وزارة المياه والكهرباء
MINISTRY OF WATER & ELECTRICITY
General department of Wastewater

Wastewater Treatment Process System and Enhancement of

Presentation Outlines

- Wastewater Treatment methods.
- Wastewater Treatment Levels.
- Primary treatment.
- Secondary treatment.
    - Aerated lagoon
    - Activated sludge
    - Extended aeration
    - Oxidation ditches
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    - Membrane Bioreactors
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- Wastewater Treatment Process Applied in Saudi Arabia
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    - Particle filtration
    - polymeric Membrane separation
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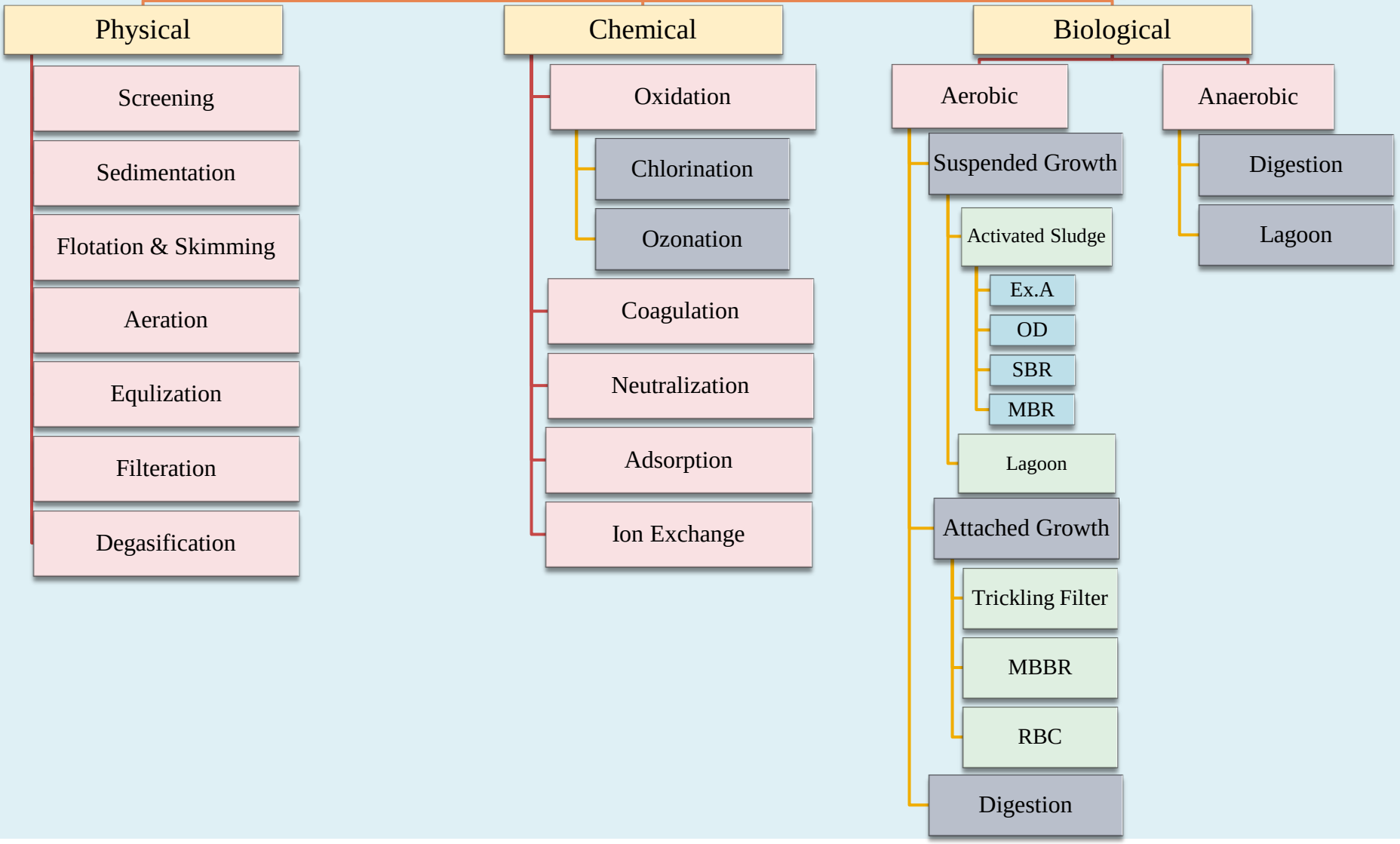
- Disinfection.
- Reuse.

Wastewater Treatment Methods



Wastewater Treatment Levels

Treatment Level	Treatment Goals
Preliminary	Removal of wastewater constituents such as pieces of wood, rags, removable floatable materials, grit, and grease which may cause problems in the operation and maintenance of the plant.
Primary	Removal of part of the suspended solids and organic matter from the wastewater
Secondary	Removal of biodegradable organic matter (in solution or suspension) and suspended solids. The disinfection is typically included in conventional secondary treatment.
Tertiary	Removal of the remaining solids that have not removed by secondary treatment, usually used gravel filters or used micro strainers, as tertiary treatment includes removal of nutrients such as nitrogen and phosphorus, And also includes disinfection
Advanced	Removal of suspended and dissolved materials that are not removed by biological treatment when required for various water reuse applications.

PRELIMINARY TREATMENT

Screening

To remove large volume solids which can make troubles in pipes, equipment, channels and tanks.

Mechanical screens

Rotary type

Semi rotary type

Screw type

Fine & coarse screens.

Manual screens

Can be used in small plants and as an emergency in large plants

PRIMARY TREATMENT

Primary settling

To remove part of suspended solids (40-70%) and biological load (30-50%) to reduce the load on secondary treatment.

- Circular tanks.
- Rectangular tanks.
- Gravity settling
- Mechanical scraping settling.
- Settling with chemicals.

