Hospital Wastewater Management

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HOSPITALS : Health Care Centers or Pollution Sources?

- Hospitals are significant consumers of water
- Generates considerable amount of wastewater which consists of:
  - Pathogens and harmful bacteria, viruses, etc.,
  - Pharmaceuticals and their metabolites (PPCP, endocrine disruptors..)
    - The environmental risk posed by these contaminants is evaluated in light of the persistence (PoPs..DT50), bioaccumulation and toxicity criteria
    - Not easily removed by conventional WWTP (present in fresh water)
  - Radioactive elements
  - Toxic chemicals & heavy metals

Impact On The Environment

- Pathogens can spread disease, adversely affect the biodiversity
- Microbial resistant strains to antibiotics can spread resistance **“vertically”** (when new generations inherit antibiotic resistance genes) and **“horizontally”** (when bacteria share or exchange sections of genetic material with other bacteria)
- Persistent, non biodegradable, hydrophilic chemicals cross the wwtp and pollute water bodies

Water/Wastewater Use/Discharge in Hospitals

- Average water consumption 750 l/d/b
- No official data regarding wastewater generation from hospitals in Lebanon: International norms it ranges typically between 570l/d/b (USA, Metcalf & Eddy, 2014) to 1000ltr/d/b (Metcalf & Eddy, 2003). Employee: Typically 40 Ltr.
- Principal areas of usage:
  - Sanitary/amenities (taps, showers, toilets)
  - HVAC system
  - Medical purposes
  - Cafeteria/kitchen
  - Laundry

Pollution Sources In Hospitals

- Excretion of patients containing pharmaceuticals (drugs & their metabolites)
- Wastewater from health care activities, laboratories & medical research
- Hospital Sewer Network: Domestic Wastewater + Industrial WW

Why We Need a WWTP?

- Hospitals Wastewater (HWW) are generally co-treated with domestic wastewater in conventional WWTPs and are then released into the environment.
- However, many pharmaceuticals are resistant to conventional treatments.

Pollutants In Hospital Wastewater

- Microbial contaminants and clinical discharges (e.g. blood, biological samples)
- Heavy metals and rare earth elements chemicals
- Pharmaceuticals and radioactive substances
- Domestic wastewater and suspended solids

A. Microbial Contaminants

- Markers of viral pollution adenovirus and enterovirus
- HIV agents
- Prions
- Multiple antibiotic resistant strain (MARS): Concentration of MARS: 2 to 10 x higher than domestic wastewater
- May cause ecological imbalance in the environment
- May accumulate in the sewer and in case of epidemic require complete elimination using chlorination or other disinfecting processes

B. Heavy Metals & Rare Earth Elements

- Mercury (Hg)
  - Persistent, bio accumulative, potent neuro toxin
  - Found in health care devices (thermometers, blood pressure cuffs), laboratory chemicals, measurement devices, fixatives, cleaning agents
  - Can pass wwtp and may end up in river sediments and may bio-accumulate in fish and other biological life in aquatic environment

- Silver(Ag)
  - Potentially toxic to aquatic environment
  - Mainly used in radiology labs for X-ray film processing
  - Concentrated in fix and bleach-fix solutions and wash waters
  - Used in dental amalgam and in some chemicals used for chloride analysis
- Zinc (Zn)
  - Originates from Laboratory reagents used for glucose test and household cleaning products like floor waxes, wax strippers, stainless steel cleaners
- Gadolinium and Indium : Used for MRI – non biodegradable (isotopes)
- Platinum : Used in Oncological treatment with cis-platinum & carbo-platinum or other cytostatic agents

C. Chemicals, Pharmaceuticals & Radioactive Substances

- Hospitals are major contributors of chemicals and pharmaceuticals in WW but not exclusive
- Major Categories :
  - Cytostatic agents
  - Anesthetics
  - Antibiotics
  - Disinfectants
  - Iodinated Contrasting Media (ICM)
  - Analgesic and anti-inflammatories
  - Absorbable Organic substances (AOX)

Main Classes of Compounds Used in Hospitals

Main classes of compounds used in hospitals.

