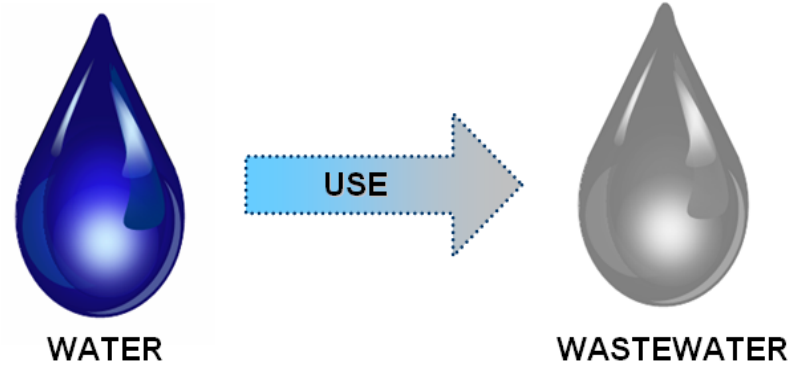
WASTEWATER 101

SEWAGE TREATMENT

What is Wastewater?

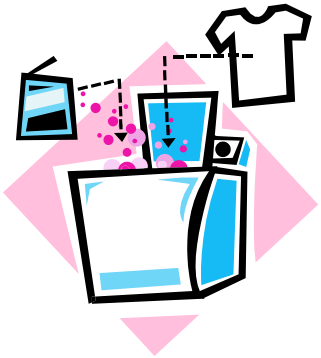
Wastewater is used water!

- Water is used for many purposes. Water that has been used and contains domestic, industrial, institutional and commercial waste products is called ***wastewater***.

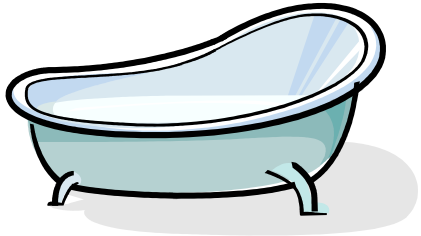


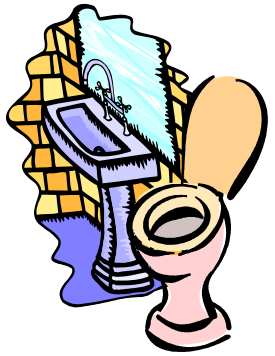
- Wastewater requires treatment before it can be returned to the environment or reused.
- Another common term for municipal wastewater is ***sewage***.

Domestic Wastewater



- ***Domestic wastewater*** (from homes) includes toilet waste and water used for laundry, bathing, and dishwashing.
  - In Ontario, each person produces about 225-450 litres of wastewater per day.





Domestic Wastewater

- In York Region, the average person generates about 300 litres of wastewater per day. That's about 150 times your recommended 8 glasses a day or 600 water bottles!

- In a city of 100,000 people, that's enough wastewater to fill twelve Olympic-sized swimming pools every day!