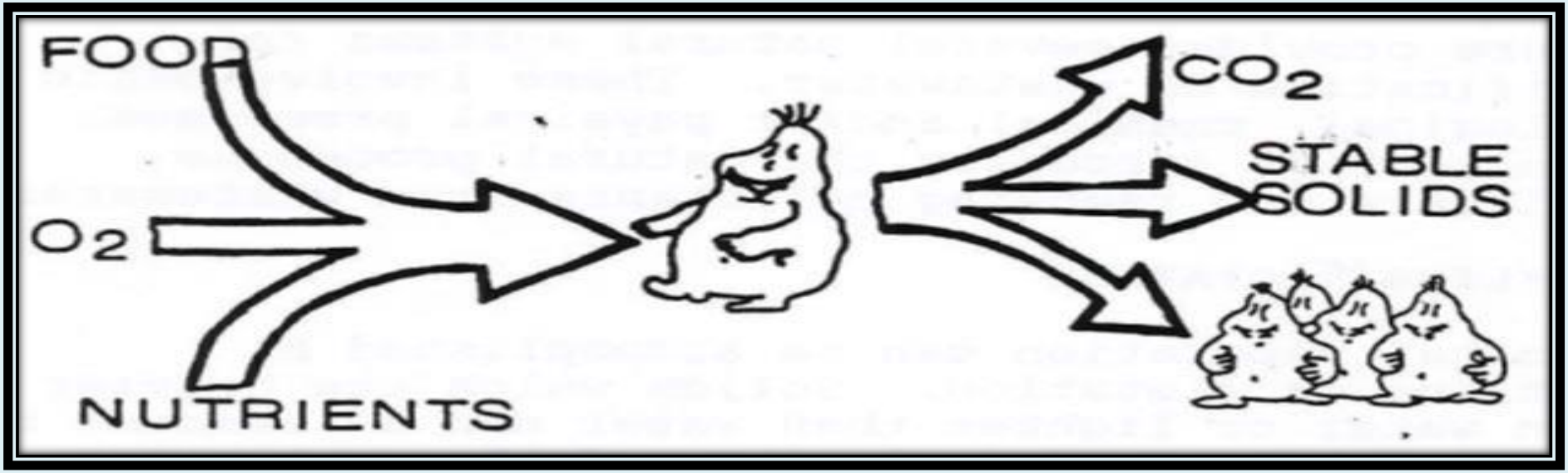
SECONDARY TREATMENT

Biological Treatment

The purpose of the secondary treatment - biological - is to convert the fine organic materials that are not settled in primary sedimentation tank, as well as the conversion of a large portion of the dissolved organic material, to a fixed suspended materials that can be settled. This is achieved by activating aerobic bacteria and other micro-organisms that rely on oxygen in her life, which leads to oxidation and stabilization of biodegradable organic materials. This method of treatment is called biological treatment because of its dependence on the activity of living organisms and biological principles.

Biological Treatment

What is meant by oxidation process of organic matter: when organic materials containing carbon, oxygen, hydrogen, and nitrogen, feed on the bacteria. The bacteria multiply and transform organic materials into gases (mostly contains oxygen. Such as carbon dioxide and nitrite CO2, NO2) in addition to the water. Chemically this process called oxidation. The rest of the organic material converted to peel and stick to the bacteria and becomes active sludge in the final sedimentation tank because their numbers are large and the food available for them.



Aeration

Sewage aeration is necessary for providing oxygen to the effluent to be treated by bacteria, aeration can be done by surface aerators which driven by electric motors or can be done by diffusers which connected to air blowers.

AERATION BY DIFFUSERS

AERATION BY AERATOR

AERATION BY DIFFUSERS

SECONDARY TREATMENT

Biological Treatment System

(Suspended growth) :

- **(Aerated lagoon)**
- **(Activated sludge)**
  - **(Extended Aeration)**
  - **(Oxidation Ditch)**
  - **(SBR)**
  - **(MBR)**

(Attached growth) :

- **(Trickling Filters)** **(RBC)** **(MBBR)**

AERATED LAGOONS

Aerated lagoons are relatively shallow lagoons in which wastewater is added at a single point either at the edge or middle of the lagoon and the effluent is removed from another point. The retention time is a function of the percent removal of BOD.

The retention time may vary from 6 to 18 days as the removal of BOD from domestic wastewater varies from 75 to 90 percent.

Oxygen is supplied by means of surface aerators or by diffused aeration units. The action of the aerators also maintains the solids of the lagoon in suspension.

Depending on the degree of mixing, lagoons may be operated as either aerobic or as aerobic-anaerobic systems.

In aerobic lagoons all biological solids are in continual suspension and stabilization of the organics occurs under aerobic conditions. In the case of the aerobic-anaerobic lagoon a large portion of the solids settles to the bottom of the lagoon.

As the solids build up, a portion will undergo anaerobic decomposition. Therefore, stabilization in this case occurs partly under aerobic conditions and partly under anaerobic conditions.

Aerated Lagoons advantages and disadvantages

Advantages

- Relatively simple construction
- Low maintenance
- Low capital cost
- Low energy cost
- Easy operation

Disadvantages

- Volatile emissions
- Sensitive to shocks and toxins
- Sensitive to seasonal changes
- Large land requirement
- No operation control

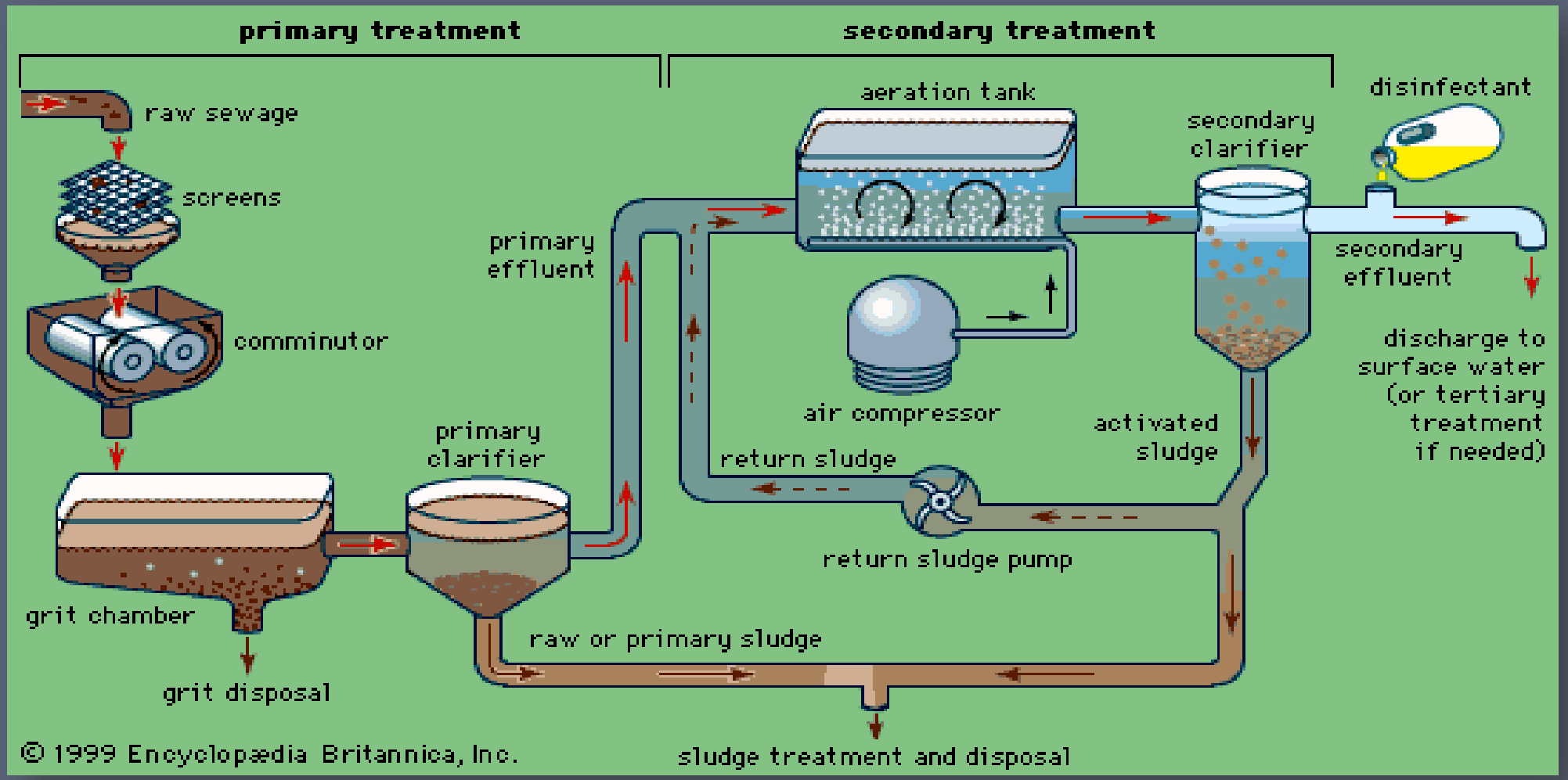
Activated sludge

- This method is the most common used because of the high effectiveness in treatment, and named activated sludge because we return part of the sludge settled in the secondary sedimentation tank to aeration tank continuously and this helps to speed up the biological process and increase efficiency due to increased biomass density in aeration tank and thus increase the oxidation rate and break down organic material to the basic components, Mixing done by mechanical aeration or by compressed air.