Class	Examples
Antibiotics	Cefazolin, chlortetracycline, ciprofloxacin, coprofloxacin, doxycycline, erythromycin, lincomycin, norfloxacin, ofloxacin, oxytetracycline, penicillin, sulfamethoxazole, , tetracycline, trimetoprim
Analgesics and antinflammatories	Codeine, diclofenac, dipyrone, ibuprofen, indomethacin, ketoprofen, mefenamic acid, naproxen, paracetamol, propyphenazone, salycilic acid
Cytostatics	5-Fluorouracil, ifosfamide
Anaesthetics	Propofol
Disinfectants	Triclosan, glutaraldehyde
Rare-earth elements	Gadolinium
Heavy metals	Platinum, mercury
Iodized contrast media (ICM)	Iopromide, iopamidol

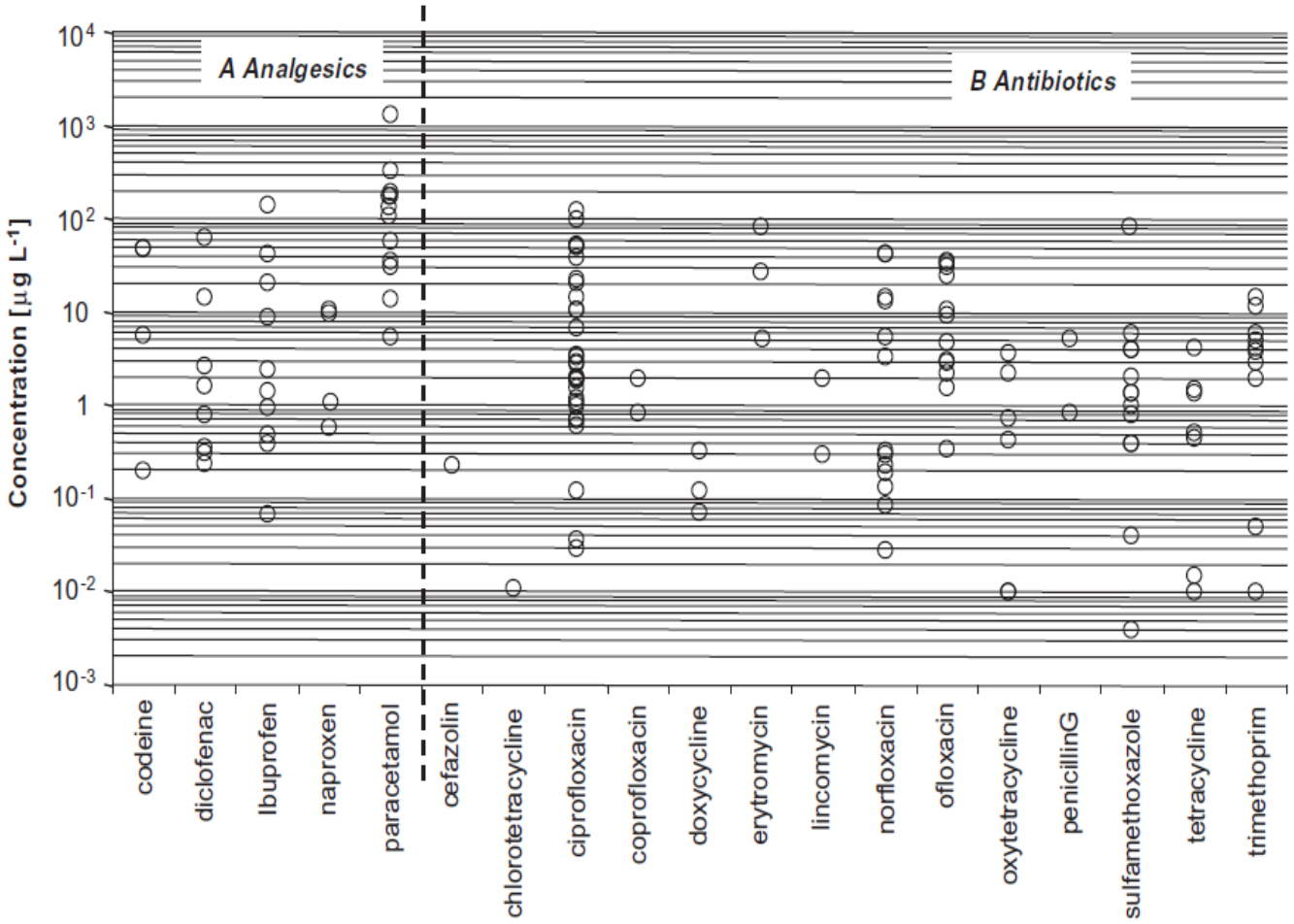
Other classes.

