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Environmental - Civil Engineering Consulting Center

مركز الإستشارات للهندسة البيئية والمدنية

Wastewater Treatment Technologies

Eng. Khaled Sharaby
General Manager

AR Riyadh – KSA
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Content...

- General Introduction
- Primary Treatment
- Secondary Treatment
- Tertiary Treatment
- Disinfection
- Sludge Treatment

SEWAGE WATER

Sewage is a relatively dilute mixture of water & wastes generated from:

1. **Domestic**
2. **Commercial**
3. **Industrial**
4. **Ground water infiltration**
5. **Storm water**

Sewage Strength for Domestic WW

CONSTITUENT	CONCENTRATION Strong	Medium	Weak
Solids, total:	1250	800	450
Dissolved, total:	890	560	350
Fixed	295	295	185
Volatile	595	265	165
Suspended, total:	360	240	100
Fixed	145	75	25
Volatile	215	165	75
Settleable solids, mℓ/ℓ	7	5	3
Biochemical oxygen demand, 5-day, 20°C (BOD_5, 20°C)	400	200	100
Total organic carbon (TOC)	290	145	75
Chemical oxygen demand (COD)	910	455	230
Nitrogen (total as N):	75	40	16
Organic	40	20	8
Free ammonia	35	20	8
Nitrites	0	0	0
Nitrates	0	0	0
Phosphorus (total as P):	15	8	4
Organic	5	3	1
Inorganic	10	5	3
Chlorides[a]	83	42	21
Alkalinity (as $CaCO_3$)[a]	200	100	50
Grease	40	20	5

All values except settleable solids are expressed in mg/ℓ.
1 mg/ℓ = 1 g/m^3

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Treatment Systems

1. Physical /or mechanical treatment
   (inlet work – screens – grit removal – PST, filteration)

2. Chemical treatment implemented through:

   a. Chemical ppt. → Heavy metal

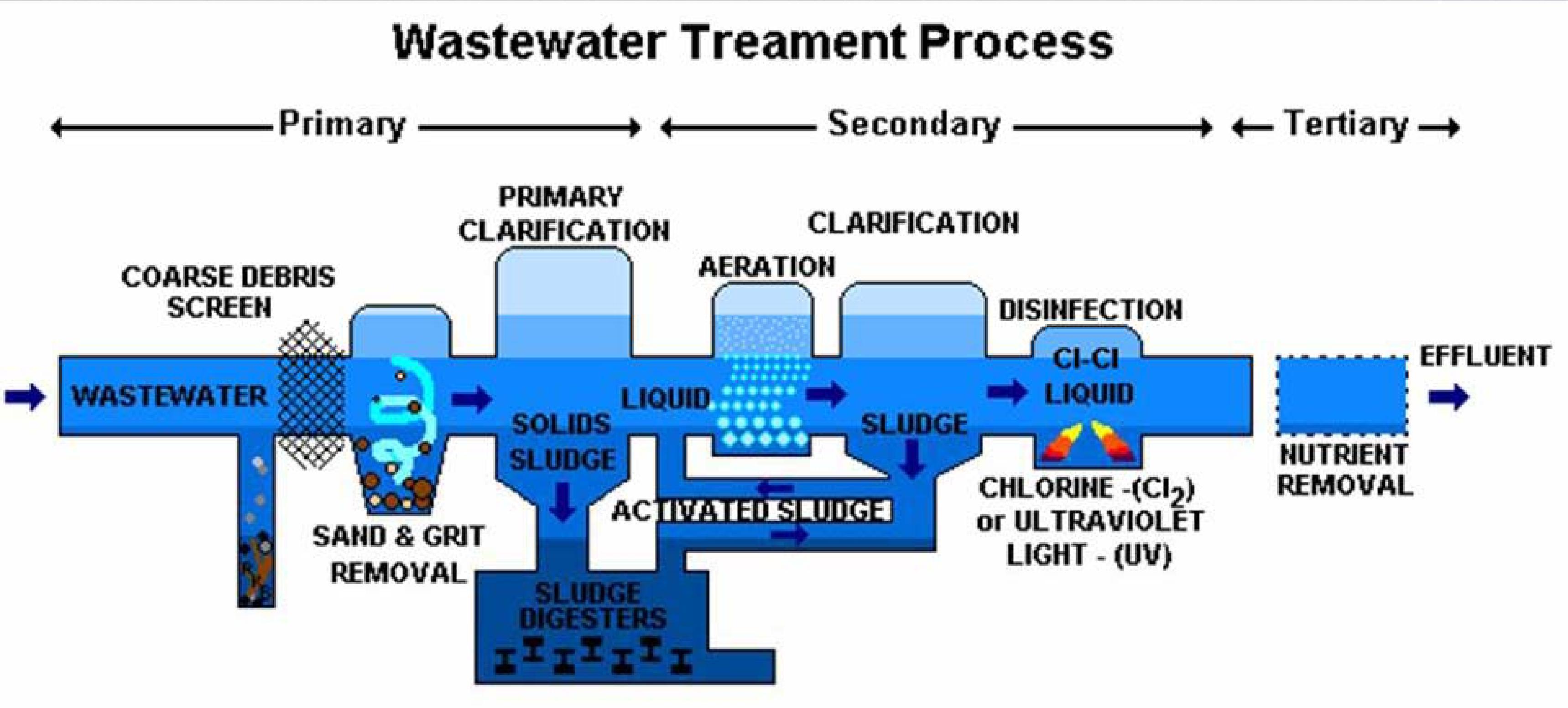
   b. Chlorination → Pathogenic organisms

   c. Ion Exchange → Dissolved inorganic solids

3. Biological treatment (aeration system – final clarifier

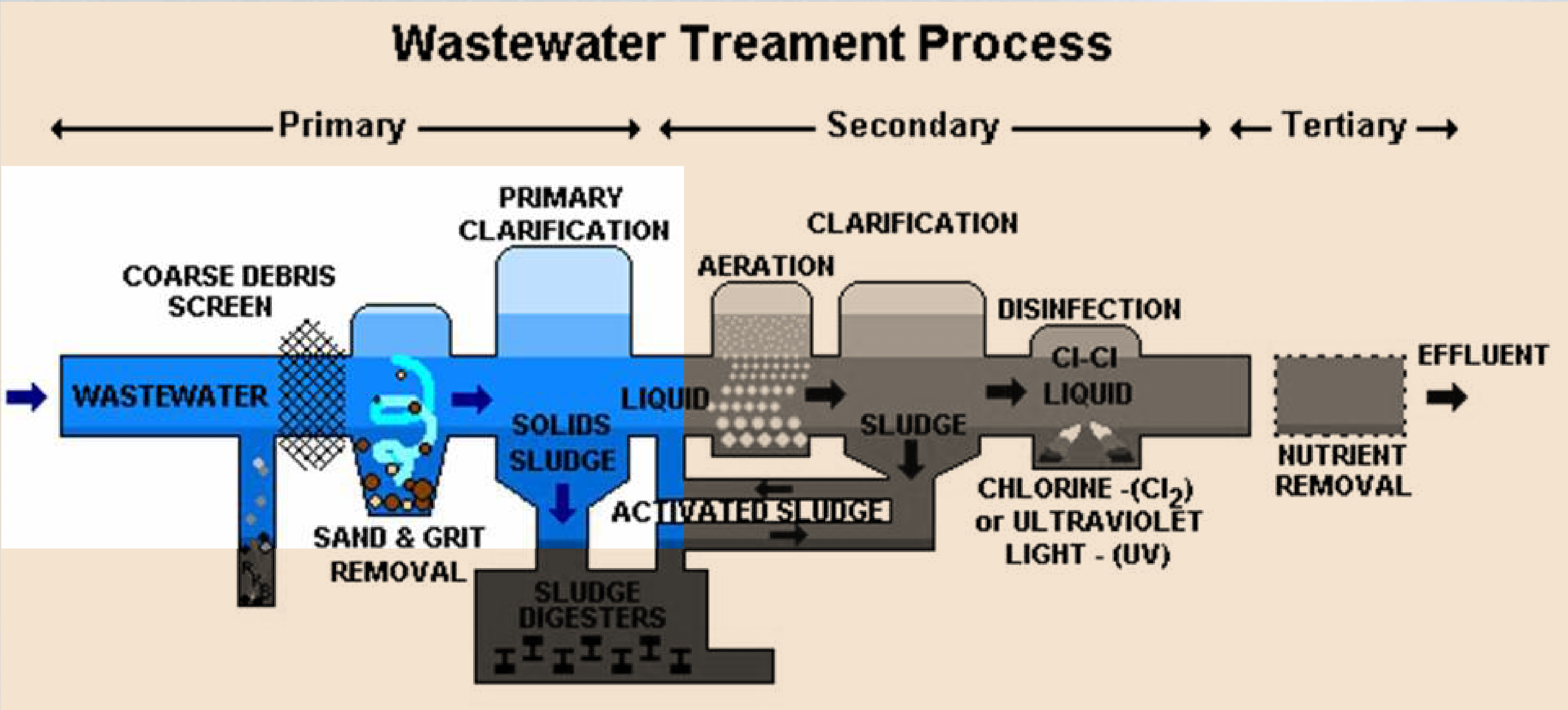
4. Disinfection

Components of a Wastewater Treatment plant



Primary Treatment

(معالجة ابتدائية)



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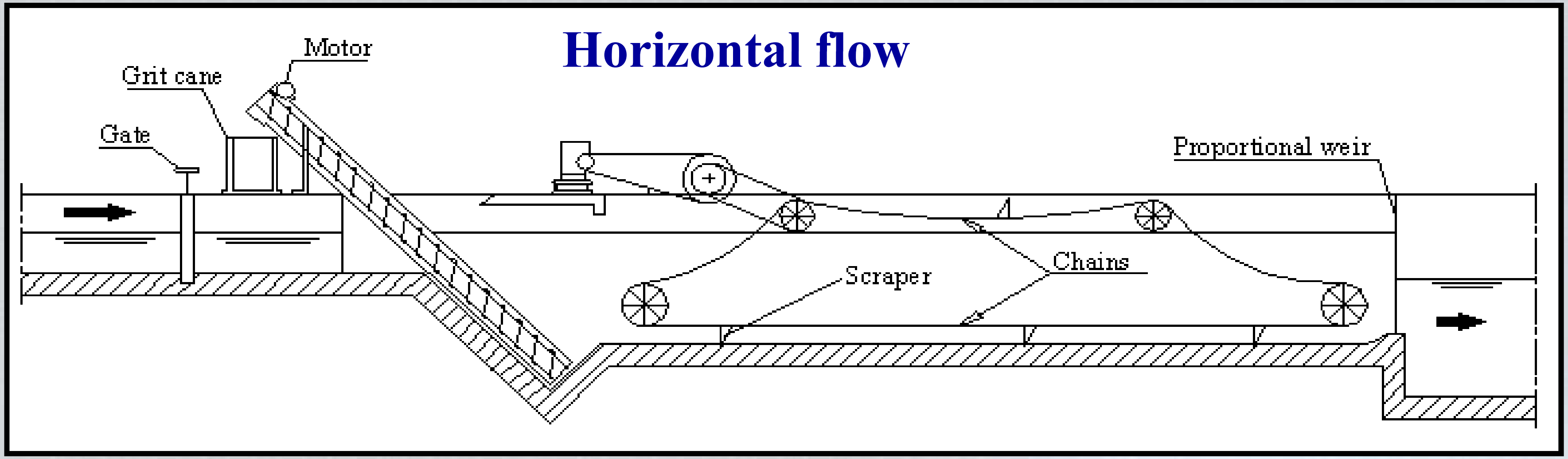
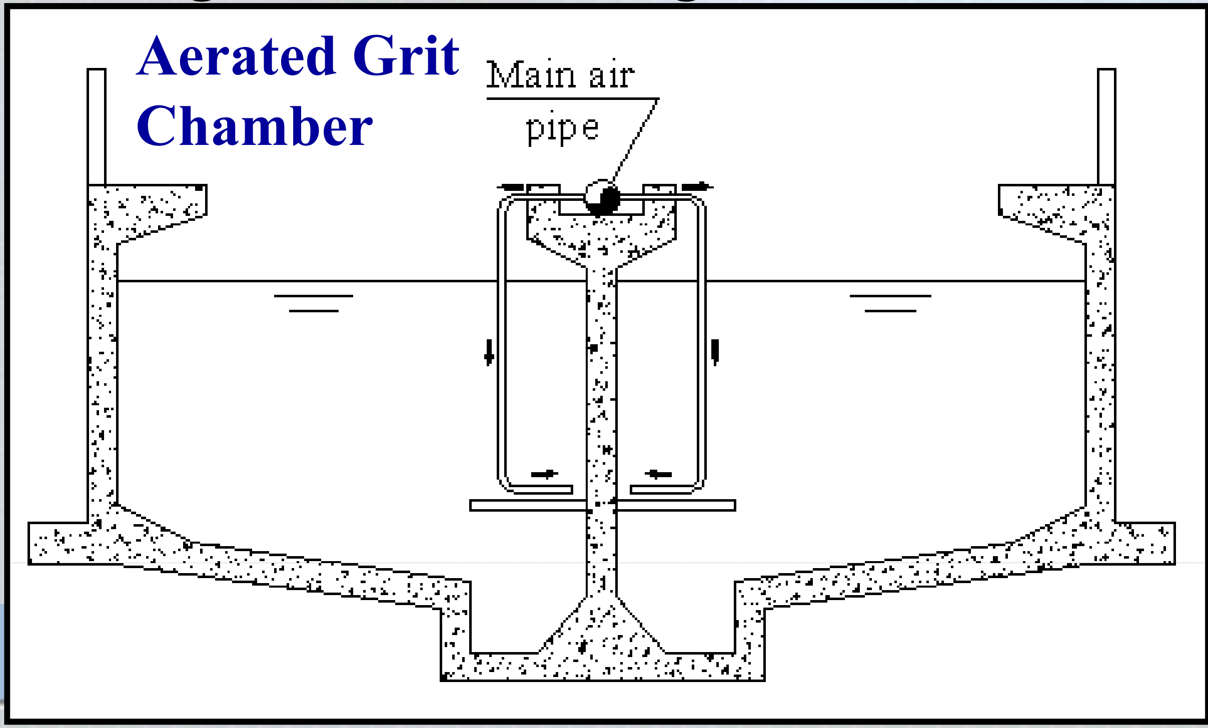
Primary Treatment Units