- Although it is more efficient than the biological filters they need to be highly skilled in operating the most important things should be followed up in operation is the following:

1) the fluctuations in the flow rates of influent entering the plant.
2) changes in the concentrations of contaminants found in sewage.
3) the concentration of suspended material in the aeration tank and the volatile materials percent.
4) the percent of returned activated sludge and the concentration of the suspended material in it.
5) dissolved oxygen concentration in the aeration tank.
6) the efficiency of mixing in the aeration tank .

ACTIVATED SLUDGE SYSTEM



activated sludge advantages and disadvantages

Advantages

- High efficiency in BOD removal
- Possibility of biological N&P removal
- Relatively Low maintenance
- Low land requirement
- Resistant to organic and hydraulic shock loads

Disadvantages

- High construction and operation cost
- Relatively sensitive to toxic loads
- Waste sludge disposal and need for sludge treatment
- High energy cost

Extended Aeration

one of the ways of activated sludge which is used for treatment of small flows, which range between 50-5000 cubic meters a day it is easy and flexible method of operation and it eliminates sedimentation primary stage and is sufficient only the process of filtering floating materials, sand.

Advantages

- No primary treatment is generally required
- Simplicity of operation
- High quality effluent efficiency
- Capability to handle shock loads
- no need for sludge digestion before drying.

Disadvantages

- Require large space and size
- High aeration requirement
- Final sedimentation required
- Expansion is difficult

Extended Aeration design criteria and applicability

design criteria

Hydraulic retention time (HRT) between (18-36) hours

Sludge concentration (MLSS) between (3000-6000)ml/l

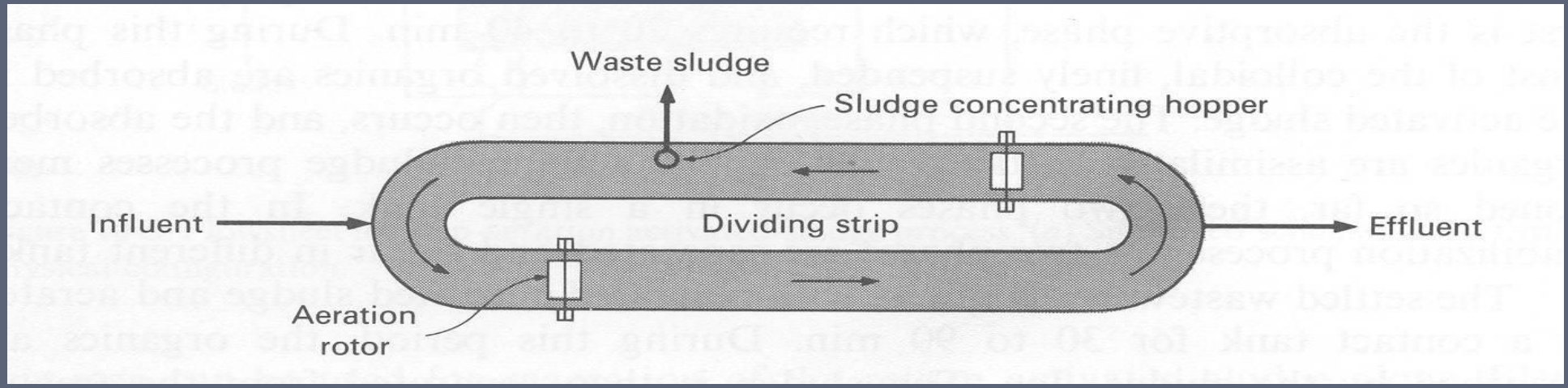
Sludge retention time (SRT) between (10-30) days