Industrial, Commercial, Institutional (ICI) Wastewater

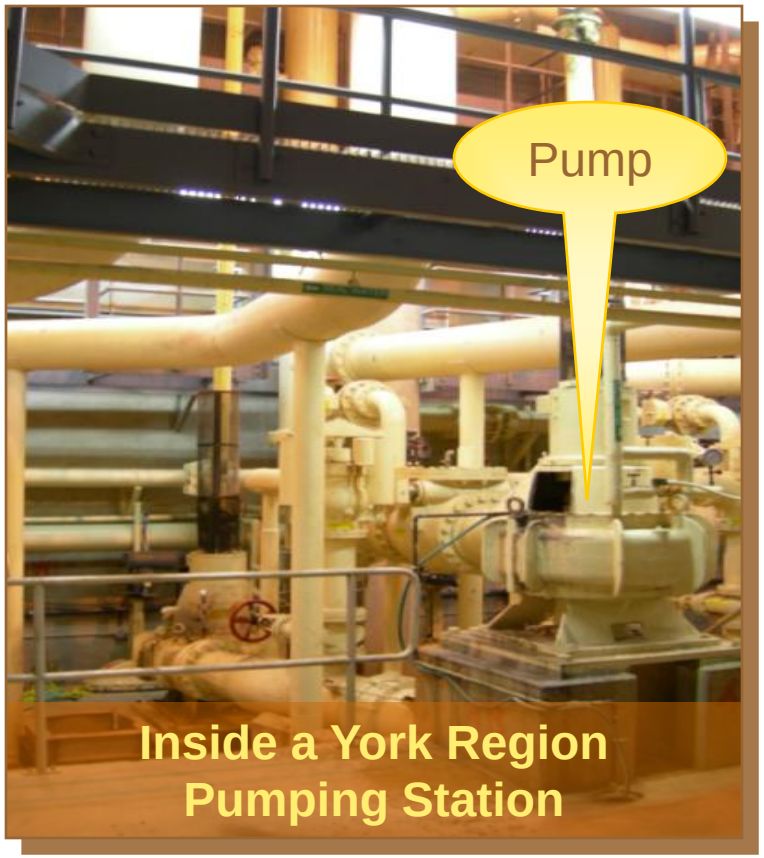
- Together, wastewater from places like factories, restaurants, stores, schools, and hospitals, is called ***ICI*** (industrial, commercial, institutional) flow.

Where does Wastewater go? How does it get there?

- All sources of wastewater in a Sewage Service Area are connected to sewers, which join together to form a network called a ***collection system.***
- The collection system leads to a ***Water Pollution Control Plant*** (WPCP).

Where does Wastewater go? How does it get there?

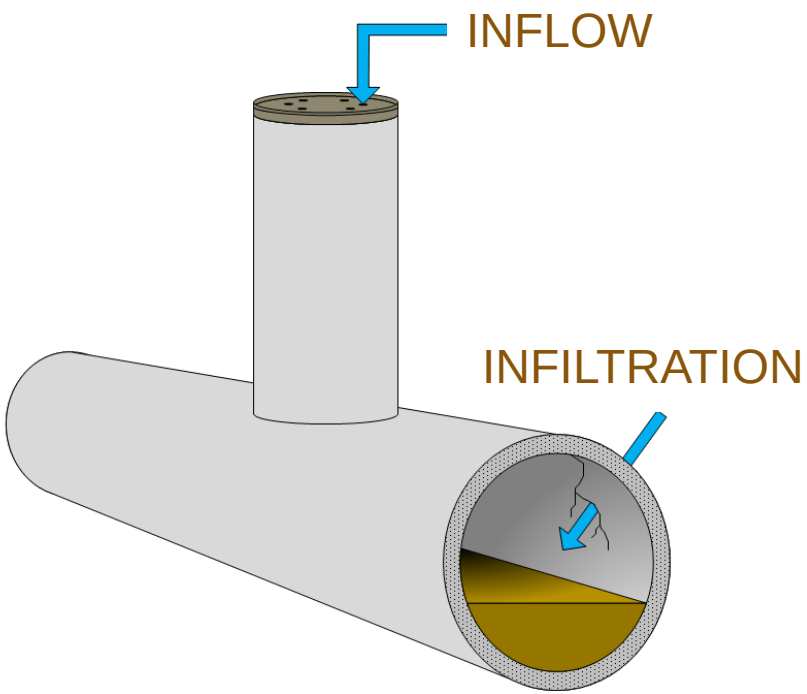
- Water flows downhill because of gravity, so the WPCP is usually located at a low-point in the service area.
- If the force of gravity isn't enough, ***pumping stations*** are used to boost wastewater through forcemains (pressurized sewers) to the WPCP.