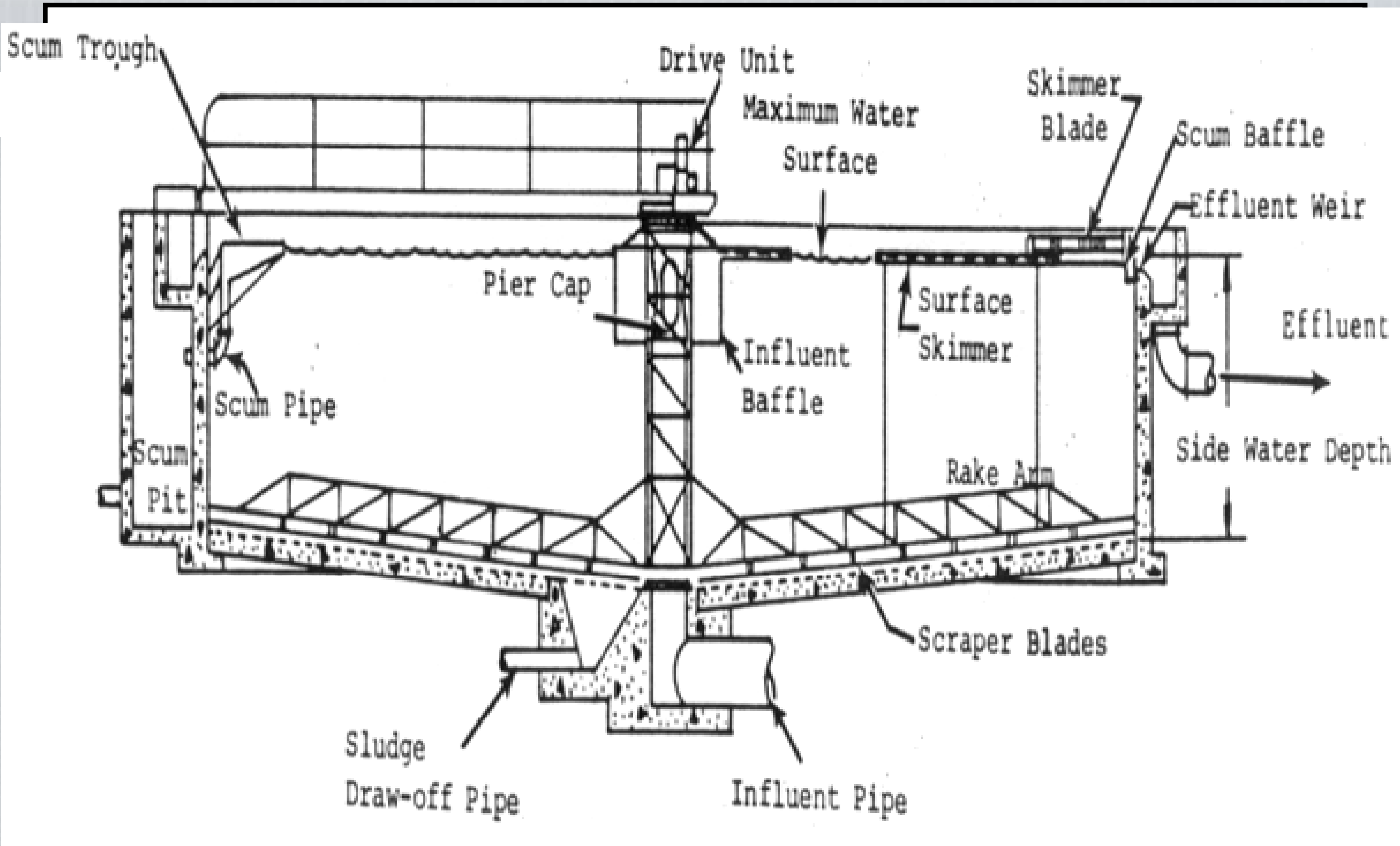


To get rid of sand and grit

To get rid of sand & grit in addition to oil & grease

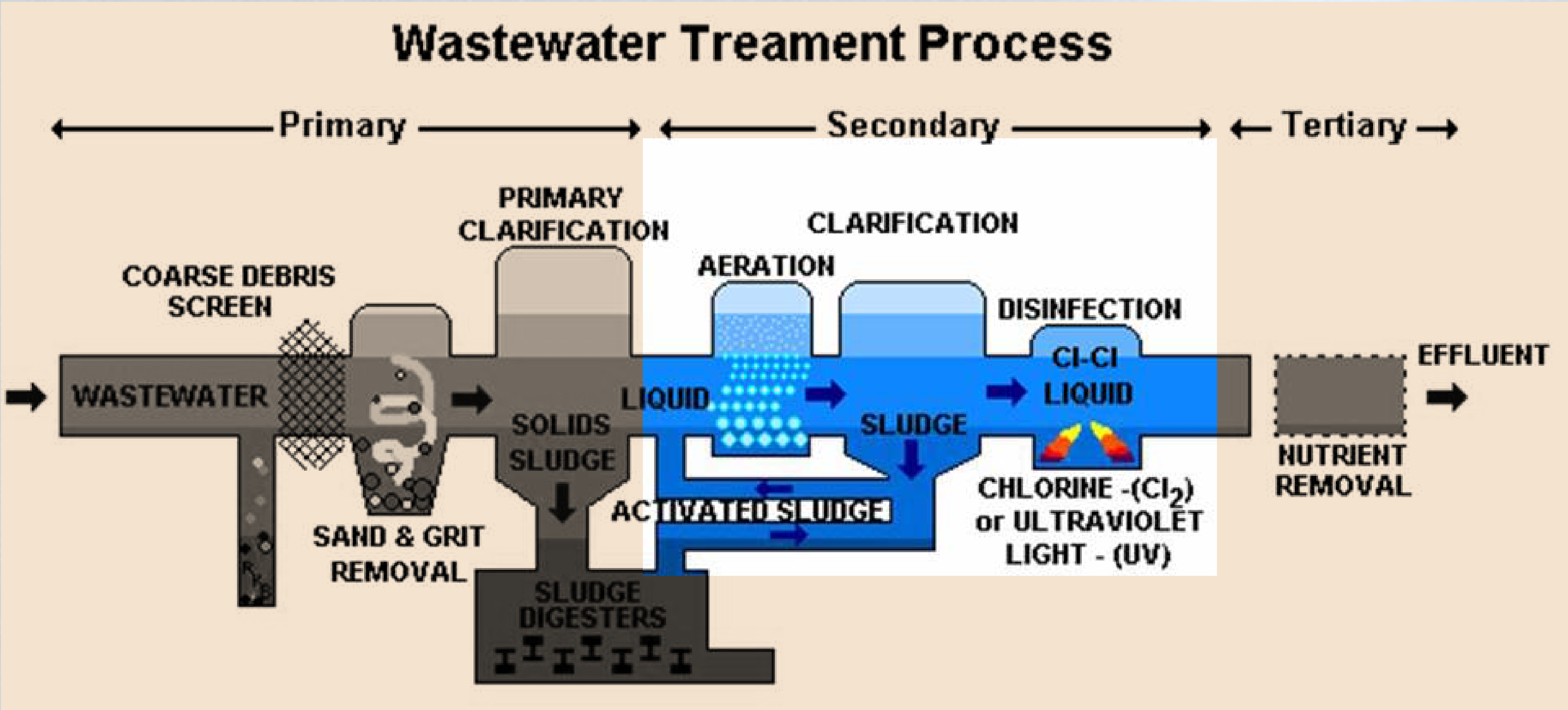


Primary Treatment Units



Biological Treatment

(Secondary Treatment)



Types of Biological Treatment

Types of Biological Systems

Attached Growth Method

1- MBR - MBBR
2- BioShaft
3- Trickling filter
4- RBC

Activated Sludge Method

1- Carrousel
2- Extended aeration
3- Conventional
4- SBR

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Types of Biological Treatment

(Suspended Growth Method)

- **1- Activated Sludge System**
  - **Extended Aeration (AT + FCT)**
    - 1- Carrousel
      2- Oxidation ditch
    - 1- SBR (sequence batch reactor)
      2- Biolac
  - **Conventional (PST + AT + FCT)**

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Biological Treatment

Activated sludge process

- To remove suspended solids, nitrogen, and phosphate
- Food to microorganism ratio (F:M ratio): 0.25 kg BOD_5 per kg MLSS (mixed liquor suspended solids) per day at 10 ^oC or 0.4 kg BOD_5 per kg MLSS per day at 20 ^oC
- Residence time: 2 days for high F:M ratio, 10 days or more for low F:M ratio
- Optimum nutrient ratio: BOD_5:N:P =>100:5:1
- 90 % removal of BOD_5 and SS
- ~20 % removal of phosphate
- >90 % removal of viruses and protozoa and 45 - 95 % removal of bacteria

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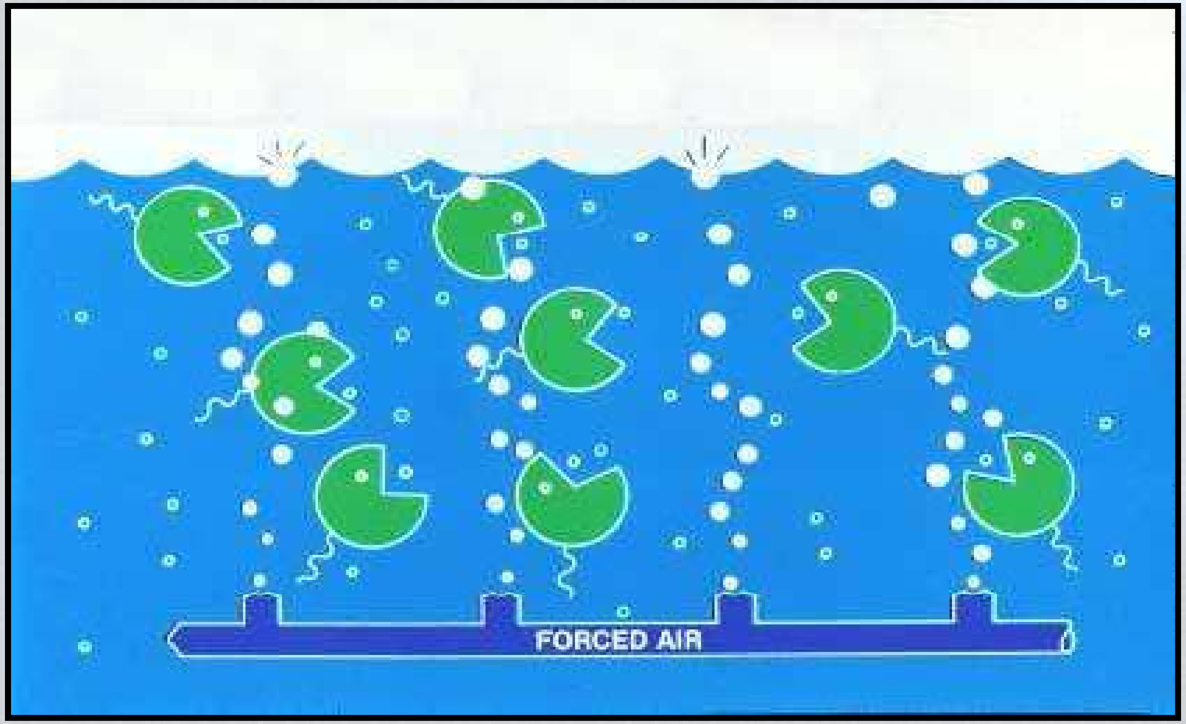
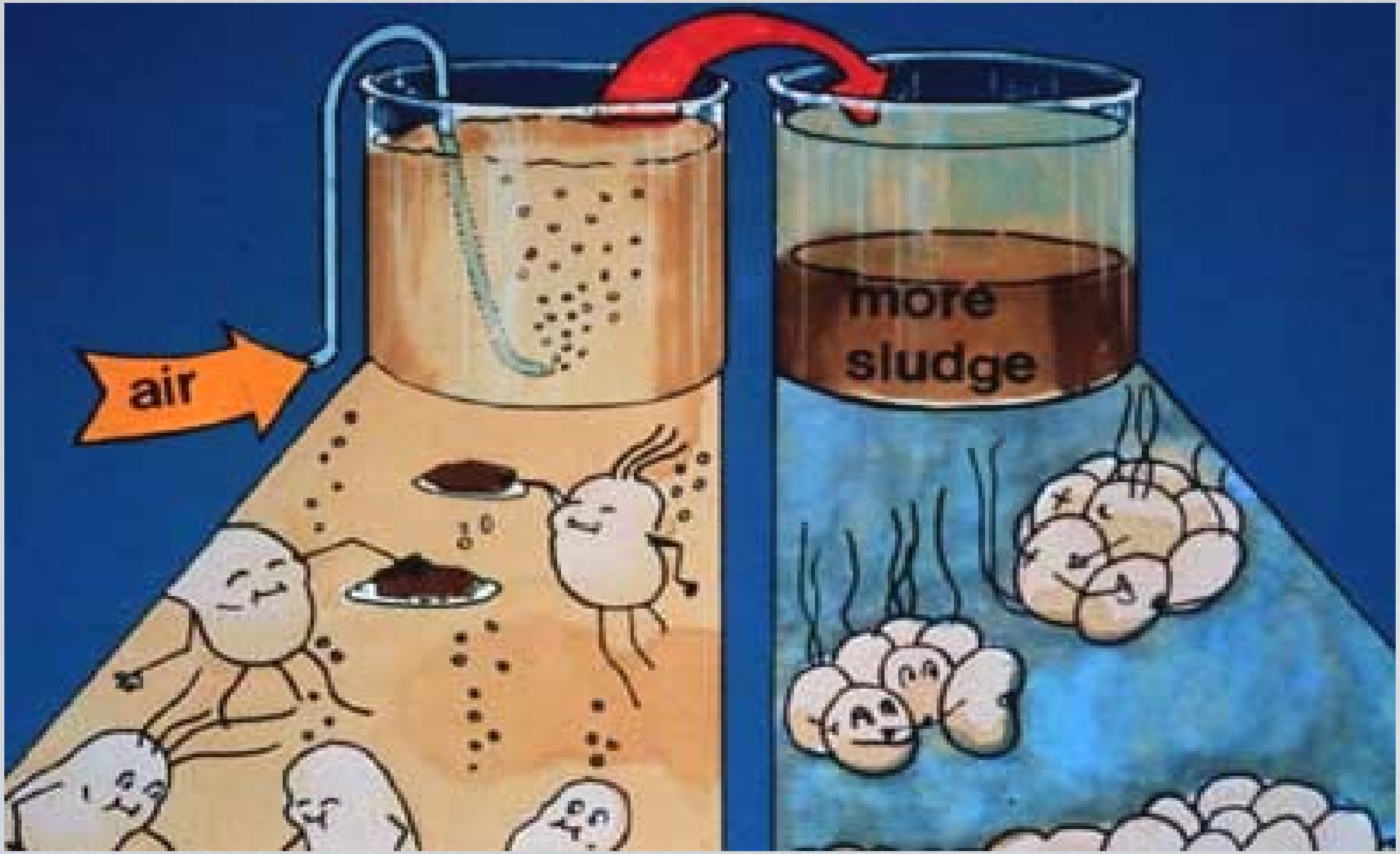
Suspended Growth Method