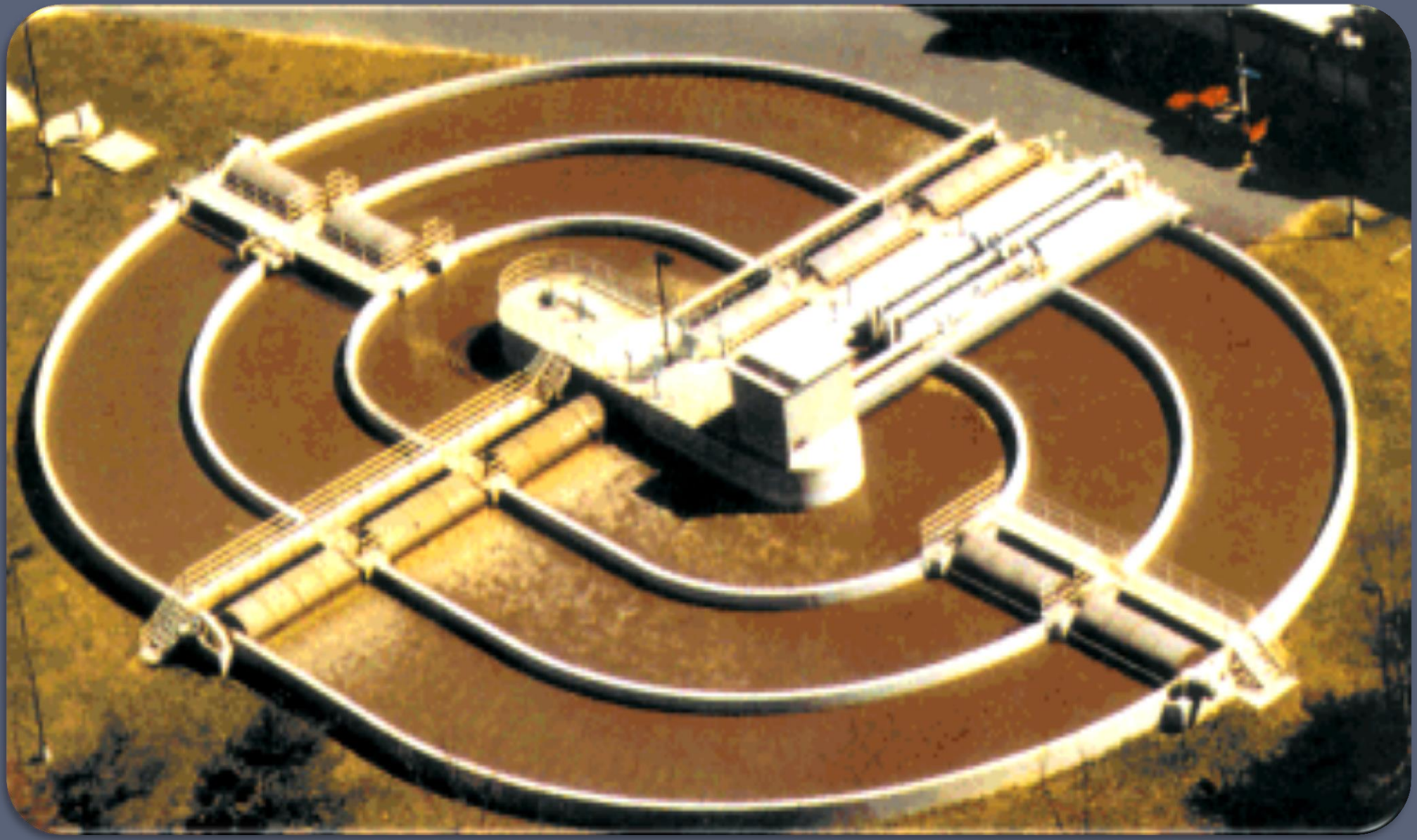
applicability

This system applicable for hydraulic and organic shock loads and suitable for high temperature atmospheres and large flows at range (250,000 m3/day)

Oxidation Ditches

it is a method of extended aeration, designed by the same principals, but it depends on the simplicity of construction and operation, consisting of one or more channels that aerate and turning wastewater by mechanical rotor and operated by electrical motor or diesel or windmills and Channel depth between (1-2 meters), so they can create by bricks, or reinforced concrete in the case of increasing the depth and width and aeration rates, and can be created in the natural soil if it is robust and stable. One of the key advantages that the sludge that is discharged from the secondary sedimentation tank relatively small and oxidizing so they can be dried on drying beds and used as fertilizer.





Oxidation Ditches advantages and disadvantages

Advantages

- No primary treatment is generally required
- Simplicity of operation
- High quality effluent efficiency
- Capability to handle shock loads
- Less aeration requirements as compared with extended aeration

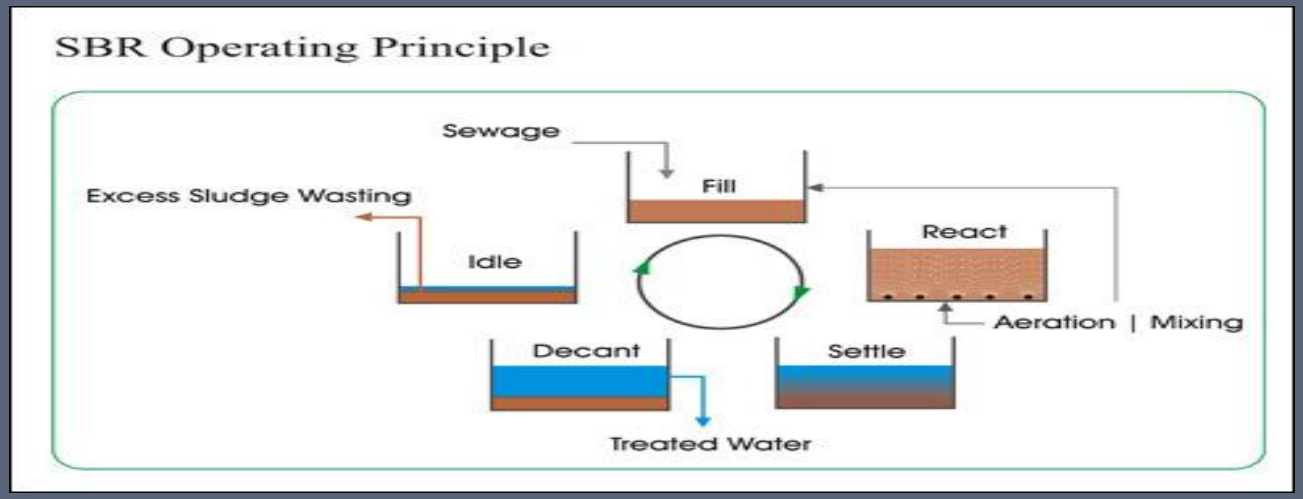
Disadvantages

- Require large space and size
- Final sedimentation required
- Expansion is difficult
- Sludge bulking is possible due to mode of operation

Sequencing Batch Reactor (SBR)

Sequencing Batch Reactors

It is one of the types of activated sludge systems, but it differs in that the reception of the raw water, aeration and secondary sedimentation processes take place in one tank sequentially so he provides much needed space and is ideal for small and intermittent flows, however, the most difficult in the operation and maintenance.



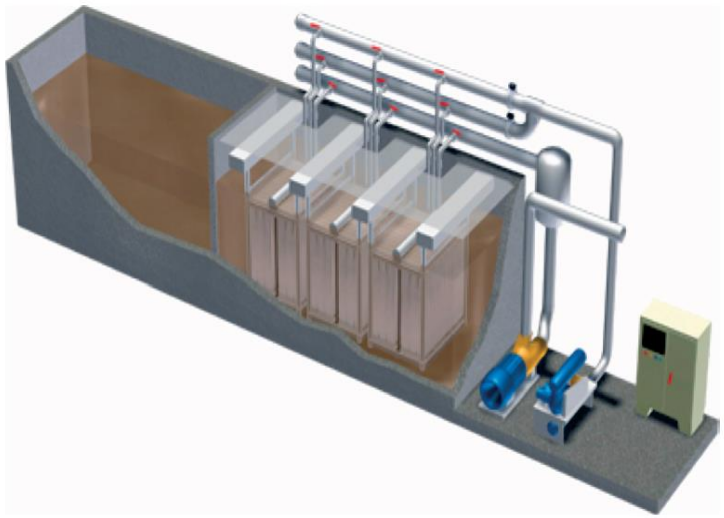
Sequencing Batch Reactor
advantages and disadvantages

Advantages

- Small foot print
- Can handle large fluctuations in flow and influent quality
- Able to achieve nitrification de nitrification and phosphors removal
- Large operation flexibility
- Minimal sludge bulking
- Able to operate remotely

Disadvantages

- High energy consumption
- High skilled operator required
- More mechanical equipment
- Difficult to adjust cycle times for small communities
- Frequent sludge disposal



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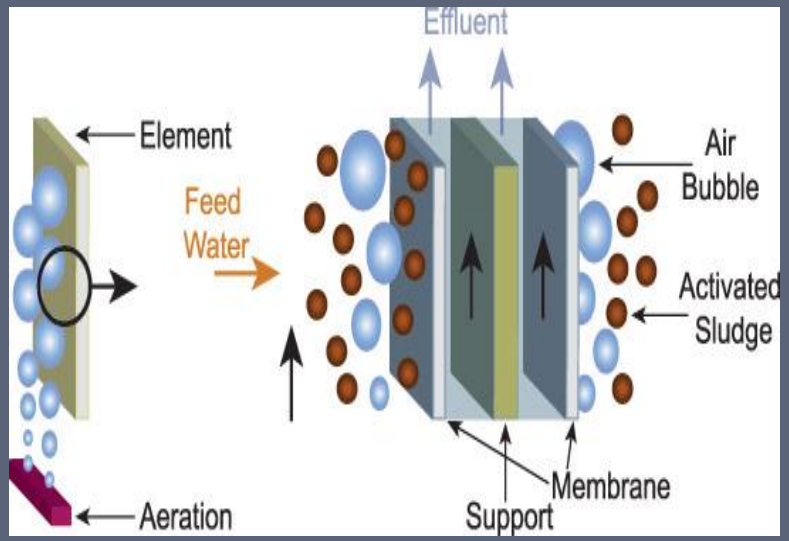


Membrane Bioreactors

It is a treatment system collect between the activated sludge system and membrane Ultrafiltration, in which we submerge the membrane in the aeration tank, so we can do the primary and secondary and tertiary treatment in one stage, and the produced sludge is stable so we do not need to digest it and this system produce high quality treated water and need a small area, because no need for secondary sedimentation so we can use this system in updating plants and when we need high quality treated water, but the disadvantages of this system is the need for skilled operators and relatively high cost of membrane and high cost of operation.