Class	Examples
Psychiatric drugs, antidepressants, anticonvulsants	Carbamazepine, gabapentin, phenytoin, valproic acid
Antihistamines	Ranitidine, cimetidine
Antihypertensives	Diltiazem
Antidiabetics	Glibenclamide
β-blockers	Atenolol, metroprolol, propranolol, solatolol
Hormones	17 β-Estradiol, estriol, estrone, ethinylestradiol
Diuretics	Furosemide, hydrochlorotiazide
Lipid regulators	Atorvastatina, bezafibrate, clofibric acid, gemfibrozil, pravastatin
Stimulants	Caffeine
Musks and fragrances	Tonalide, galoxolide

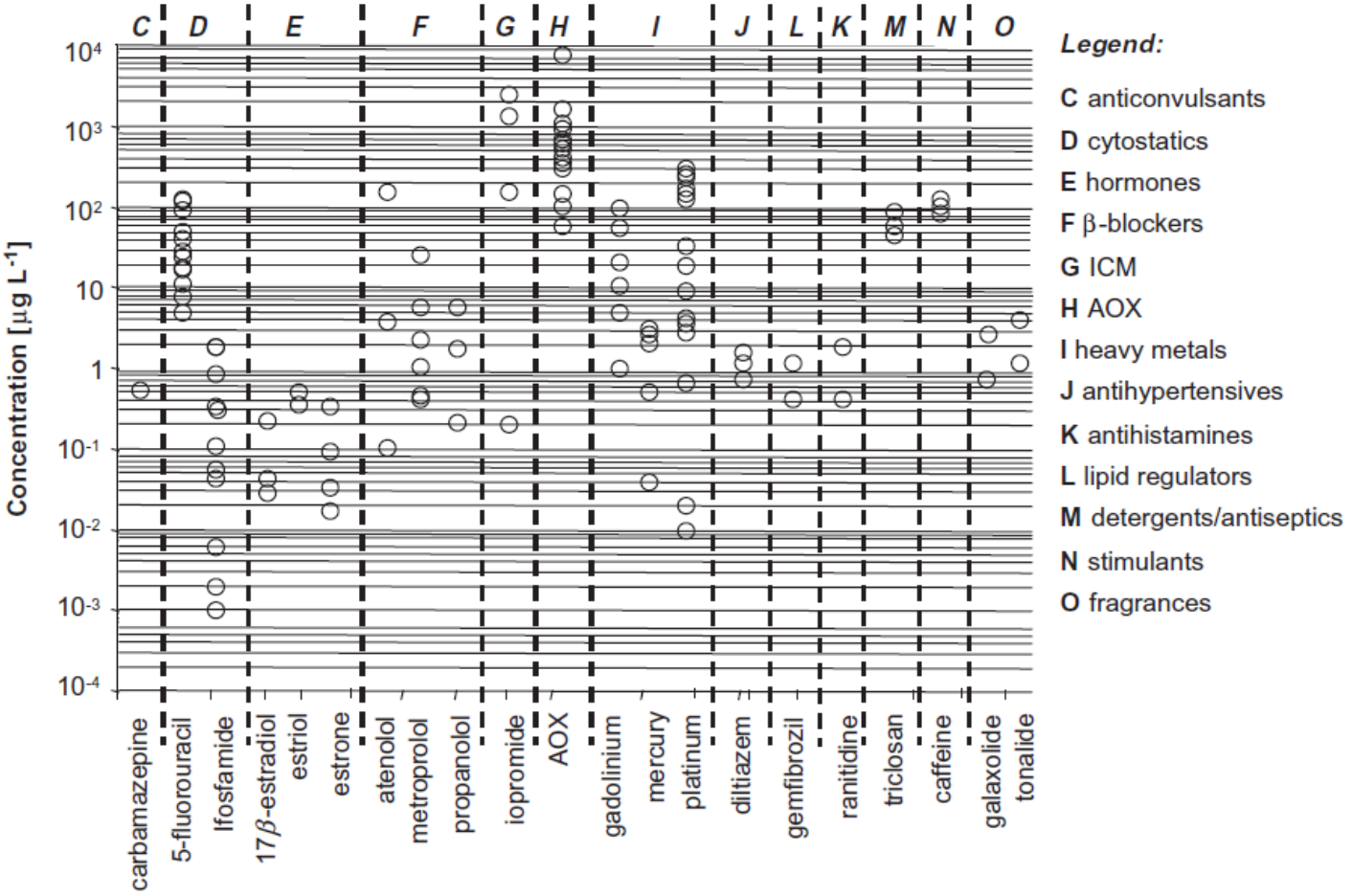
Average Concentrations For The Main Classes Of Micropollutants In HWWs & UWWs