$$\text{Org. matter (BOD)} + O_2 \xrightarrow{\text{aerobic bacteria}} \text{stable org. matter} + CO_2 + H_2O + \text{New Cells}$$



Biological Treatment

The Activated Sludge Process

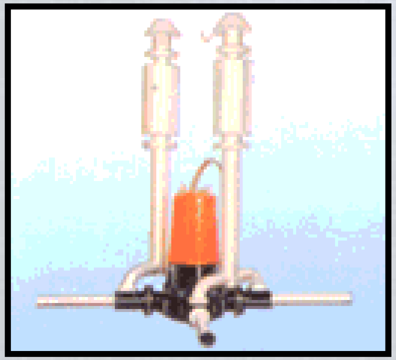


Aerobic microbes utilize carbon and other nutrients to form a healthy activated sludge (AS) biomass (floc) in presence of O_2

The biomass floc is allowed to settle out in the next reactor; 25-100% of the AS is recycled

Suspended Growth Method

Diffused Aeration System



Surface Aeration System

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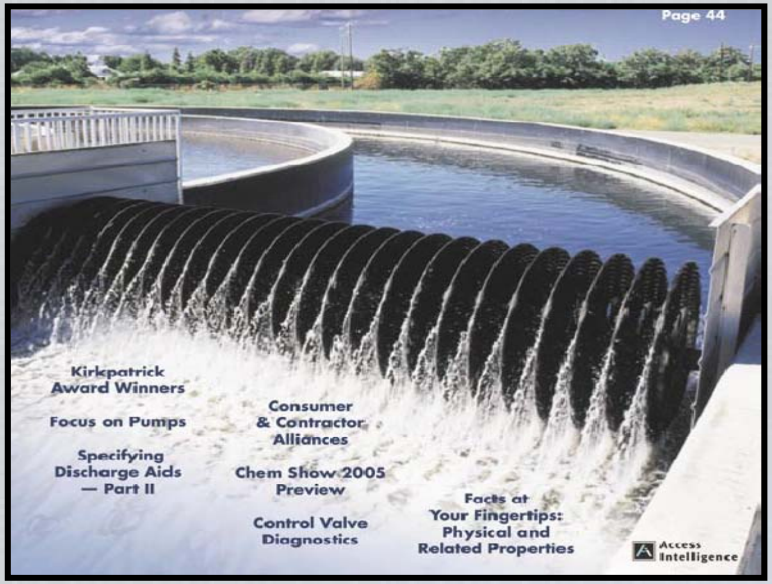
Suspended Growth Method



Carrousel System

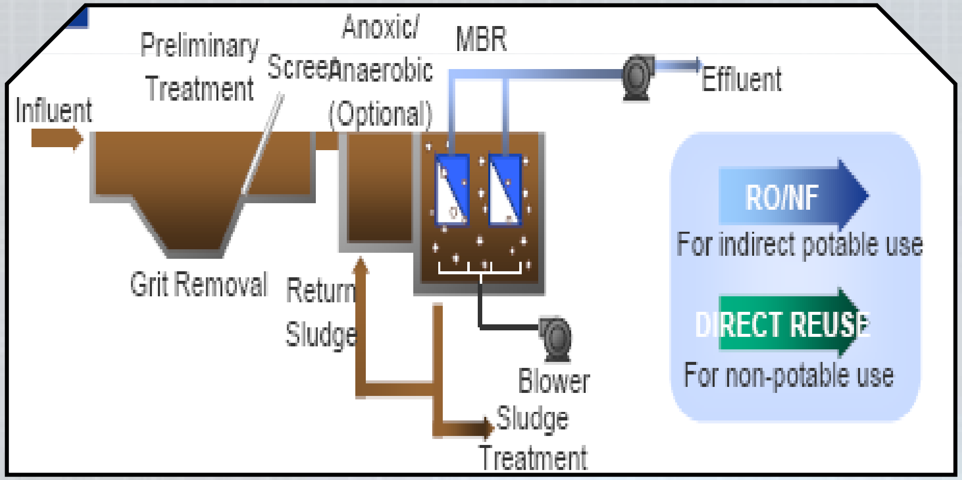
Using Brush aerators

- **Carrousel System**

(Extended Aeration)

- **retention time (18-36 hrs)**

Suspended Growth Method



Membrane biological reactors also know as membrane bioreactor systems or MBRs:

•A unique wastewater treatment process designed for numerous municipal and industrial applications.

•Membrane bioreactor systems may be used in such applications as water reuse, new housing developments, parks and resorts, retrofits, and turnkey projects.

The need to recycle wastewater and stricter environmental regulations make an MBR system a viable solution for current and future wastewater treatment

Suspended Growth Method

•**SBR - Sequencing Batch Reactor technology is well known for its simplicity and low cost. It has been widely used for municipal and industrial wastewater treatment applications to meet specific effluent requirements.**

•**Sequencing Batch Reactor System is a fill and draw Activated Sludge System.**

•**SBR process uses high-efficiency oxygen transfer aeration equipment to satisfy the high-rate oxygen consumption requirement at the beginning of the "fill" and "aeration" cycles.**

•**SBR is efficient in carbonaceous pollutant removal, and is easily modified to satisfy nutrient removal of nitrogen (N) and phosphorous (P).**

•**Because the fill, aeration, settlement and draw take place in the same reaction tank, thus SBR tank itself also serves as the clarifier itself.**

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Suspended Growth Method

Sequencing Batch Reactor (SBR) Technology Advantages/Benifits

- Lower installed cost than "Conventional" methods
- Less land space required for SBR treatment plants
- Consistent high-quality, low nutrient level effluent
- Tolerates wide swings in flow and organic loading
- No clarifier required
- Better control over filamentous growth and settling problems
- Nutrient removal without chemicals - nitrification and denitrification, phosphate removal
- Simple sludge process management
- Less equipment to service and maintain
- Existing plants can often be converted to SBR process
- Less operator attention than "Conventional" processes

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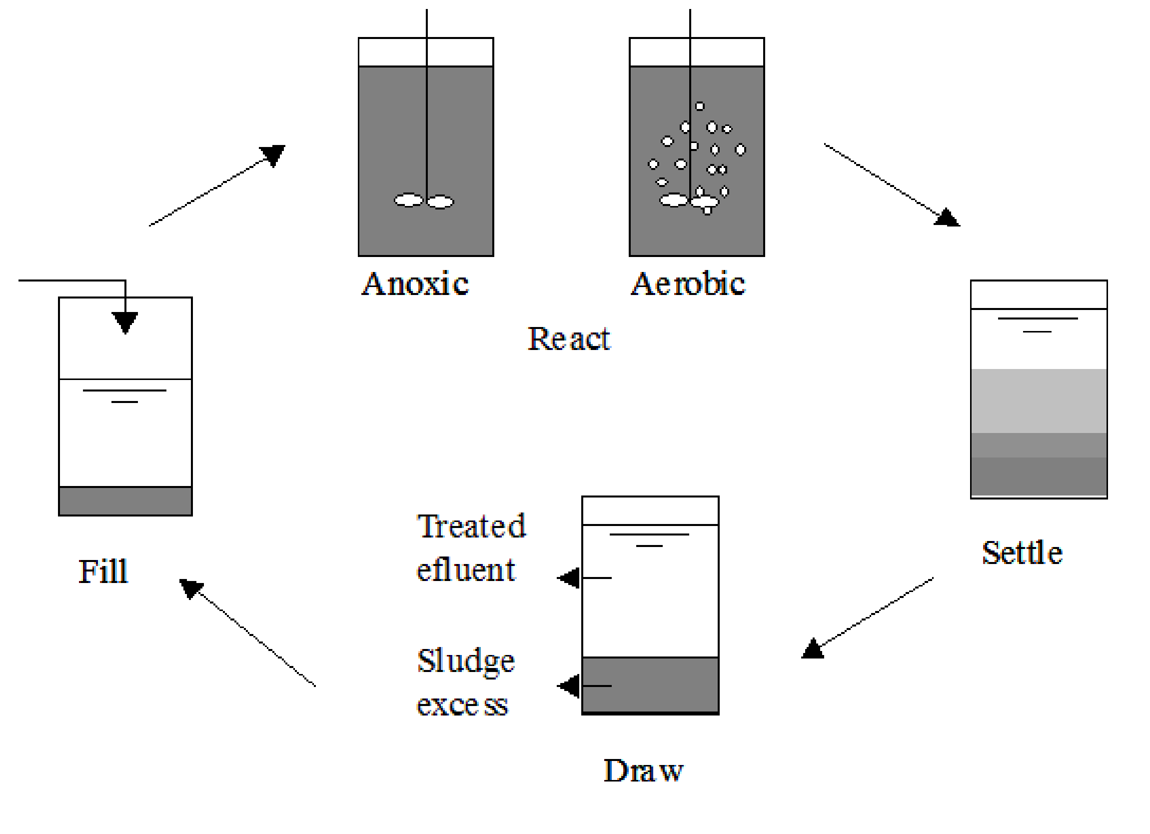
Suspended Growth Method

Sequencing Batch Reactor (SBR) Technology Advantages/Benefits



SBR Process

Sequencing Batch Reactor (SBR) Technology Advantages/Benefits

Table 1. Design parameters for IF-type SBR treatment systems

Parameter	SBR systems
Pretreatment	Septic tank or equivalent
Mixed liquor suspended solids (mg/L)	2,000–6,500
F/M load (lb BOD/d/MLVSS)	0.04–0.20
Hydraulic retention time (h)	9–30
Total cycle times (h) [a]	4–12
Solids retention time (days)	20–40
Decanter overflow rate[a] (gpm/ft^2)	<100
Sludge wasting	As needed to maintain performance

[a] Cycle times should be tuned to effluent quality requirements, wastewater flow, and other site constraints.

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Biological Treatment

Process name	Type of reactor	SRT, d	F/M kg BOD/kg MLVSS. d	Volumetric loading Lb BOD/ 1000 ft^3.d	Volumetric loading Kg BOD/ m^3.d	MLSS, mg/l	Total τ , h	RAS % of influent
High-rate aeration	Plug flow	0.5–2	1.5–2.0	75–150	1.2–2.4	200–1000	1.5–3	100–150
Contact stabilization	Plug flow	5–10	0.2–0.6	60–75	1.0–1.3	1000–3000[b] 6000–10000[c]	0.5–1[b] 2–4[c]	50–150
High-purity oxygen	Plug flow	1–4	0.5–1.0	80–200	1.3–3.2	2000–5000	1–3	25–50
Conventional plug flow	Plug flow	3–15	0.2–0.4	20–40	0.3–0.7	1000–3000	4–8	25–75[f]
Step feed	Plug flow	3–15	0.2–0.4	40–60	0.7–1.0	1500–4000	3–5	25–75
Complete mix	CMAS	3–15	0.2–0.6	20–100	0.3–1.6	1500–4000	3–5	25–100[f]
Extended aeration	Plug flow	20–40	0.04–0.10	5–15	0.1–0.3	2000–5000	20–30	50–150
Oxidation ditch	Plug flow	15–30	0.04–0.10	5–15	0.1–0.3	3000–5000	15–30	75–150
Batch decant	Batch	12–25	0.04–0.10	5–15	0.1–0.3	2000–5000[d]	20–40	NA
Sequencing batch reactor	Batch	10–30	0.04–0.10	5–15	0.1–0.3	2000–5000[d]	15–40	NA
Countercurrent aeration system (CCAS™)	Plug flow	10–30	0.04–0.10	5–10	0.1–0.3	2000–4000	15–40	25–75[f]

[a] Adapted from WEF (1998); Crites and Tchobanoglous (1998).