Membrane Bioreactors advantages and disadvantages

Advantages

- Small foot print
- Application of higher organic loadings
- No final settling required
- High quality effluent efficiency
- Sludge bulking is not a problem
- Ease of expansion
- Reduction of labor requirements (can be automated)

Disadvantages

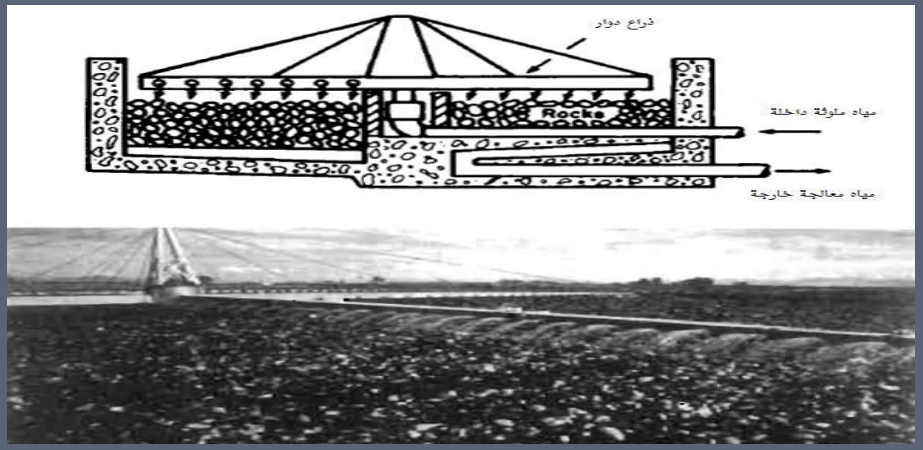
- Energy requirement are much greater
- Membrane fouling replacement requirements
- Frequent backwashing required

Trickling Filters Or Biological filter Or Aerobic fixed film reactor

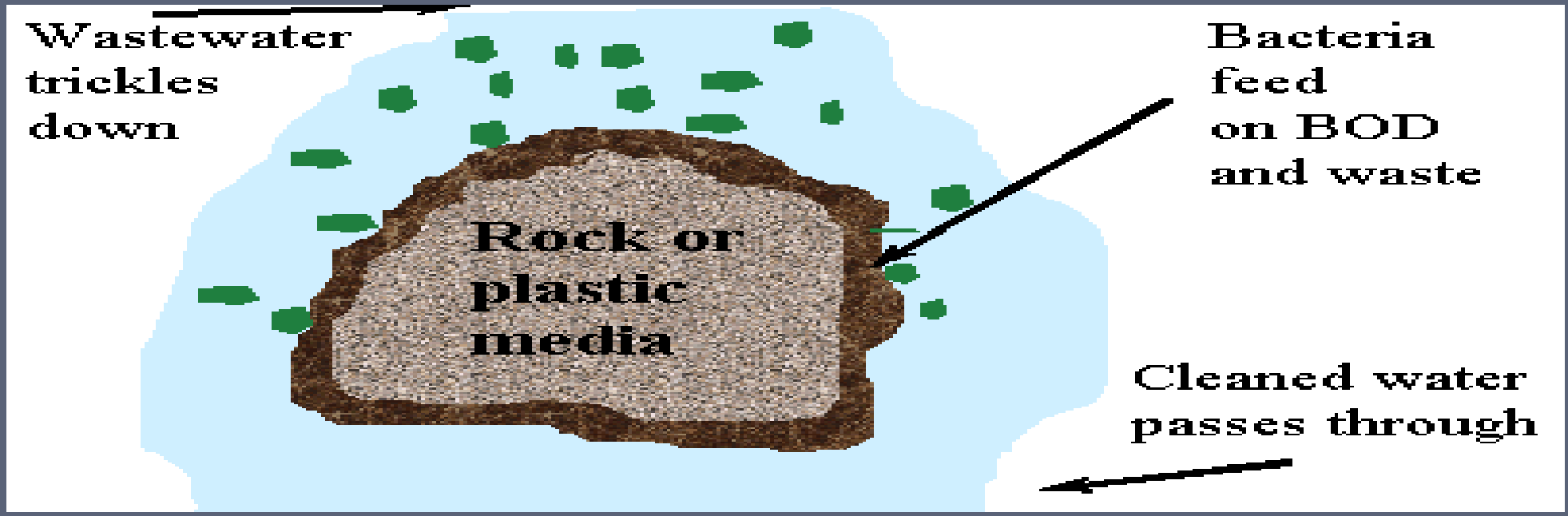
this method have begun to used in 1910 and still used right now This treatment method consist of tanks usually constructed from reinforced concrete or buildings, bricks, and fill these tanks with graves or break bricks or stones in suitable size and depth and recently used balls of plastic or rings of non-metallic pipes and this material called (fixed film media)

Its operation Based on water distribution by rotating perforated pipes with determined speed and during rotation water falling down from the holes and falling on the surface of the filter and permeate gaps between gravel or stones consists on the surfaces of these materials bio film layer, these biological layers contains bacteria, protozoa, fungi and other organisms.

- the biological filters is the oldest biological treatment methods and now using it is only in some of the industrial waste water treatment applications.
- Biological filter consists of a bed of gravel materials or plastic media and the sewage distributed above it by distribution arm where sewage water go through the spaces contact with this medium in which to grow the micro-organisms that are oxidize the organic material and water go from filter down to a secondary sedimentation tank to separate and remove the sludge from the water.
- Biological filters are two types of high or low filtration rate, and the sludge need for drying only.
- the most important disadvantage of this method is the spread of flies and mosquitoes at the site and treatment result is not constant.



