financial resources to investinimprovement of infrastructure.

5.1.4 Social issues

It is a key challenge. This is considering as key issue for the fact that there is currently no real demand for implementingeffectivesystems for wastewater treatment, as a result of this, there is generally little willingness to pay for services. This many relate to a lack of concerns or awareness of environmental pollution and of the healthimplicationsrelating to wastewater disposal and reuse.

5.1.5 Government policy and regulations

Lack of government commitment to address the wastewater related problems creates a political andinstitutionalenvironment that offers little incentive to manage wastewater effectively.In policy andregulations, there is a need to incorporate wastewater management within anintegratedframework of wastewater resources managementand other services of water supply and solid waste managements which means one cannot separates wastewater from the water from solid waste managements. Because if we treat wastewater that means there is a sludge produced, so it is a part of solid waste managements. The official standardsmightnotbeframedin a way that supports the development of decentralized systems. Therefore, there is a need to develop appropriate standards for the construction of decentralized systems. Also, to promote realistic andacceptable standard treated wastewater is reused, this policy needs to bebasedupon political experience andrealisticobjectivesand should be developed by the collaboration with organizationsinvolved with those communities that the decentralised wastewater treatment systems are designed to serve. So, it does notmakeanysense to comply the standards on the centralized systems similar to the decentralised systems. That is why policy and regulations are also considered as an obstacle that should be overcome to scaling up the decentralised wastewater systems.

5.1.6 Fragmentation of the water and sanitation agencies.

5.1.7 Segregation of actions among policy makers, professionalsandacademics.

5.1.8 Minimum investment in research.

5.1.9 Failure cases with fragmentation and little information.

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CHAPTER – 6

CONCLUSION

Across the world nearly 4.5 Billion people still lack access to harmless and properly managed sanitation amenities [Khalid et al., 2019]. In the developing world around two-thirds of its population is facing problems related to unhygienic way of disposal of excreta and even a higher risk due to improper disposal of wastewater. Most of the effect is experienced by developing countries where around 300 million urban residents, that is about 34% in South Asia do not have sanitation facilities. Many cities lack suitable collection and treatment of wastewater systems this is since there are investment issues.

In India, according to constitution (Item No. 5 & 6 of the 12th Schedule of Article 243 W), water supply and sanitation is a state matter. State government and urban local bodies are responsible for implementing operating and maintenance of sanitation system and also, they have tomanage the financial aid. Later, the 74th Constitution Amendment Act, 1992 provides a frame work and give the responsibilities to urban local bodies to supply and sanitation of urban area of the country. It is mandatory on behalf of the concerned agency who is responsible for the approval of decentralised wastewater management systems to include proper legal provisions in the municipal by-laws, to accommodate and motivateabout the decentralized wastewater management their jurisdiction. During city development plan, some land should be demarcated at different places of the for implementing decentralized wastewater systems.

REFERENCES

Arklow Wastewater Treatment Plant Project. (2018). [online] *UISCE irish water*. Available at: https://www.water.ie/docs/arklow-wwtp/Appendix-G-EIA-Reports/EIAR-Volume1-NTS/Arklow-WWTP-EIAR-Vol-1-(NTS)_Issue.pdf [Accessed 9 Jul. 2020].

Anforderungen (Changing requirements for water infrastructure. Part 1: Climate change, demographic change, new ecological requirements). KA – Abwasser, Abfall 12 (53), 1265–1271 (in German).

Augustin, Kim; Skambraks, Anne-Katrin; Li, Zhiqiang; Giese, Thomas; Rakelmann, Ulf; Meinzinger, Franziska et al. (2014): Towards sustainable sanitation – the HAMBURG WATER Cycle in the settlement Jenfelder Au. In: *Water Supply* 14 (1), S. 13–21. DOI: 10.2166/ws.2013.158.

Bautista Angeli, J. R.; Morales, A.; LeFloc'h, T.; Lakel, A.; Andres, Y. (2018): Anaerobic digestion and integration at urban scale: feedback and comparative case study. In: *Energy Sustain Soc* 8 (1). DOI: 10.1186/s13705-018-0170-3.

Bhushan Tuladhar, Prajwal Shrestha, and Rajendra Shrestha (2014), "*Decentralised wastewater management using constructed wetlands*", pp 87-94.