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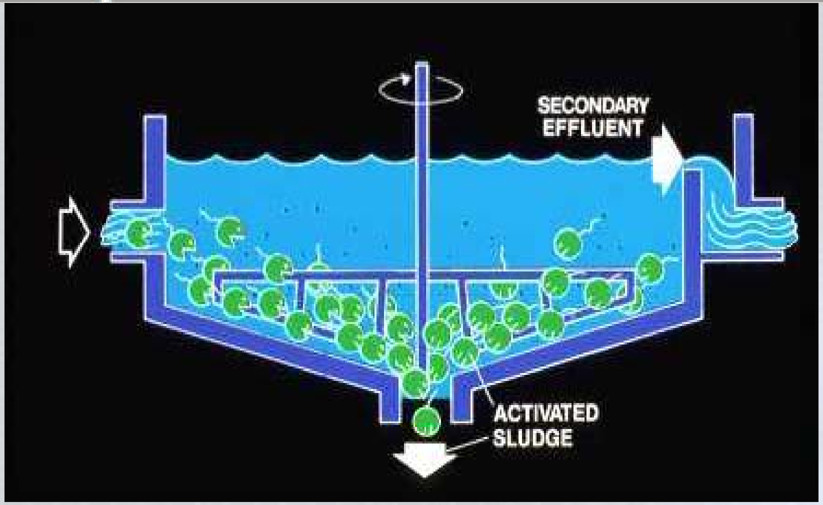
Suspended Growth Method

Typical diffused Aeration system

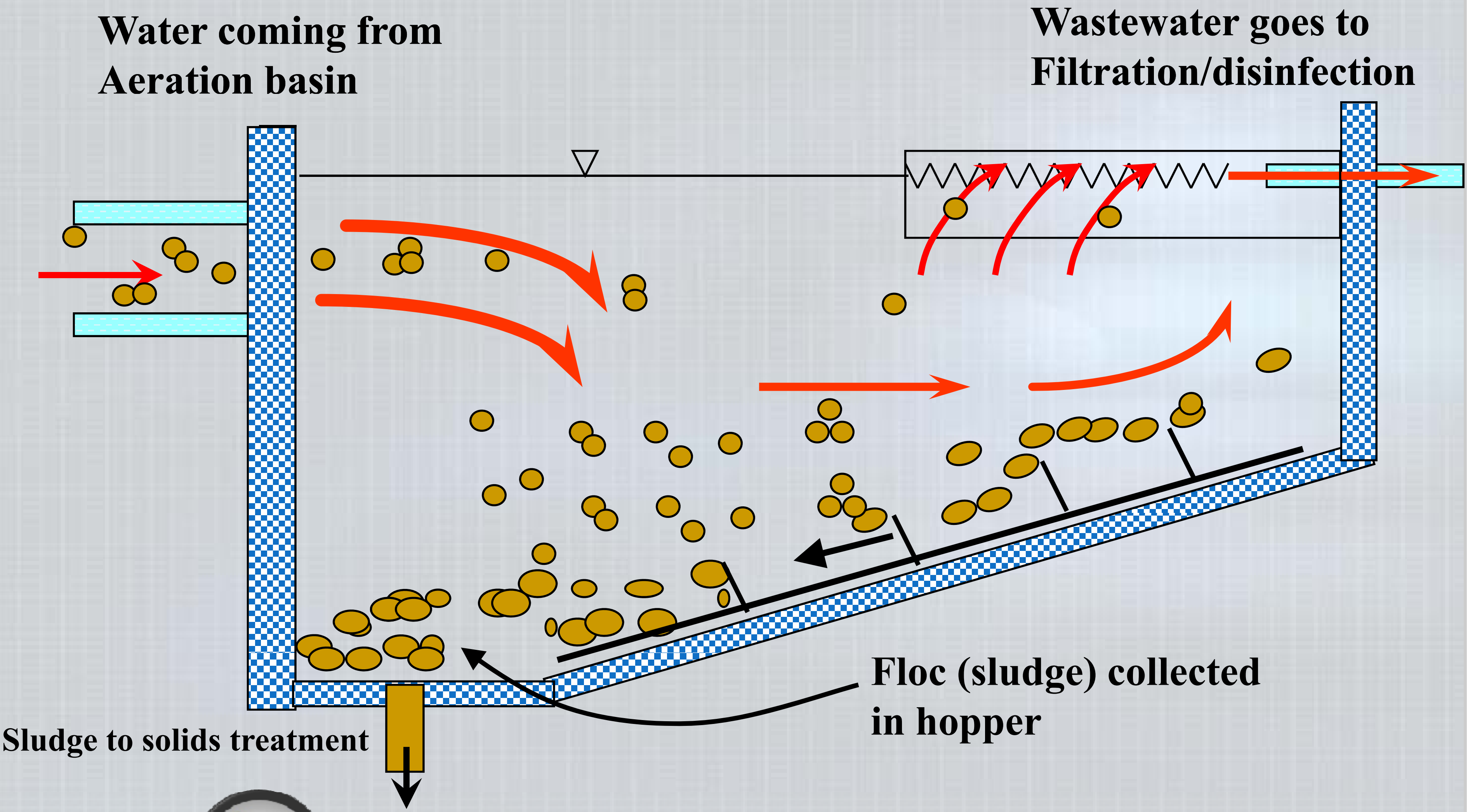
Diffuser type and placement	Air flowrate/diffuser ft³/min	m³/min	SOTE (%) at 4.5 m (15 ft) submergence[b]
Ceramic disks—grid	0.4–3.4	0.01–0.1	25–35
Ceramic domes—grid	0.5–2.5	0.015–0.07	27–37
Ceramic plates—grid	2.0–5.0[c]	0.6–1.5[d]	26–33
Rigid porous plastic tubes			
Grid	2.4–4.0	0.07–0.11	28–32
Dual spiral roll	3.0–11.0	0.08–0.3	17–28
Single spiral roll	2.0–12.0		13–25
Nonrigid porous plastic tubes			
Grid	1.0–7.0	0.03–0.2	26–36
Single spiral roll	2.0–7.0	0.06–0.2	19–37
Perforated membrane tubes			
Grid	1.0–4.0	0.03–0.11	22–29
Quarter points	2.0–6.0	0.6–0.17	19–24
Single spiral roll	2.0–6.0	0.6–0.17	15–19
Perforated membrane panels	N/A	N/A	38–43[e]
Jet aeration			
Side header	54–300	1.5–8.5	15–24
Nonporous diffusers			
Dual spiral roll	3.3–10	0.1–0.28	12–13
Midwidth	4.2–45	0.12–1.25	10–13
Single spiral roll	10–35	0.28–1.0	9–12

[a] Adapted in part from WPCF (1988) and U.S. EPA (1989).
[b] SOTE = standard oxygen transfer efficiency. Standard conditions: tap water 20°C (68°F); at 101.3 kN/m² (14.7 lb_f/in^2); and initial dissolved oxygen = 0 mg/L.
[c] Units are ft³/ft² of diffuser·min.
[d] Units are m³/m² of diffuser·min.
[e] Personal communication, Parkson Corporation.
N/A = not applicable.

Final Clarifiers



Sedimentation Basin Example



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BREAK

(Attached Growth Method)

Attached Growth Method

- 1- MBR – MBBR
- 2- Bio-Shaft
- 3- Trickling filter
- 4- RBC

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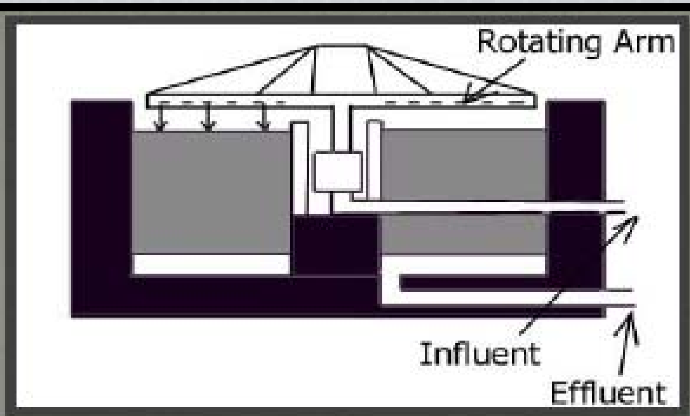
Trickling Filters



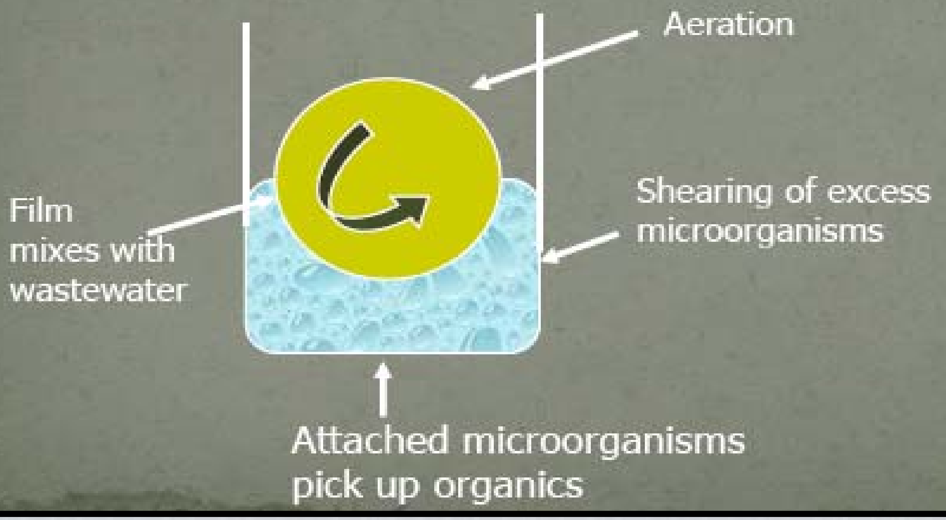
Material only provides surface on which bacteria to grow

Can use plastic media

- lighter - can get deeper beds (up to 12 m)
- reduced space requirement
- larger surface area for growth
- greater void ratios (better air flow)
- less prone to plugging by accumulating slime

Rotating Biological Contactors (RBCs)

- Called RBCs
- Consists of series of closely spaced discs mounted on a horizontal shaft and rotated while ~40% of each disc is submerged in wastewater
- Discs: Steer or light-weight plastic
- Slime is 1-3 mm in thickness on disc



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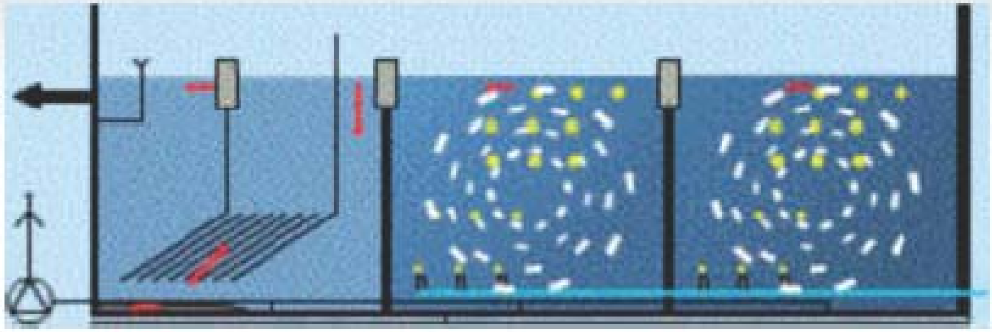
Technology of MBBR Process



- Standard Wastewater Treatment Plant Configuration is Two or More Reactors in Series, Followed by a Settling Chamber and/or Tertiary Treatment Unit