And as continuously sewage go across the surface of gravel it increases the thickness of the biological layer, which the internal part of it away from the activity aerobic bacteria and are adjacent layer to the surface of the gravel subjected to the activity of anaerobic bacteria and the resulting gases such as carbon dioxide with the falling water help on the separation of bio film from the gravel surfaces



Trickling Filters advantages and disadvantages

Advantages

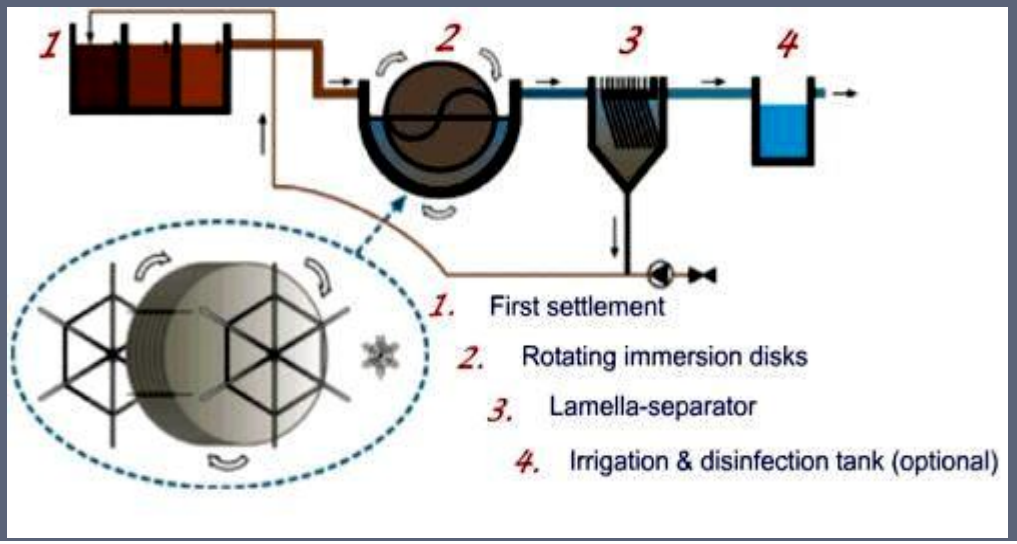
- Simple and reliable
- Rapidly reduce soluble BOD
- Appropriate for small to medium size communities
- Efficient nitrification units
- Low power requirements

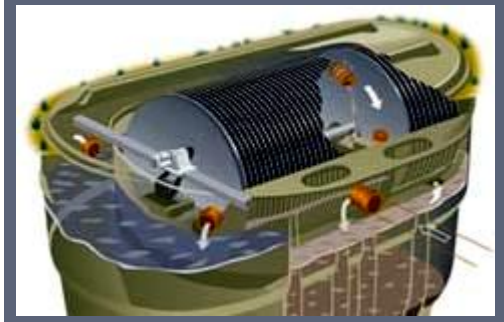
Disadvantages

- Additional treatment required to meet some discharge standard
- Requires regular operator attention
- Flexibility and control are limited
- Vector and odor and snail problems
- Incidence of clogging is relatively high

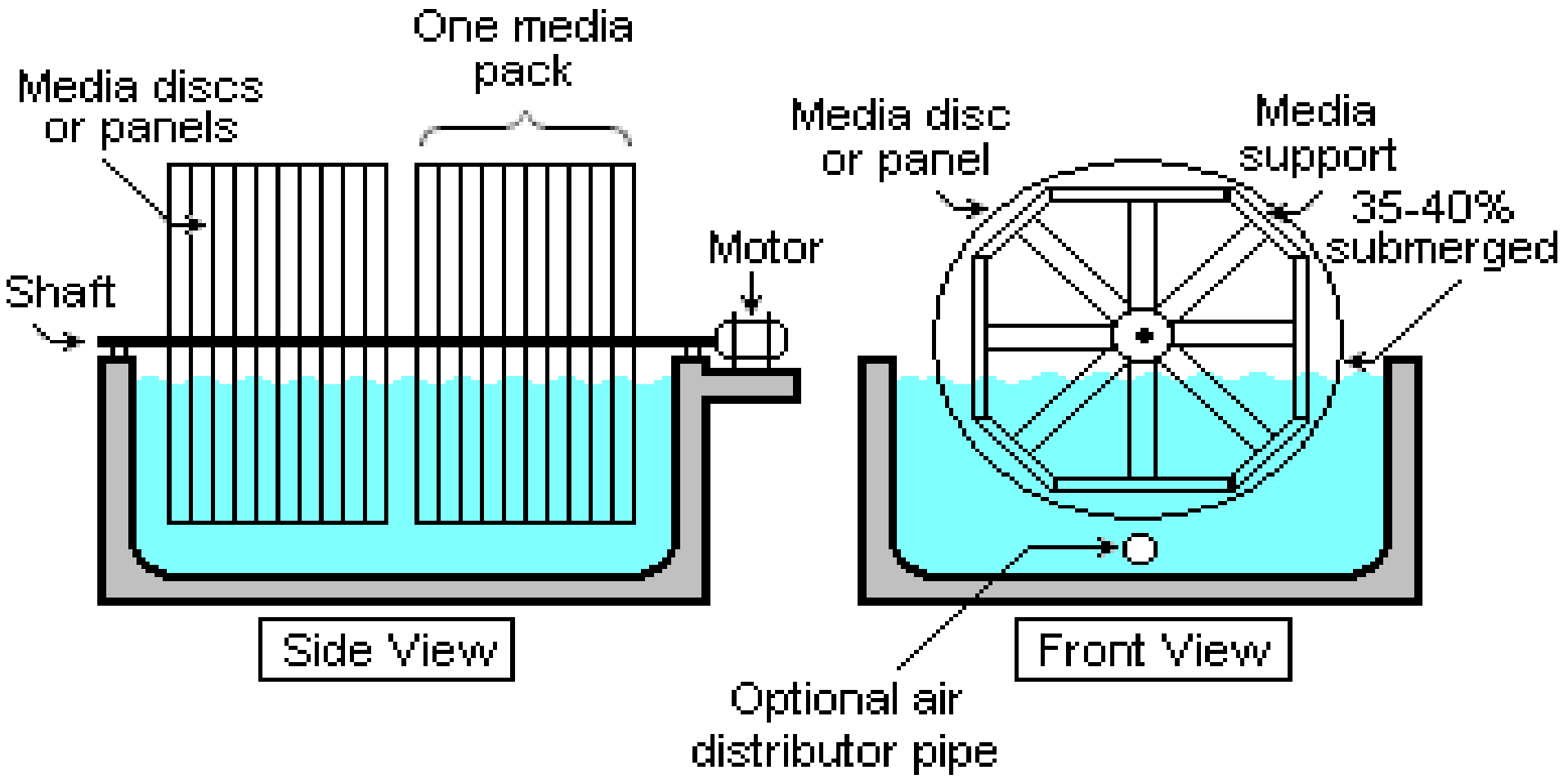
ROTATING BIOLOGICAL CONTACTOR (RBC)

- This method is one of the ways of fixed bio film growth as is the case in biological filters, except that the biomass is that touches the water during the drive rotation, not water that comes into contact with the biomass as in biological filters.
- contactor is composed of the tablets (plastic often) revolves around an associated axis and submersible to about half the diameter within the sewage, and during rotating air enters them touching biological bio film (biological layer grows on the surface of the disk) which treatment done by it.
- This method is used in small treatment plants and usually composed of a number of contactors rows behind others in the aeration tank.
- This method is characterized consume little power and the resulting small amount of sludge and a treatment rate of 85%.