Therapeutic class	HWWs, average values	UWWs, average values	$\frac{HWWs|_{av}}{UWWs|_{av}}$
Analgesics, $\mu g\ L^{-1}$	100	11.9	8–15
Antibiotics, $\mu g\ L^{-1}$	11	1.17	5–10
Cytostatics, $\mu g\ L^{-1}$	24	2.97	4–10
β-blockers, $\mu g\ L^{-1}$	5.9	3.21	1–4
Hormones, $\mu g\ L^{-1}$	0.16	0.10	1–3
ICM, $\mu g\ L^{-1}$	1008	6.99	70–150
AOX, $\mu g\ L^{-1}$	1371	150	7–15
Gadolinium, $\mu g\ L^{-1}$	32	0.7	35–55
Platinum, $\mu g\ L^{-1}$	13	0.155	60–90
Mercury, $\mu g\ L^{-1}$	1.65	0.54	3–5

Analgesics and antibiotics in HWWs



Other Emerging Contaminants In HWWs



- Cytostatic agents: Mainly used for cancer therapy
  - Known for their carcinogenic, mutagenic and toxic effects
  - Excreted by the patients undergoing chemotherapy
  - Highly polar and non volatile. Thus bound to stay in water phase
  - Varying biodegradability
- Antibiotics:
  - Of total consumption, 26% are used in hospitals
  - Antibiotics along with their metabolites end up in WW due to human excretion in urine and feces

- Iodinated Contrasted Media (ICM) :
  - Used for X-ray imaging of soft tissues
  - About 30% of it represents Absorbable Organic Iodinated Media (AOI)
  - Biologically inert and stable towards metabolism thus easily pass from body and end up in wastewater
  - Risk of ending up in groundwater
- Adsorbable Organic Halogen Compounds (AOX):
  - Derived as byproducts of disinfectants application
  - ICU are significant source of AOX and radiology department contributes maximum to AOX concentrations
  - Most persistent in the environment (toxic to humans & aquatic organisms)
  - Accumulate in food chain
  - Poorly biodegradable

Water Management & Abatement of Emissions

- Water use efficiency
- Source Reduction/ Segregation: Source controls could be an effective precautionary measure.
- Treatment and disposal
- Recycle/reuse

Example: Water Management & Abatement of Emissions

- Iodinated Contrast Media (ICM, radioactive):
  - Separate collection (tank) of urine for the patients undergoing X-ray imaging
  - Treat it as hazardous waste in incinerator
  - Avoid residual quantities while preparation and separate collection for the residuals

Quantitative Characteristics Of Hospital Wastewater

Pollutants : Parameter	HWW	Urban WW
pH	7.7-8.1	7.5.- 8.5
BOD_5 (mg/l)	300-400	200-300
COD (mg/l)	800-1000	600-800
SS (mg/l)	400-600	150-300
TKN (mg/l)	5-80	20-70
Total – P (mg/l)	0.2-13	4-10
Fat, oil and Grease(mg/l)	5-60	50-100
Total Surfactant	3-7.2	4-8
E. coli MPN/100 ml	10 - 10^6	10^6-10^7
Fecal coliform	10 -10^7	10^6-10^8
Total Coliform	10^5-10^8	10^7-10^9

Discharge Standards: Lebanon

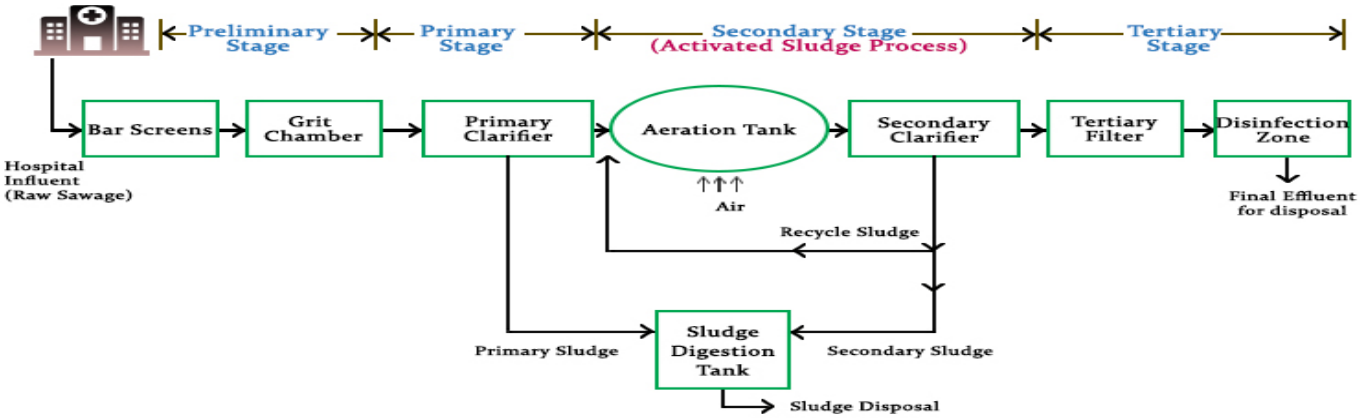
- No specific standards for hospital wastewater
- If no standards we rely on the international norms (WHO, EPA, ETC.,)
- Lebanese standards (MoE decision 8/1,2001: Surface water..)
  - pH: 6-9
  - TSS: 60 mg/l
  - BOD: 25 mg/l
  - O & G: 30 mg/l
  - COD: 125 mg/l
  - + other parameters