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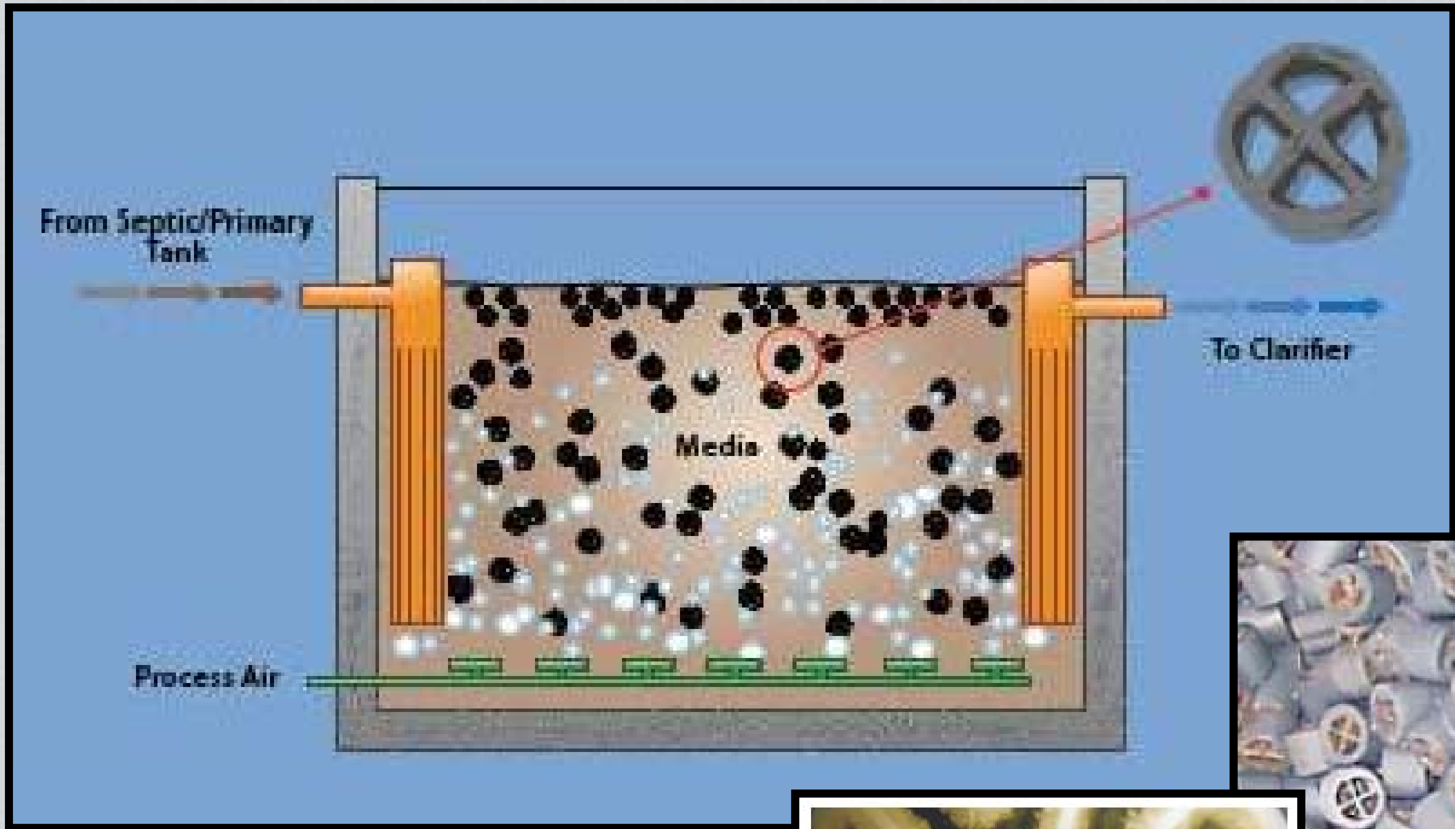
Applications of MBBR Technology

- MBBR Technology is Applicable to Wide Range Wastewater Flows
  - Large Plants from 10,000 m^3/day to 150,000 m^3/day
  - Package plants from 60 m^3/day to 400 m^3/day

Moving Bed Bio-Reactor



BioShaft System

What is the BioShaft System?

• A fixed film wastewater treatment process that virtually eliminates sludge.

• Uses a biological process that uses thousands of special carriers.

• These carriers are designed to create a large surface area in order to promote the growth of biofilm.

What is biofilm?

•The microorganisms found in wastewater are capable of replicating on their own.

• The microorganisms attached to our special carriers secrete a gelatinous material which serves to protect the microorganism.

• This material and the microorganism itself are known as biofilm.

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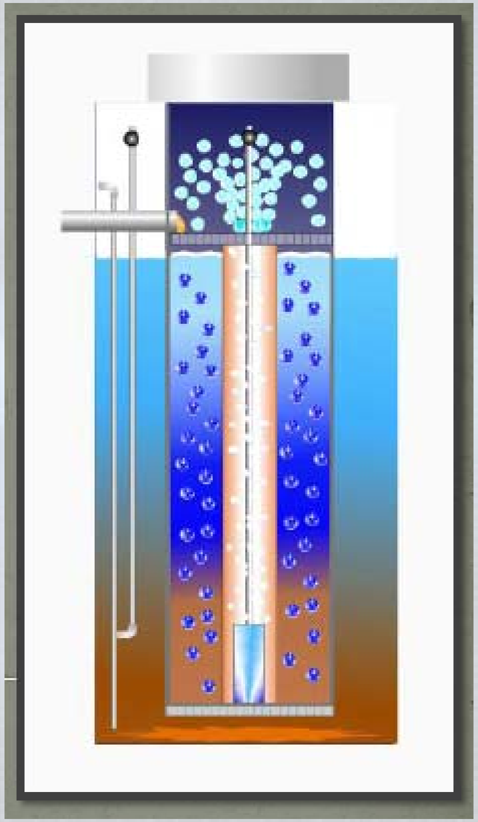
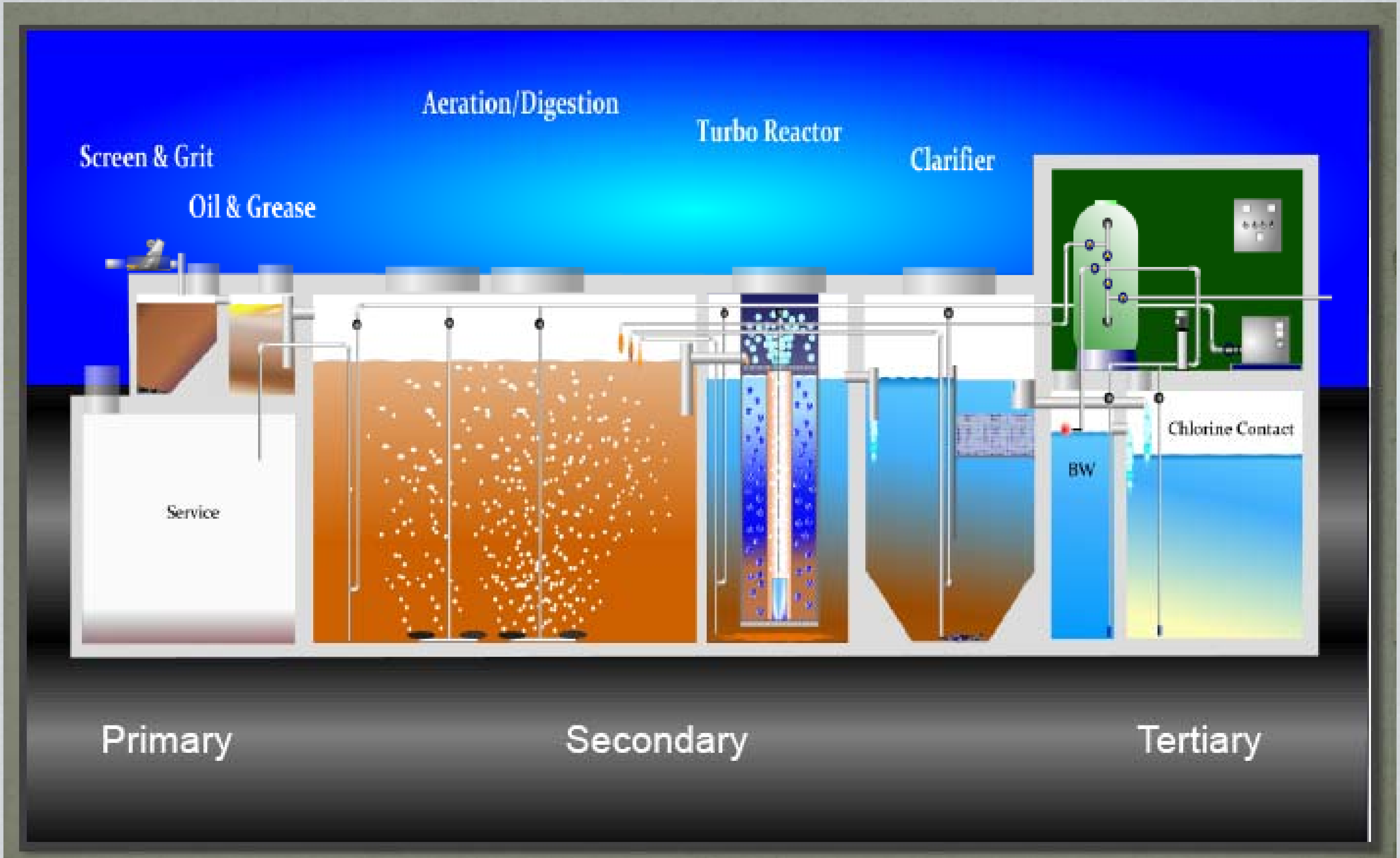
BioShaft System

Some unique benefits include:

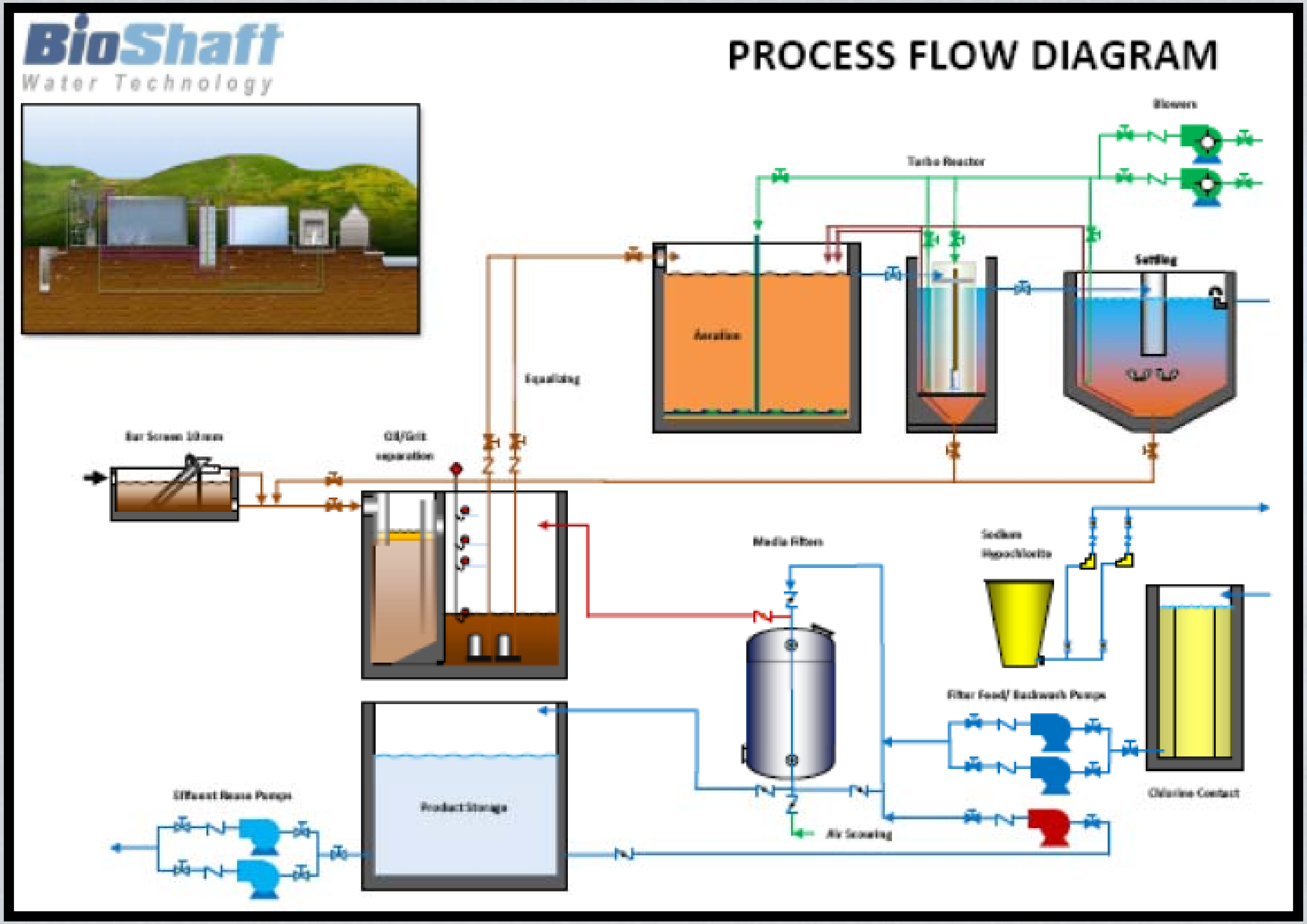
- A BioShaft plant produces up to 95% less sludge.
- Minimal Footprint
- Minimal Odor: The amount of odor produced by the system is negligible.
- Lower Initial Investment: It costs less to manufacture.
- Lower Operational Costs: It takes less personnel to operate.
- Lower Energy Costs.
- Lower Maintenance Costs.