Brown, V., Jackson, D. W., &Khalifé, M. (2010). 2009 Melbourne metropolitan sewerage strategy: A portfolio of decentralised and on-site concept designs. *Water Science and Technology*, *62*(3), 510–517. https://doi.org/10.2166/wst.2010.296

Capodaglio, A. G., Callegari, A., Cecconet, D., &Molognoni, D. (2017). Sustainability of decentralized wastewater treatment technologies. *Water Practice and Technology*, *12*(2), 463–477. https://doi.org/10.2166/wpt.2017.055

Capodaglio, A. G., Conti, F., Fortina, L., Pelosi, G., &Urbini, G. (2002). Assessing the environmental impact of WWTP expansion: odour nuisance and its minimization. *Water Science and Technology*, *46*(4-5), 339–346. https://doi.org/10.2166/wst.2002.0620

Anda Martin, Radin Maya Saphira Radin Mohamed, Kuruvilla Mathew, S. Dallas, and G. E. Ho. "Decentralised wastewater treatment and recycling in urban villages." *Water Practice and Technology* 5, no. 3 (2010).

van Afferden, Manfred, Jaime A. Cardona, Mi-Yong Lee, Ali Subah, and Roland A. Müller. "A new approach to implementing decentralized wastewater treatment concepts." *Water Science and Technology* 72, no. 11 (2015): 1923-1930.

van Afferden, Manfred, Jaime A. Cardona, Mi-Yong Lee, Ali Subah, and Roland A. Müller. "A new approach to implementing decentralized wastewater treatment concepts." *Water Science and Technology* 72, no. 11 (2015): 1923-1930.

Maurer, Max, Dieter Rothenberger, and T. A. Larsen. "Decentralised wastewater treatment technologies from a national perspective: at what cost are they competitive?." *Water Science and Technology: Water Supply* 5, no. 6 (2005): 145-154

Libralato, G., Ghirardini, A.V. and Avezzù, F., 2012. To centralise or to decentralise: An overview of the most recent trends in wastewater treatment management. *Journal of environmental management*, *94*(1), pp.61-68

Wölle, J., Steinmetz, H., Hansen, J., Einsfeld, K. and Ebert, A., 2007. An intelligent visualisation and decision support system for decentralised wastewater treatment plants. *Water Science and Technology*, *56*(5), pp.183-191.

Istenic, D., Bodík, I. and Bulc, T., 2015. Status of decentralised wastewater treatment systems and barriers for implementation of nature-based systems in central and eastern Europe. *Environmental Science and Pollution Research*, *22*(17), pp.12879-12884.

Arias, A., Rama, M., González-García, S., Feijoo, G. and Moreira, M.T., 2020. Environmental analysis of servicing centralised and decentralised wastewater treatment for population living in neighbourhoods. *Journal of Water Process Engineering*, *37*, p.101469.

Haddad, M. and Mizyed, N., 2011. Evaluation of various hydroponic techniques as decentralised wastewater treatment and reuse systems. *International journal of environmental studies*, *68*(4), pp.461-476.

Ho, G. and Anda, M., 2006. Centralised versus decentralised wastewater systems in an urban context: the sustainability dimension. *2nd IWA leading edge on sustainability in water-limited environments. IWA Publishing*, pp.81-89.

Orth, H., 2007. Centralised versus decentralised wastewater systems?. *Water Science and Technology*, *56*(5), pp.259-266

Li, Z.H., Kuba, T. and Kusuda, T., 2006. Aerobic granular sludge: a promising technology for decentralised wastewater treatment. *Water science and technology*, *53*(9), pp.79-85.

Sharma, A.K., Tjandraatmadja, G., Cook, S. and Gardner, T., 2013. Decentralised systems–definition and drivers in the current context. *Water Science and Technology*, *67*(9), pp.2091-2101.

Capodaglio, A.G., Callegari, A., Cecconet, D. and Molognoni, D., 2017. Sustainability of decentralized wastewater treatment technologies. *Water Practice and Technology*, *12*(2), pp.463-477

Tesfamariam, E.H., Musazura, W., Odindo, A.O. and Buckley, C.A., 2018. Decentralised wastewater treatment effluent fertigation: preliminary technical assessment. *Water SA*, *44*(2), pp.250-257.

Saha, S.R. and Alamgir, M., 2013, November. Wastewater quality at different stages of decentralised wastewater treatment process in the Peoples Panchtala Colony at Kalishpur, Khulna. In *Khulna International Conference on Mechanical, Industrial and Materials Engineering*.

Nayono, S., Lehn, H., Kopfmüller, J. and Londong, J., 2011. OPTIONS FOR DECENTRALIZED WASTE WATER TREATMENT IN RURAL KARST AREA IN GUNUNG KIDUL: SOCIAL ACCEPTANCE