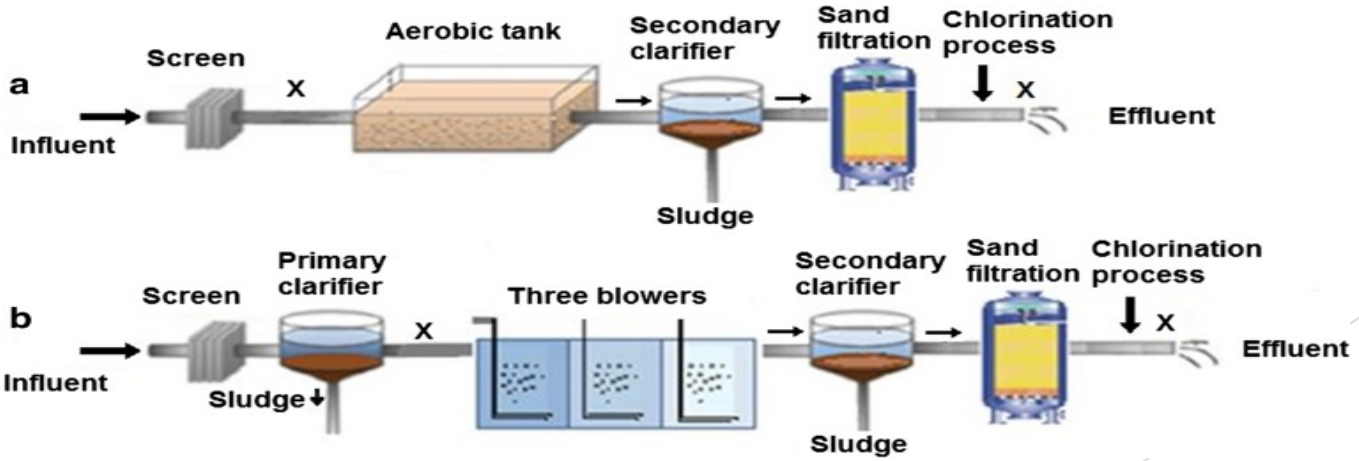
Discharge Standards: WHO (World Bank Guidelines)

- BOD_5: 50 mg/l
- COD: 250 mg/l
- TSS: 20 mg/l
- Oil and grease: 10 mg/l
- Cadmium: 0.1 mg/l
- Chromium: 0.5 mg/l
- Lead: 0.1 mg/l
- Mercury: 0.01 mg/l
- Chlorine (Total residue): 0.2 mg/l
- Phenols: 0.5 mg/l
- Fecal Coliforms: 400 MPN/ 100 ml

Wastewater Treatment Stages

WWTP for Hospitals is shown below:





Wastewater Treatment Methods
A. Physico-Chemical Treatment

- Much of the hospital wastewater has similar characteristics as domestic wastewater

A. Physico-chemical treatment: Pre-treatment

- A coagulation-flocculation process was generally found to be unable to remove personal care products
- Chemical treatments add up harmful byproducts

B. Biological Wastewater Treatment Technologies(Secondary Treatment)

- Most sustainable & cost-effective option
- Available Technologies/Biological WWT:
  - Conventional Activated Sludge (CAS)
  - Sequencing Batch Reactor (SBR)
  - Membrane Bio reactor(MBR)
  - Moving Bed bio reactor (MBBR)
  - Constructed Wet lands
  - Submerged Aerated Fix Film Reactor (SAFF)

• Principle: Biochemical oxidation processes

• Under controlled conditions Micro-organism utilize organic matter for the production of energy for cellular respiration and new biomass production

• Types of processes on the basis of kinetics:

- Aerobic Process:
  - Presence of oxygen (Aerobic MO)
  - Production of new cells and CO_2,H_2O
  - More sludge production
- Anaerobic Process:
  - Absence of oxygen
  - Certain slow growing microorganisms utilize oxygen bound to inorganic compounds like nitrate and sulfate
  - Less sludge production

- Two Types of Aerobic processes:

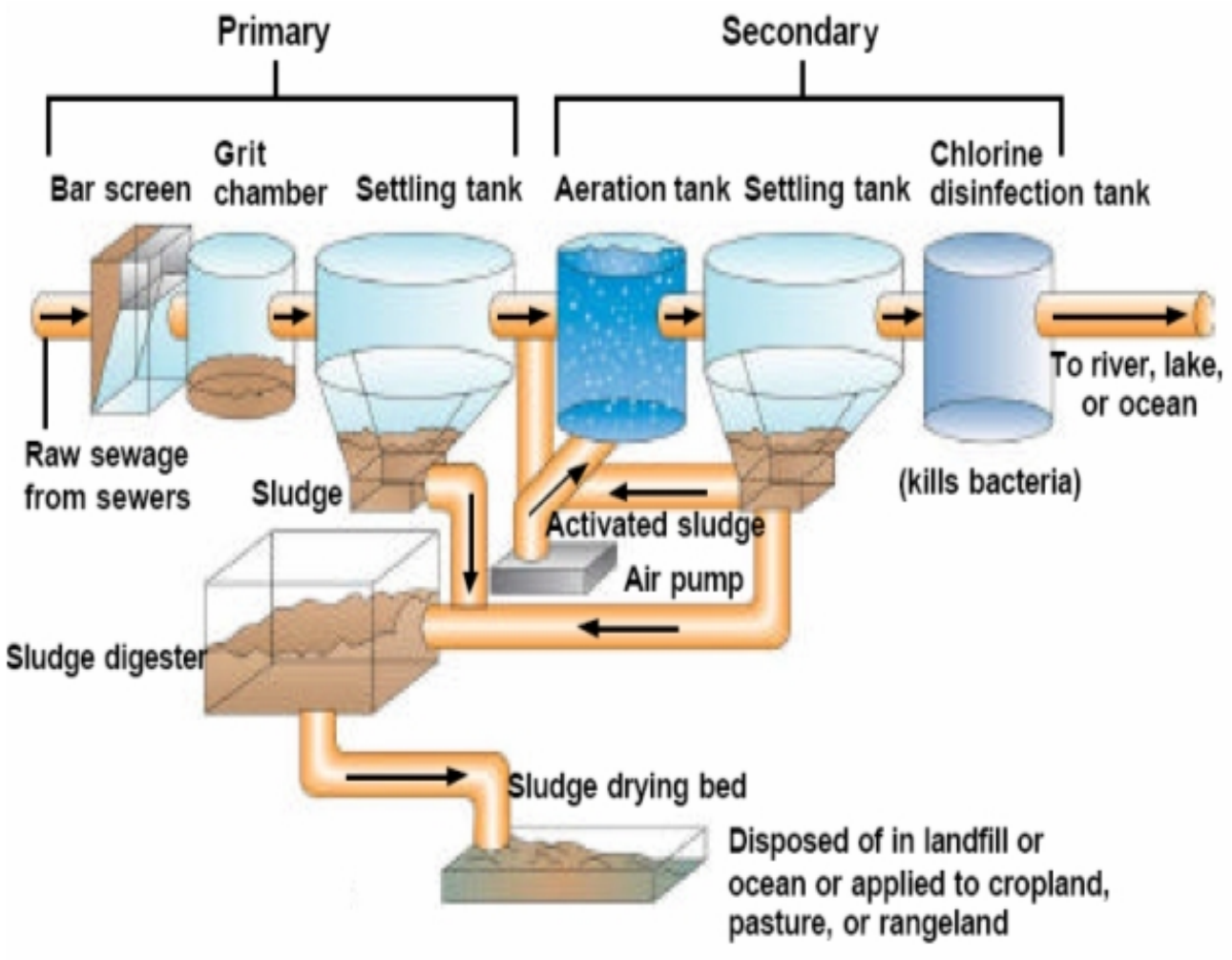
a. Suspended Growth:

- Microorganisms responsible for degradation are maintained in liquid suspension
- Conventional Activated Sludge System (CAS), Sequencing batch reactor (SBR), Oxidation ditch ponds, Contact Stabilization

b. Attached Growth:

- Micro-organisms responsible for degradation are allowed to grow on fixed, inert plastic media
- Moving Bed Bio Reactor (MBBR), Fluidized Bed Reactor (FBR) , Rotating Biological Contactor (RBC)

Conventional Processes (CAS)