BioShaft System



BioShaft System



Technology Comparison

Comparative Point	BioShaft	Conventional	Membrane Bio-Reactor
Process	Attach growth process	Activated sludge process	Separation process
Capital Investment	Competitive	Standard	Not competitive
Cost & Efficiency	Low (very simple with high efficiency)	High	Very high
Required Area for Sewage Treatment Plant	Less than others (less aeration area, less sedimentation area , less sludge treatment required)	Large	Large
Sludge Treatment	Minimal Required	Required	Required
Energy Consumption	Low (only air pumps), 0.004-0.006 KW-hr/gal (1-1.6KW-hr/m3)	High (air pumps and large number of mechanical motors required), 0.011-0.015 KW-hr/gal (3-4 KWhr/ m3)	Very high (air pumps and large number of mechanical motors required) - up to 0.026 KW-hr/gal (7 KW-h/m3), ref Stefan Geizler, Aachen University Chemical Engineering Institute
Maintenance & Cleaning Process (Chemicals)	Maintenance free self cleaning process	Maintenance needed - sludge removal and chemical treatment of sludge.	Intensive maintenance and chemicals required for flushing and cleaning membranes

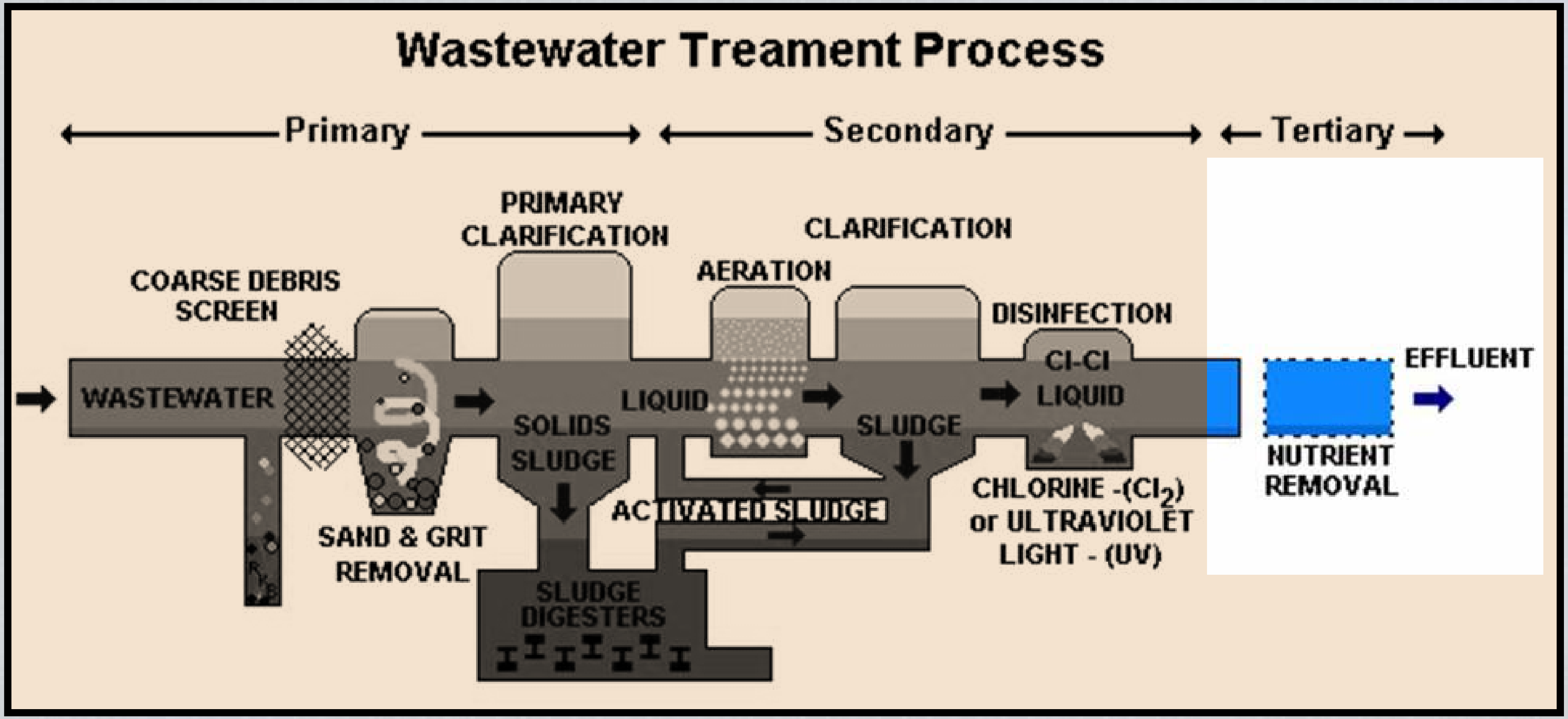
Replacement of Major Items	No replacement	electromechanical parts (ie. sludge pumps, recycling pumps, gears, etc)	Membrane replacement periodically
Possibility of Expansion	Unlimited	Limited	Limited
Operating Cost	Low (air compressor only, no electromechanical equipment, low number of personnel required)	High (air pumps and large number of mechanical motors required, large number of personnel required)	High (air pumps and large number of mechanical motors required, large number of personnel required)
Maintenance	Very low (no mechanical equipment only standard compressor)	High	High
Construction Possibilities	Above and underground	Above ground and some of them can be erected under ground (with limited capacity)	Some of them can be erected under ground (with limit capacity)
Relocation of the Sewage Treatment Plant	Possible	Not possible	Not possible
Population Limit	No limits	No limits	No limits
Landscape Disturbance	Low	High	High
Odor	Negligible	Present	Low
Water Effluent Quality (BOD/TSS)	Tertiary 10/10ppm (10/10 mg/l)	Secondary - requires filtration to reach tertiary quality 30/30 ppm (30/30 mg/l)	High quality 5/5 ppm (5/5 mg/l)

Parameter	Oxidation Pond	Extended Aeration	SBR	MBR	Anaerobic/ Aerobic	MBBR
Area	High	High	Medium	Low	Medium	Low
Buffer Zone	High	High	Medium	Low	Medium	Low
Capital Cost	Low	Low	Medium	High	Medium	Low
O & M Cost	Low	High	Medium	Medium	Medium	Low
Replacement Cost	Low	Medium	Medium	High	Medium	Low
Operational Ease	Low	Low	High	High	High	Low

BREAK

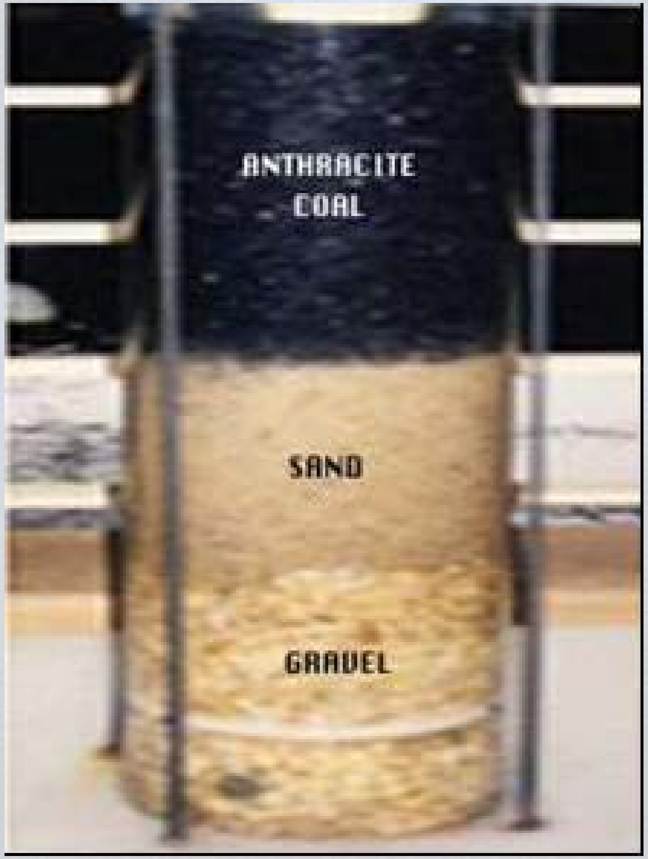
Tertiary Treatment

(معالجة ثلاثية)



Filtration (tertiary treatment)

- **To remove particles and floc that do not settle by gravity in sedimentation process**
- **Types of granular media**
  - a. **Sand**
  - b. **Sand + anthracite**
  - c. **Granular activated carbon**
- **Media depth ranges from 60cm to 180 cm**



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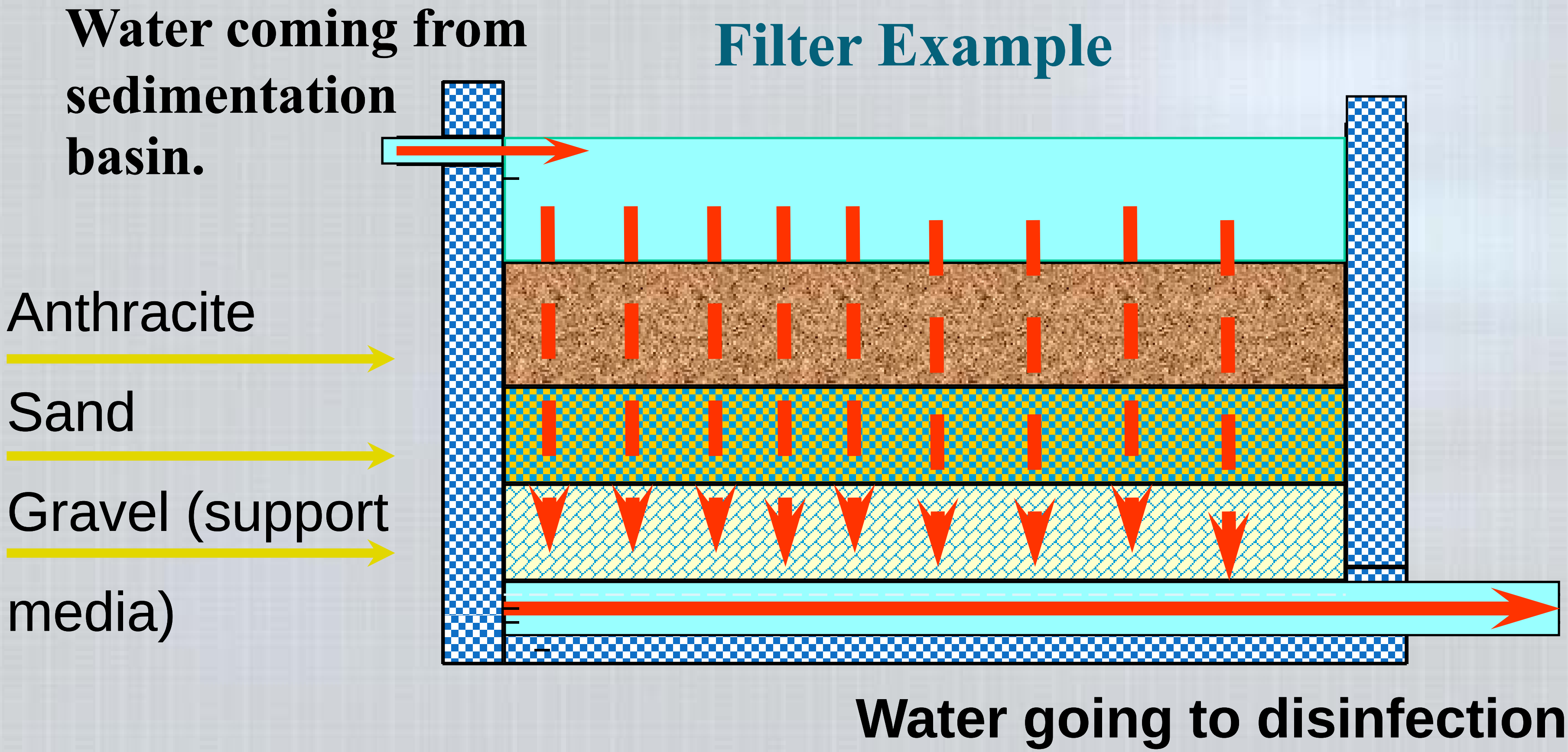
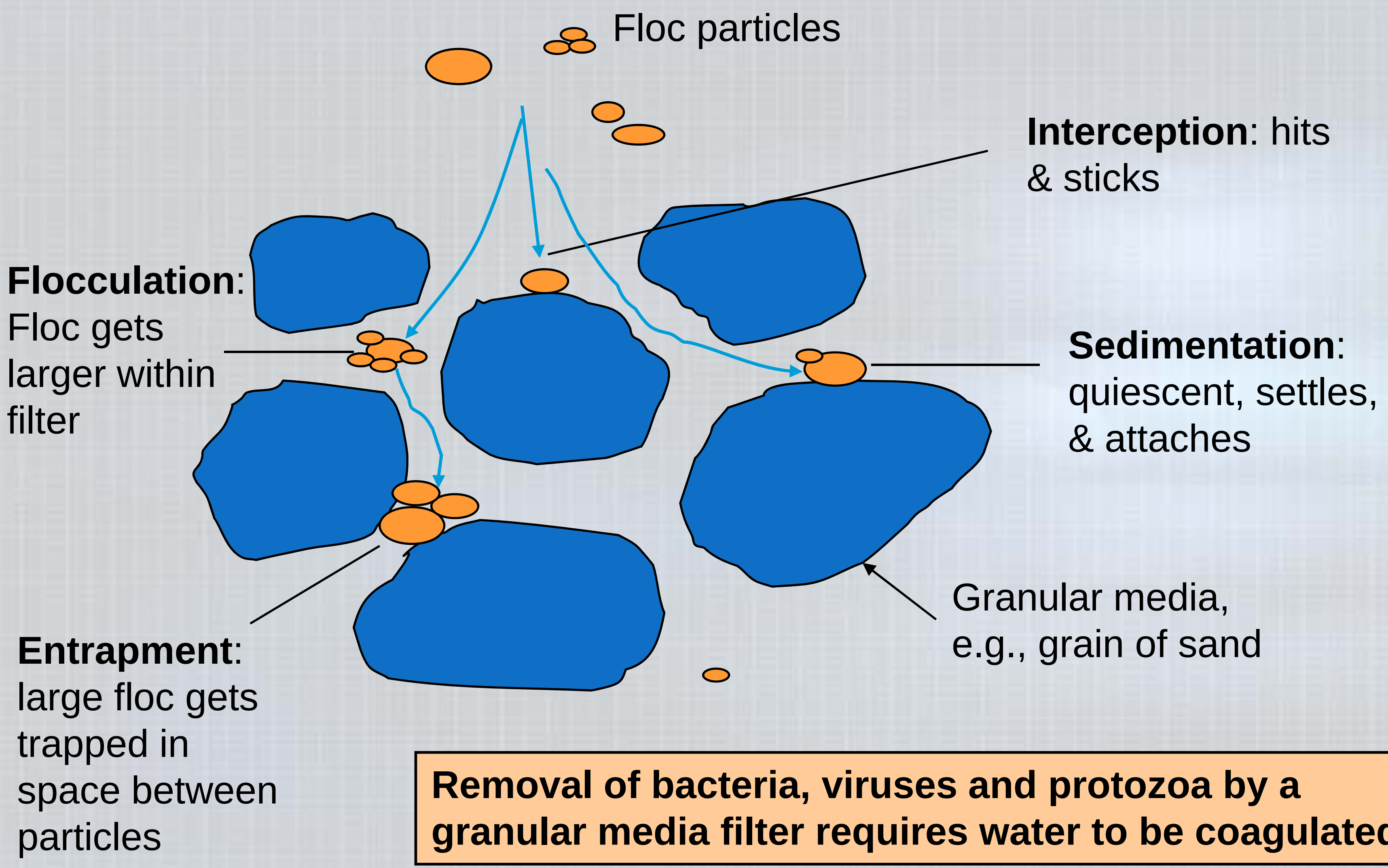


Mechanisms Involved in Filtration



Removal of bacteria, viruses and protozoa by a granular media filter requires water to be coagulated

Disinfection

Types of Disinfection

1- Chlorination

•In the past, wastewater treatment practices have principally relied on the use of chlorine for disinfection.