Rotating Biological Contactor (RBC)



Rotating Biological Contactor (RBC)

Rotating Biological Contactor advantages and disadvantages

Advantages

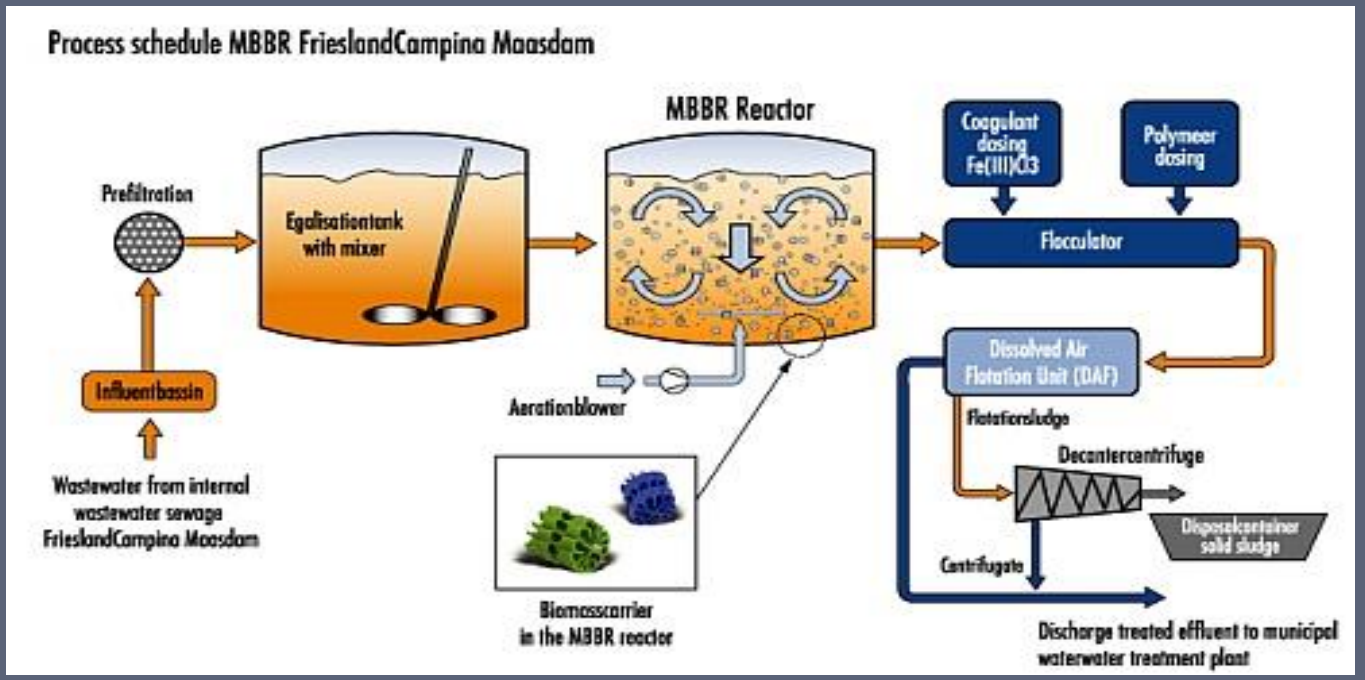
- Low sludge production and excellent process control.
- Short retention time
- RBCs are capable of handling a wide range of flow
- Short contact periods are required because of the large active surface
- Flexibility of operation
- Operating costs are low because little skill is required in plant operation

Disadvantages

- Process control is complicated
- Higher maintenance skills is required
- Energy requirement relatively high
- More than one unit is required

Moving Bed Biofilm reactor

MBBR technology employs thousands of polyethylene biofilm carriers operating in mixed motion within an aerated wastewater treatment basin. Each individual biocarrier increases productivity through providing protected surface area to support the growth of heterotrophic and autotrophic bacteria within its cells. It is this high-density population of bacteria that achieves high-rate biodegradation within the system, while also offering process reliability and ease of operation.



Moving Bed Biofilm reactor

Moving Bed Biofilm Reactor MBBR process is attached growth biological process used for wastewater treatment both municipally and industrially for BOD removal, nitrification and denitrification.

A Moving Bed Biofilm MBBR reactor consists of a tank with submerged but floating plastic (usually HDPE, polyethylene or polypropylene) media having specific gravity less than 1.0. The large surface area of the plastics provide abundant surface for bacterial growth. Biomass grows on the surface as a thin film whose thickness usually varies between 50-300 microns. Medium or coarse bubble diffusers uniformly placed at the bottom of the reactor maintains a dissolved oxygen (DO) concentration of > 2.5-3 mg/L for BOD removal. Higher DO concentrations are maintained for nitrification. To retain the media flowing out of the tank.

For denitrification, anoxic Moving Bed Biofilm Reactor MBBR tanks are used. The anoxic tank is similar to aerobic Moving Bed Biofilm Reactor MBBR tank described above except that no oxygen is supplied. The tank contains no diffusers and the media is kept in suspension in the reactor through submersible mixers. Other feature such as the screen is the same as aerobic reactor although the design may be slightly different.

Moving Bed Biofilm reactor advantages and disadvantages

Advantages

- Small foot print
- High quality effluent efficiency
- Low capital and operation cost
- Ease of expansion
- Simplicity of operation and maintenance
- Can be automated (reduce labor requirements)
- Tolerance to shock loads

Disadvantages

- Final settled required
- Require high cost aeration

Moving Bed Biofilm reactor advantages and disadvantages

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Comparison between Activated sludge and MBR and MBBR

Comparison Criteria	Activated Sludge	MBR	MBBR
Treatment type	Activated sludge + separation of suspended solids by secondary settling	Activated sludge + separation of suspended solids by membrane filtration	Attached growth + separation of suspended solids by secondary settling
Treatment level	secondary	Tertiary or advanced	secondary
Foot print	Large (100%)	Small (25-30%)	Small (50%)
Plant rehabilitation and expansion and upgrading	difficult	easy	easy
ease and speed of execution	Difficult and slow	easy and fast	Medium
Usage as compact plant in temporary solutions	Not suitable	suitable	suitable
establishing standards and contracting methods	Easy and available	Need restricted conditions because of membrane guarantee	Easy and available
Ability to dealing with fluctuations in flow and organic loads	Not a problem	Can cause problems in membranes	Not a problems
Automatic control with operation and maintenance	difficult	easy	easy
Need for replacing equipments	Need to replace some electromechanical equipments	Need to replace membranes and some electromechanical equipment	Need to replace some electromechanical equipments

Comparison between Activated sludge and MBR and MBBR

Comparison Criteria	Activated Sludge	MBR	MBBR
Damage of main parts	No damage in main parts	Membrane may damage due to fouling	No damage in main parts
Produced sludge amount	Large (100%)	Small (60%)	Very small (30%)
Odour production	high	low	Very low
Effluent quality (BOD/TSS/NH3) mg/l	(20/20/10)	(5/5/1)	(10/10/5)
Effluent disinfection level	low	medium	low
Effluent reuse in agriculture	Can not	Can be	Can not
reliability	high	medium	medium
MLSS	(1 - 4) g/l	(5 – 20) g/l	Attached growth
F/M	(0.04 – 0.3)	(0.1 – 0.4)	-----
SRT	(17 – 20) day	(20 – 60) day	-----
HRT	(8 – 36) hours	(4 – 6) hours	(2-9) hours
Capex for cubic meter 2005	(1000 – 2000) SAR	(6000 – 10000) SAR	(3000 – 5000) SAR
Capex for cubic meter 2012	(2000 – 2500) SAR	(2500 – 5000) SAR	(2300 – 3000) SAR
Opex for cubic meter	(0.2 – 0.4) SAR	(0.5 – 1) SAR	(0.3 – 0.5) SAR

filtration

The purpose of filtration : is to remove suspended particles from water by passing the water through a medium. As the water passes through the filter, floc and impurities get stuck in the medium and the clean water goes through.