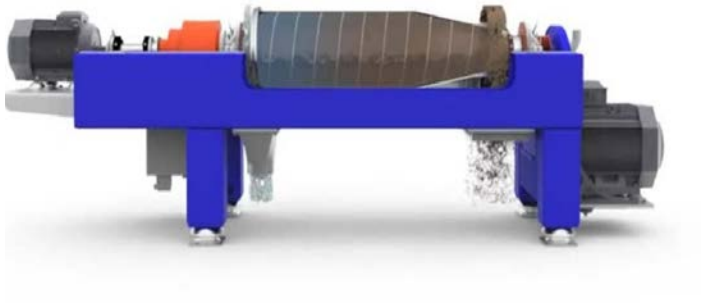


Wastewater Treatment Plant: Aerobic Tanks

Wastewater Treatment Plant: Clarifiers

Sludge Treatment Processes: Dewatering

Membrane Filter Press - Belt Filter Press - Decanter Centrifuge



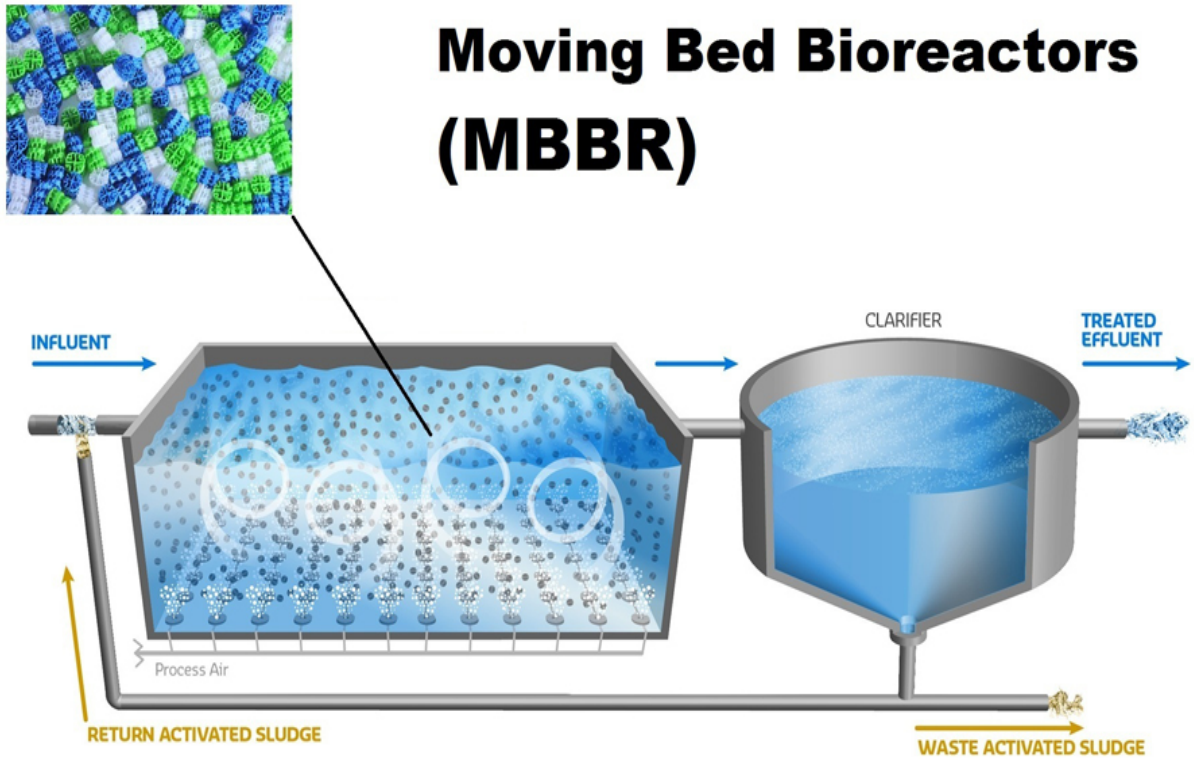
Moving Bed Bioreactor (MBBR)/ Integrated Fixed Film AS (IFAS) Processes

- A combination of suspended growth as well as fixed film-based technology
- Utilize specialized carriers in suspension for biomass retention