• The prevalent use of chlorine has come about because chlorine is an excellent disinfecting chemical and, until recently, has been available at a reasonable cost.

•However, the rising cost of chlorine coupled with the chemical's toxicity to fish and other biota and the production of potentially harmful chlorinated hydrocarbons has made chlorination less favored as the disinfectant of choice in wastewater treatment

Typical chlorine dose: 5-10mg/l

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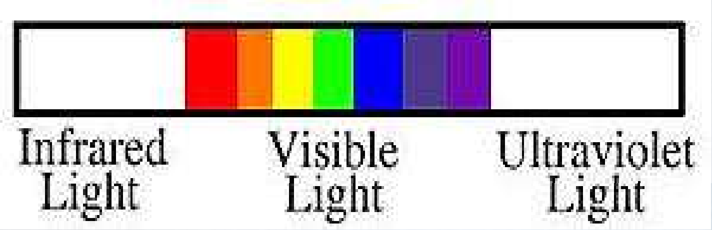
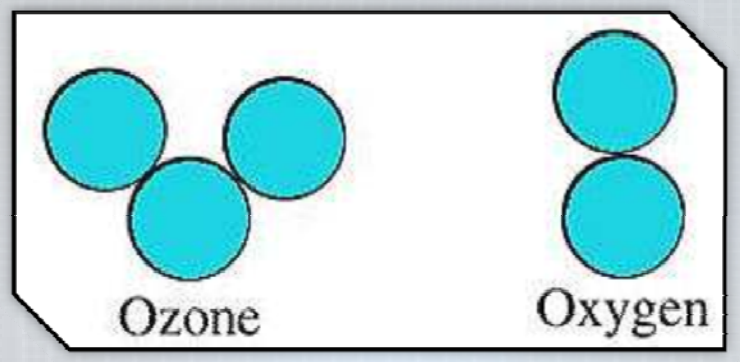
Types of Disinfection

2- Ultra-violet (UV) light



1. **Ultraviolet**, or **UV**, light is light outside the range usually detectable by the human eye. It can be used to deactivate protozoans so that they can't reproduce and to significantly reduce the bacteria in water.
2. The **primary disadvantage** of UV light is a high operating cost. In addition, anything which blocks UV light from reaching the water will result in a lack of treatment.



3- Ozonation

1. Oxygen in the air (O2) is composed of two oxygen molecules.
2. Under certain conditions, three oxygen molecules can be bound together instead, forming ozone (O3).
3. Ozone has many advantages as a disinfectant.
4. It kills all pathogenic organisms by a direct effect on their DNA.
5. Disinfection occurs 30,000 times faster than with chlorine, so a prolonged contact time is unnecessary.
6. There is no harmful residual left in the system.
7. The disadvantages of an ozone disinfection system are a corrosive nature, a high cost for the initial set-up, and a high electricity consumption.

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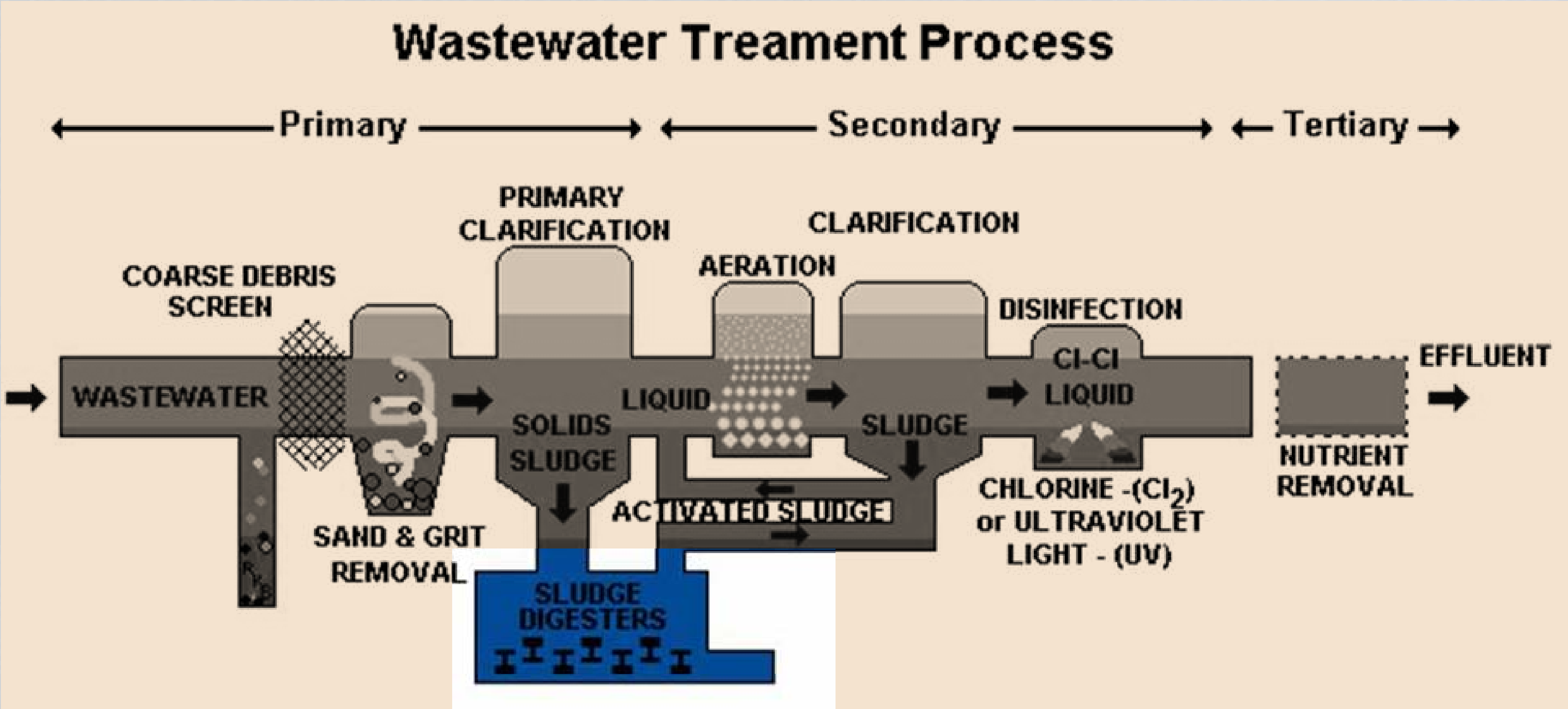
Sludge Treatment

(معالجة الحمأة)



Sludge Treatment Units

Thickening/ dewatering of Sludge

1. **Removal of water from liquid sewage sludge is divided into 3 different processes:**
   · thickening (up to approx. 7% TS)
   · dewatering (up to approx. 35% TS)
   · drying (up to approx. 100% TS)
2. **Gravity thickening is one of the most common methods used and is accomplished in a tank similar in design to a conventional sedimentation tank.**
3. **Normally, a circular tank is used, and dilute sludge is fed to a center feed well.**
4. **The feed sludge is allowed to settle and compact and the thickened sludge is withdrawn from the bottom.**

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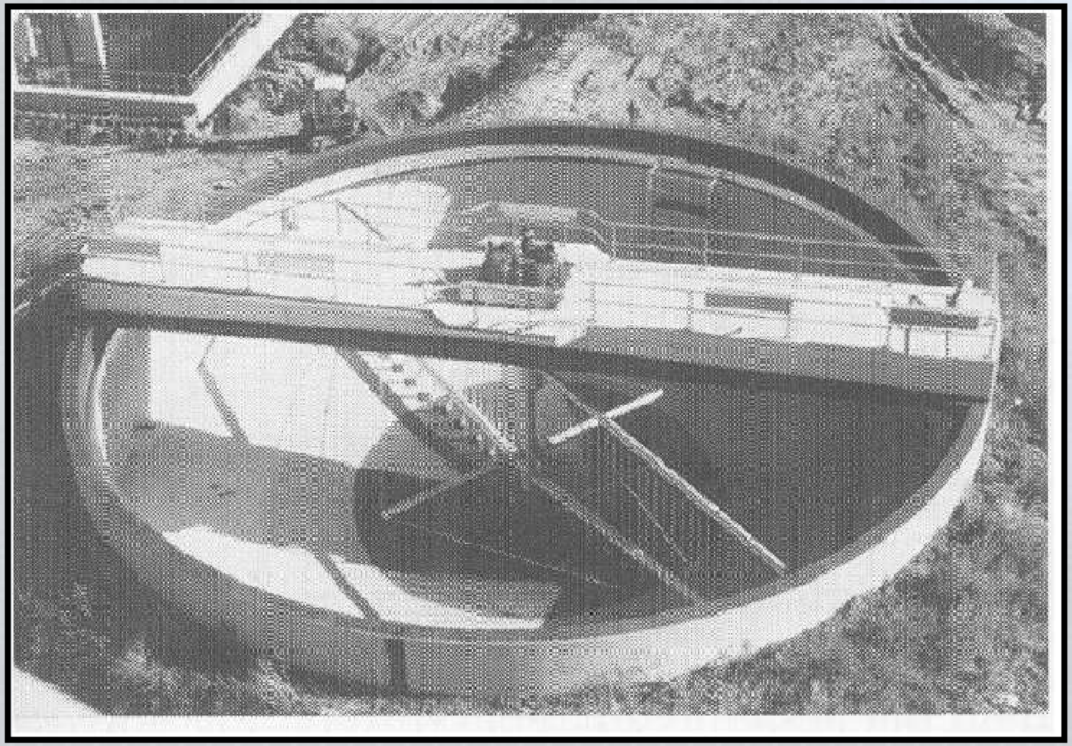
Gravity Thickeners

Vertical pickets stir the sludge gently, thereby opening up channels for water to escape and promoting densification. The supernatant flow that results is drawn off and returned to the influent of the treatment plant or a return-flow treatment process.



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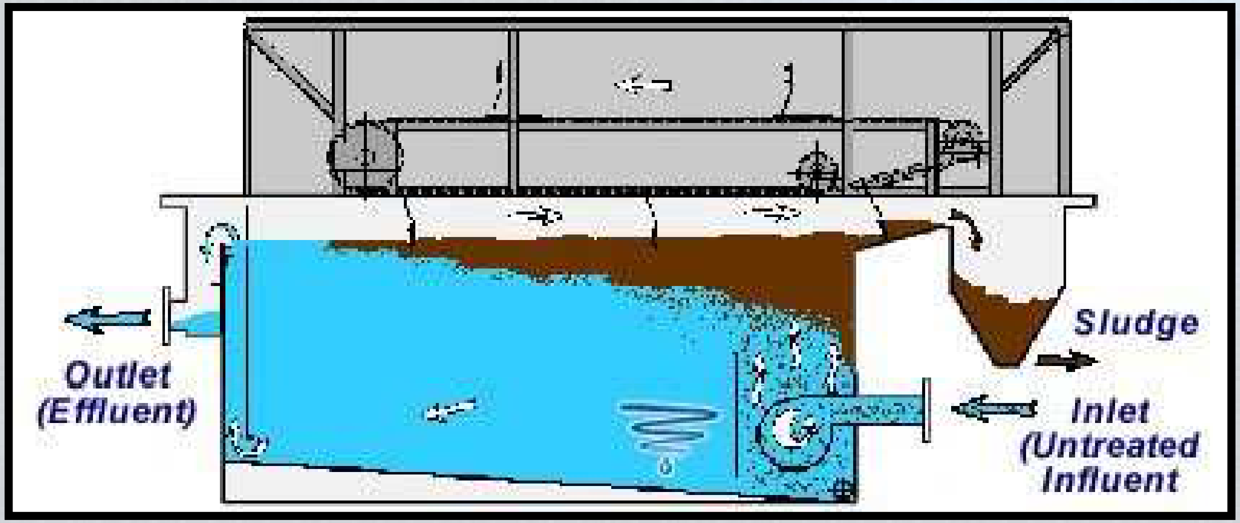
Dissolved air flotation (DAF) is a water treatment process that clarifies wastewater (or other waters) by the removal of suspended matter such as oil or solids. The removal is achieved by dissolving air in the water or wastewater under pressure and then releasing the air at atmospheric pressure in a flotation tank or basin. The released air forms tiny bubbles which adhere to the suspended matter causing the suspended matter to float to the surface of the water where it may then be removed by a skimming device.