Filtration is usually the final step in the solids removal process which began with coagulation and advanced through flocculation and sedimentation.

In the filter, up to 99.5% of the suspended solids in the water can be removed, including minerals, floc, and microorganisms.

filtration

Mechanisms of Filtration

Straining, passing the water through a filter in which the pores are smaller than the particles to be removed. This is the most intuitive mechanism of filtration, like sand filters, membrane filters, disk filters.

Adsorption, in many cases the most important mechanism of filtration, is adsorption. **Adsorption** is the gathering of gas, liquid, or dissolved solids onto the surface of another material.

Absorption, the soaking up of one substance into the body of another substance. Absorption should be a very familiar concept - sponges absorb water.

filtration

Straining **Filtration methods are divided into**

Particle filtration and Membrane filtration

Particle filtration including

Slow Sand Filtration (SSF)

Rapid Sand Filtration (RSF)

Membrane filtration including

Microfiltration (MF),

Ultrafiltration (UF),

Nan filtration (NF),

Reverse Osmosis (RO).

Particle filtration

The water and wastewater passes through filters, some made of layers of sand, gravel, and charcoal that help remove even smaller particles.

Filters may be classified according to the types of media used as follows:

- ☐ ***Single–media filters***: These have one type of media, usually sand or crushed anthracite coal.
- ☐ ***Dual–media filters***: These have two types of media, usually crushed anthracite coal and sand.
- ☐ ***Multi–media filters***: These have three types of media, usually crushed anthracite coal, sand, and garnet.

Membrane Separation

A membrane is a semi permeable, or selectively permeable, barrier that allows some molecules or ions to cross it while hindering the passage of others.

In membrane separation a portion of fluid known as permeate (or filtrate) passes through the membrane, while other constituents are rejected by the membrane and retained in the retentate (or concentrate) stream.

Membranes are fabricated from a variety of materials, including both organic and inorganic materials such as metals, polymers and ceramics.

Ceramic Membrane Filters

The ceramic membranes are often formed into an asymmetric, multi-channel element. These elements are grouped together in housings, and these membrane modules can withstand high temperatures extreme acidity or alkalinity and high operating pressures, making them suitable for many applications where polymeric and other inorganic membranes cannot be used. Several membrane pore sizes are available to suit specific filtration needs covering the micro, ultra, and nanofiltration ranges (from 5 mm down to 1000 Daltons)

* Molecule of water is equal to 18 Daltons

Disinfection

It is the most important treatment stages that depend on them to the re-use of water

the disinfection of effluent from the treatment plant using different methods most important :

***Chlorination* :**

Liquefied Chlorine gas

Hypochlorite solution

Chlorine is characterized by high efficiency in disinfection with ease of use and adjust the dose and follow the remaining sterilization effect, but it may result in secondary materials harmful to health and the environment, as well as serious of transport and storage of liquefied chlorine gas.

Ultraviolet

Ozonation

Advanced Oxidation process

Wastewater treatment process selection

IMPORTANT PARAMETERS TO BE CONSIDERED WHEN EVALUATING AND SELECTING UNIT OPERATION AND PROCESSES

Factor	Description
Process Applicability	The applicability of a process is evaluated based on past experience, Published data as well as data from operating works and pilot plants. If new or unusual conditions are found, pilot scale studies are necessary.
Applicable Flow	The process must be adequate for the expected flow range.
Acceptable Flow	The majority of the operations and processes must be designed to operate over a wide flow range. The highest efficiency is usually obtained at constant flow although some variation can be tolerated. Equalization of the flow could be necessary if the variation is large.
Influent Characteristics	The characteristics of the influent wastewater affect the process types to be used (e.g. chemical, biological) and the requirements for their adequate operation.
Inhibiting Compounds	What are the constituents in the wastewater that could be inhibitory or toxic and under what conditions? What constituents are not affected by treatment?

Wastewater treatment process selection cont.

IMPORTANT PARAMETERS TO BE CONSIDERED WHEN EVALUATING AND SELECTING UNIT OPERATION AND PROCESSES

Factor	Description
Climatic Aspects	Temperature affects reaction rates of most chemical and biological processes. Temperature can also affect the physical operation of the units. High temperatures can accelerate odor generation.
Process Kinetics	The design of the reactor is based on reaction kinetics. Kinetic data are normally obtained from experience, literature or pilot treating. Reactor configuration also plays an important part in the removal of some constituents.
Performance	Performance is normally measured in terms of the quality of the effluent, which should be consistent with the discharge requirements and /or discharge standards.
Treatment residuals	The type, quantity and quality of the solids, liquids and gaseous byproducts need to be known or estimated.
Sludge Processing	Are there limitations that could make the sludge disposal expensive or unfeasible. The selection of the sludge processing must be done in parallel with the selection of the treatment processes of the liquid phase.

Wastewater treatment process selection cont.

IMPORTANT PARAMETERS TO BE CONSIDERED WHEN EVALUATING AND SELECTING UNIT OPERATION AND PROCESSES

Factor	Description
Environmental constraints	Environmental factors such as prevailing winds and proximity to residential areas could restrict the use of certain processes.
Energy Requirements	The energy requirement together with future energy costs need to be estimated.
Personnel Requirements	How many people and at what levels of skill are necessary to operate the system. Are the skills easily found and what training will be necessary.
O&M requirements	What are the special operational requirements that need to be provided. Which and how many spare parts will be required and what are their availability and cost.
Reliability	What is they reliability of the operation and process in consideration. Is the unit likely to give frequent problems. Can the process resist occasional shocks. If yes is the effluent quality affected.

Wastewater treatment process selection cont.

IMPORTANT PARAMETERS TO BE CONSIDERED WHEN EVALUATING AND SELECTING UNIT OPERATION AND PROCESSES

Factor	Description
Complexity	What is the complexity of the process and what level of training will be necessary.
Compatibility	Can the unit operation be used satisfactorily with existing units. Can plant expansion be easily accomplished.
Area Availability	Is there sufficient space available and also for future expansion.

Importance of Reuse of Treated Water

There are several re-use fields of wastewater, and according to their resource and the degree of quality required by the re-use and re-use of wastewater after treatment in the following fields:

Industrial uses, such as use in factories and industries that require large amounts of water, such as cement, building materials, paper and cardboard industry cooling towers.

Agricultural uses, such as planting some crops such as sunflower plants and mulberry trees to feed silkworms and production of natural silk.

Reuse in the new land reclamation and cultivation.

Use in fish farms.

Use in other activities such as planting trees, wood, and the creation of golf and private gardens and public playgrounds.

Used in administrative buildings and hotels with high human density and reservoirs to combat the fire expulsion funds.

In the special units of the tunnels, trains and subway cars washing stations.

Groundwater, water or rain water treatment mixing in some areas to take advantage in the agricultural business in the desert areas.

Fill some of the deficit in the balance of water needs.

Realization of the principle of sustainability, a development that meet the needs of the present generation without compromising the possibility of future generations to meet their needs.