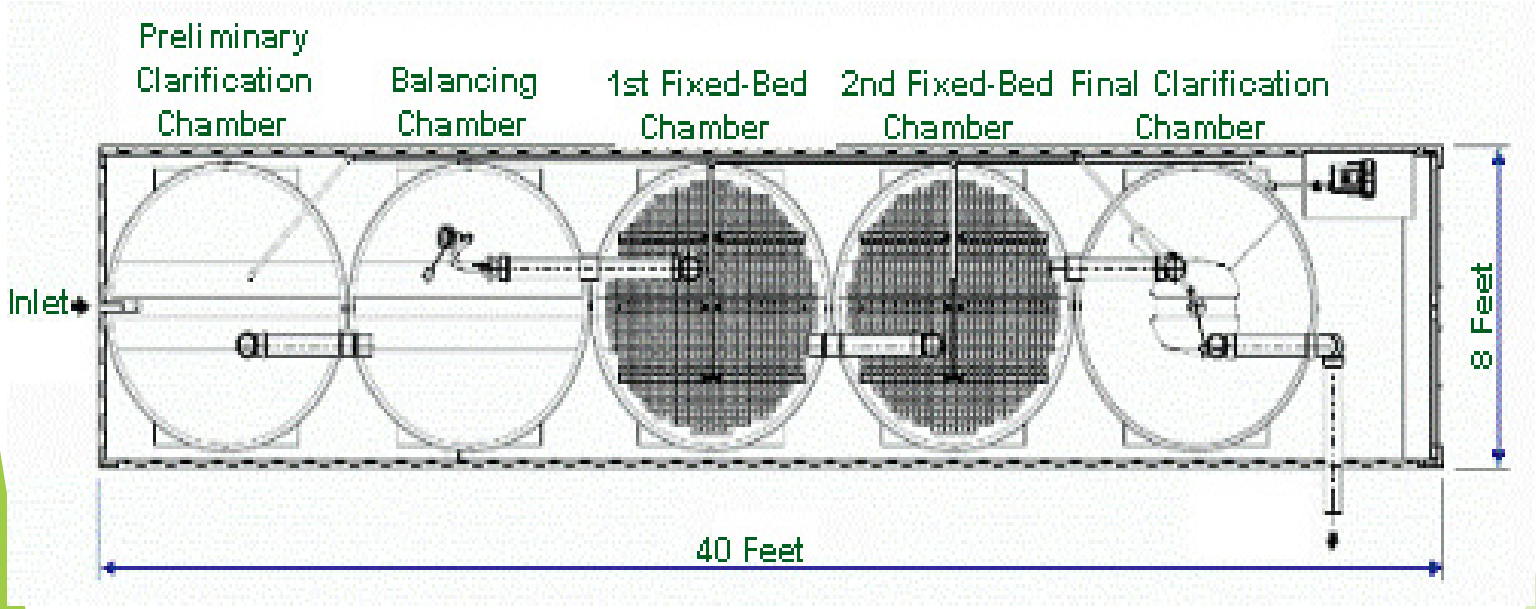
MBBR :
- Once through process
- No sludge is recycled back
- Separate reactors for BOD, COD , nitrification removal

IFAS :
- Sludge is recycled back to aeration basin
- Additional biomass in suspended phase as well

MBBR Model


Moving Bed Bioreactors
(MBBR)
INFLUENT
CLARIFIER
TREATED EFFLUENT
Process Air
RETURN ACTIVATED SLUDGE
WASTE ACTIVATED SLUDGE

Fixed Bed/Film Bioreactor Plant



ADVANTAGES OF MBBR/IFAS PROCESS

- Continuous flow and thus eliminating need of backwashing unlike other fixed film processes
- Additional biomass in the reactor without increasing solids loading to clarifiers
- Achieving better SS removal
- Reduced sludge production (0.3 g VSS/g COD compared to 0.4-0.6 for CAS)
  - The typical yield aerobic yield coefficient from CAS : Range ~ 0.4-0.7
  - The typical yield anaerobic yield coefficient : Range ~ 0.1-0.35
- High rate treatment and thus offers space saving due to smaller foot print
- Improved process stability and faster recovery from shock loads
- Better settling properties of sludge reducing handling costs

ADVANTAGES FOR HOSPITAL WWT

- Removal of pharmaceutical micro pollutants possible due to adsorption and higher SRTs compared to conventional systems
- Development of specialized biomass providing more diverse community of micro- organisms with broader physiological properties
- Better process stability towards shock loadings due to adsorption and internal porosity

C. Tertiary Treatment Processes

- Filtration through gravel, sand & activated carbon (GAC/PAC)
- Adsorption by activated carbon has great potential for the removal of trace emerging contaminants
- Disinfection by chlorine, peracetic acid, UV or Ozone is considered sometimes as part of this step (mainly it is considered part of the secondary treatment)

D. Advanced Treatment Processes

- Reverse osmosis (RO)
- Nanofiltration (NF)
- Advanced oxidation processes (AOPs):
  - The use or generation of Hydroxyl radical (OH.)
  - It can be used in the pretreatment step
  - Ozonation (O_3), Radiation, Fenton's (H_2O_2), Photolysis/Photocatalysis, sonolysis, electrochemical

Application of Treated Water (Reuse)

- Cooling Water systems
- Irrigation (Restricted)
- Toilet Flushing


Thank
You!