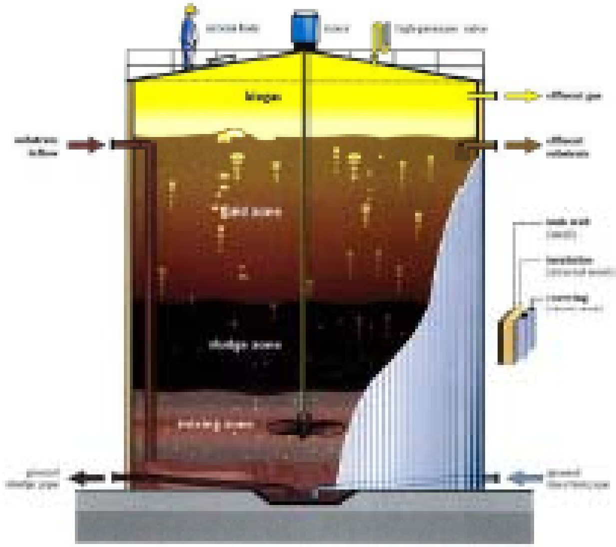


Anaerobic Digester

Egg shaped digester

http://farm3.static.flickr.com/2492/4010262996_9348af988a.jpg

Inside of the digester



http://www.personal.psu.edu/sat5090/blogs/english_202c_technical_writing/anaerobic_digester_diagram.jpg

Purpose: to reduce the mass of sludge, release CH_4 gas

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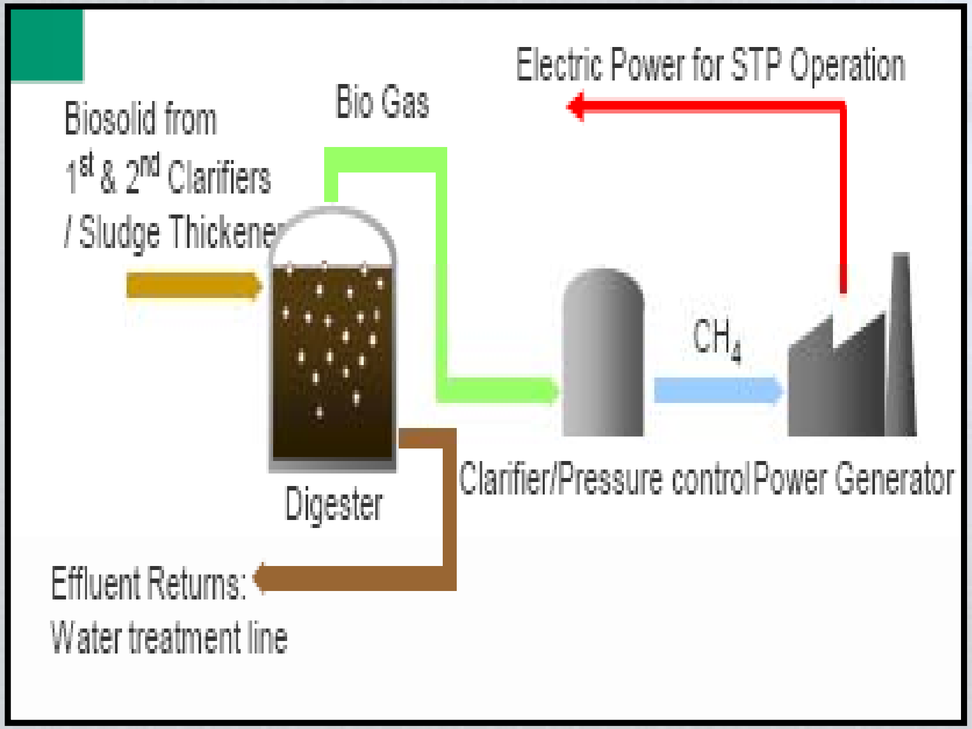
Biosolid Treatment

1- Renewable energy from the biosolid

2- High efficiency of methane production



Belt Press Unit

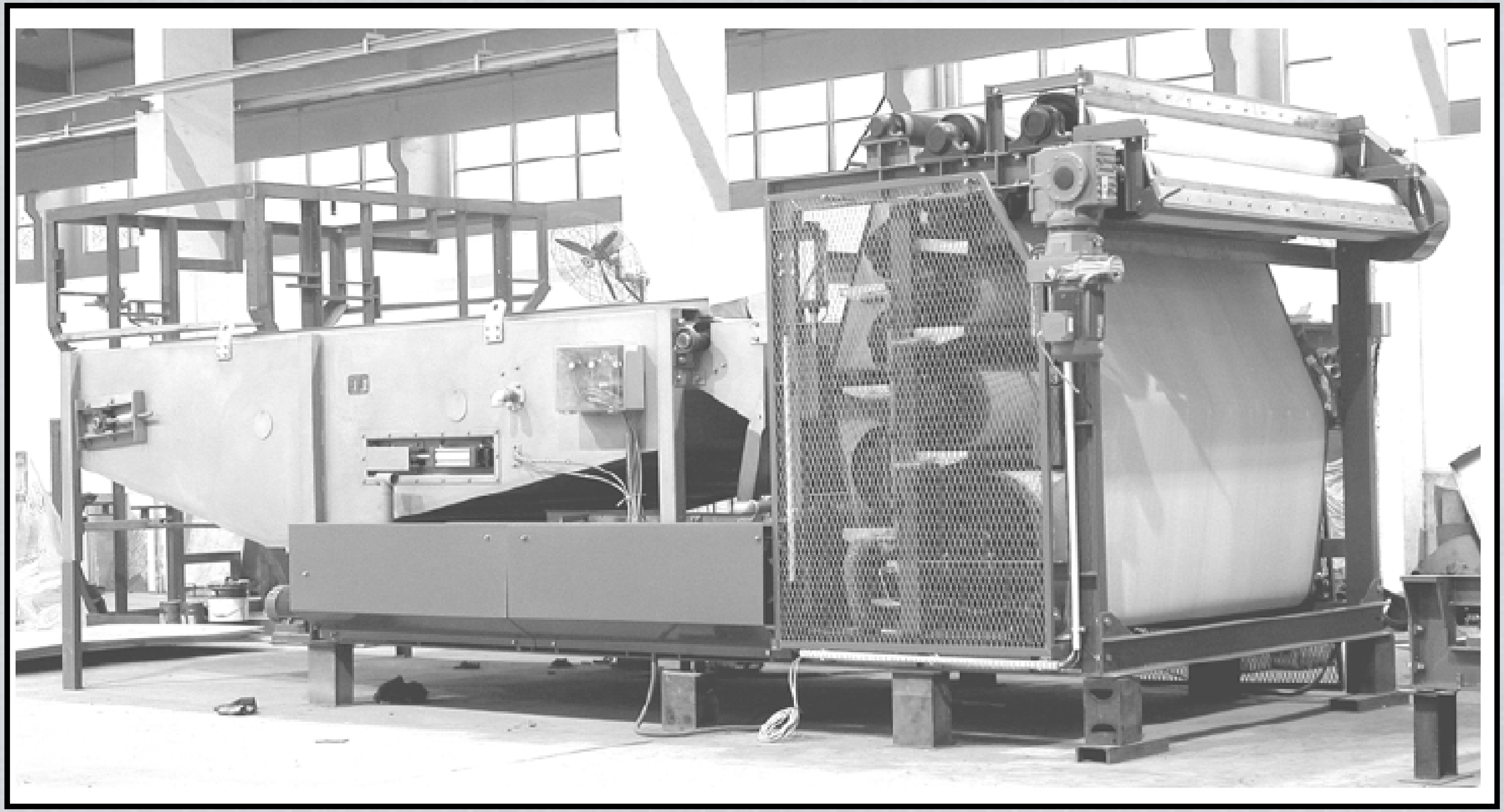
Basic Idea

Apply pressure to the biosolids to squeeze out the water. Biosolids are sandwiched between two-tensioned porous belts

Advantages	Disadvantages
1- produce very dry cake	1- release of undesirable odor
2- low power is required	2- presence of oil & grease may affect the drying process
3- Relative simple maintenance	3- screening of wastewater solids to remove sharp objects that could harm the belts
4- Start and shut off quickly compared to other methods	

Sludge Treatment

Belt Press Unit



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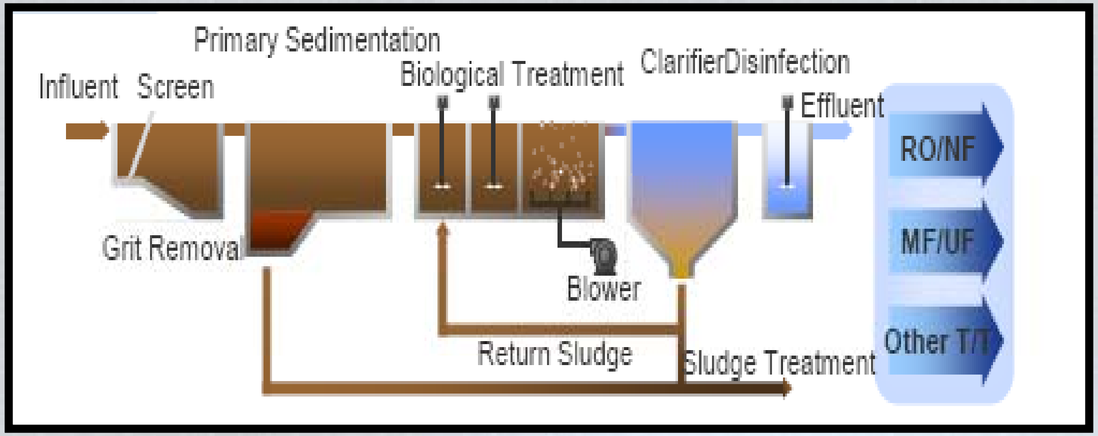
Sludge Treatment Centrifugal System

In wastewater treatment plant, dewatering process is usually the last step used for liquid and solid separation. The purpose of doing this is to get sludge cake of certain density and strength in order to allow better handling when it comes to transportation of the sludge for final disposal. This dewatering process usually follows right after clarification and there are actually different methods which one can choose such as <u>Solid Bowl Centrifuge.</u>

Centrifugal Dewatering Machine - (Centrifugal Decanter)

Wastewater and Sludge Reuse



Reuse of Wastewater

1- In irrigation of:

a- shrubs

b- green areas (landscape)

c- fruits & vegetables

depending on level of treatment (3^{rd} degree, 4^{th} degree)

2- Sell treated wastewater to agricultural investors (income)

Reuse of Sludge

To be used as fertilizers for agriculture instead of adding chemicals (income)

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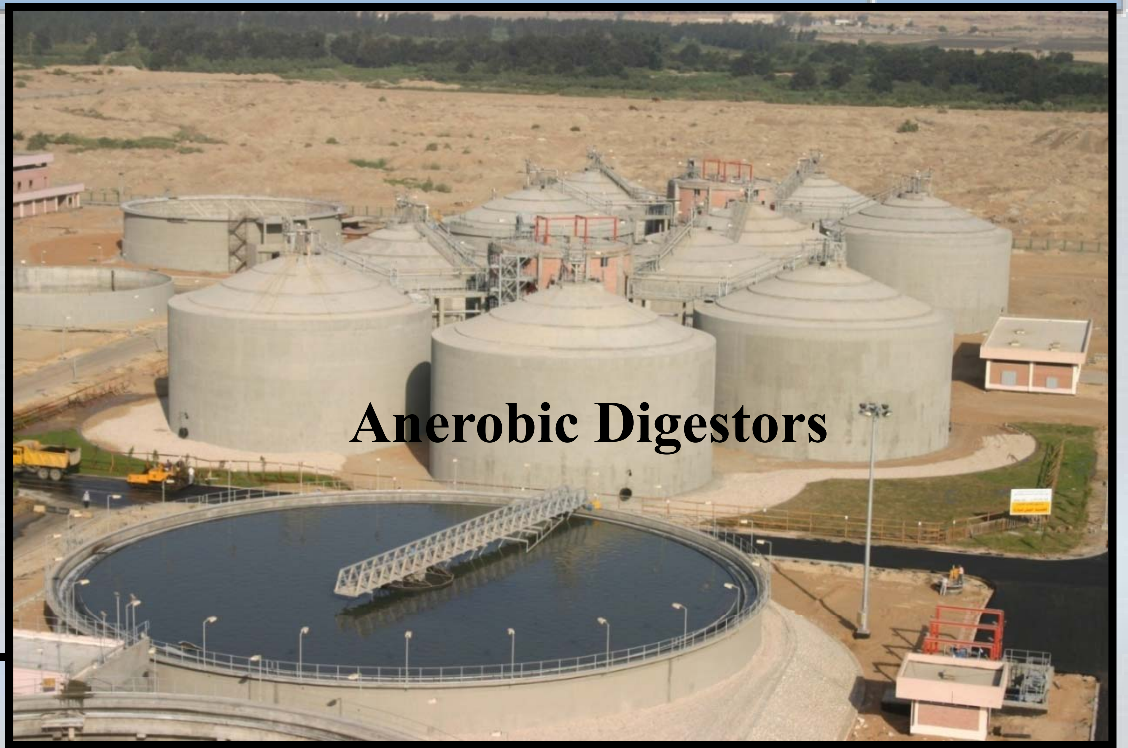
Gabal EL Asfar WWTP

Design Capacity: 500,000 m^3/d

Design Capacity: 500,000 m^3/d

Gabal EL Asfar WWTP

Design Capacity: 500,000 m^3/d



Design Capacity: 500,000 m^3/d

Gabal EL Asfar WWTP

Design Capacity: 500,000 m^3/d

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References

1. Egyptian Code (wtp - wwtp – water network – wastewater network – irrigation and reuse)
2. Metcalf & Eddy
3. German Code: ATV

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THANK YOU