Inside a York Region Pumping Station

Other Sources of Wastewater

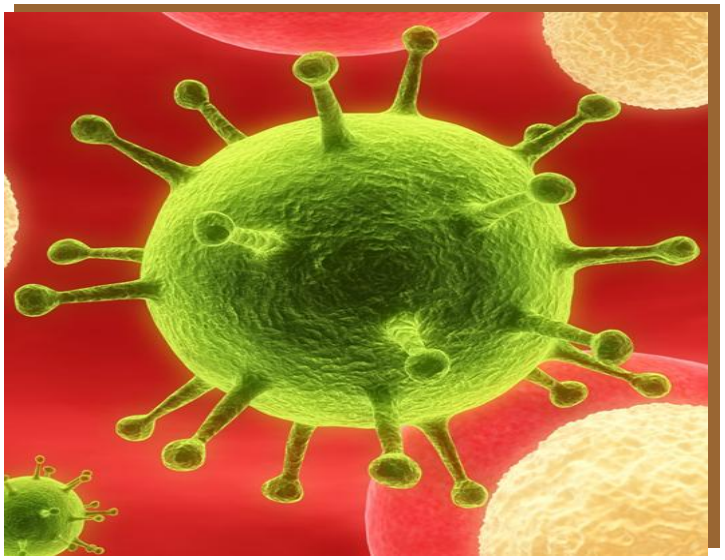
- Water often seeps into sewers through cracks in the pipe. This is called ***infiltration***.



- Water can also enter the sewer from above ground, for example through holes in maintenance covers (manholes). This is called ***inflow***.
- In ***combined sewer systems***, storm water is also mixed with wastewater.

Why do we need to treat Wastewater?

- Wastewater treatment is important to remove constituents or contaminants that could harm people or the environment.
- Common constituents in domestic wastewater are:
  - Organics
  - Solids
  - Nutrients
  - Pathogens



How do we remove these constituents?

- Treatment processes that remove wastewater contaminants include:

Physical

Screen

Chemical

Coagulant Tanks

Biological means…

Aeration Basin

What happens to treated Wastewater?

- Treated wastewater (effluent) may be discharged to a nearby water body such as a stream or lake.
- It may also be reused, for example, for irrigation or industrial processes

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WASTEWATER TREATMENT

Wastewater to Clean Water

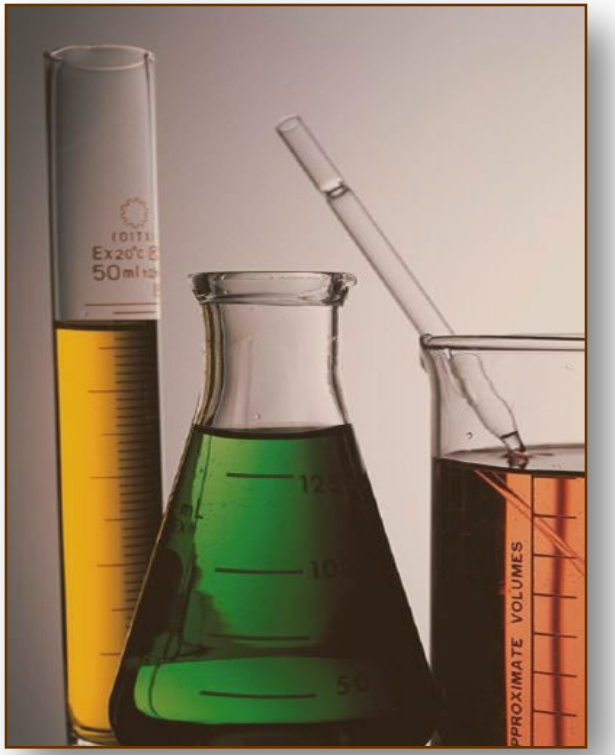
York Region

Wastewater Generation

- We all generate wastewater throughout our day. When we shower, do laundry or do the dishes it creates a daily flow pattern.
- Typically, wastewater flows received at municipal treatment plants follow the daily lifestyle patterns of the community.

Raw Sewage Constituents

- The quantities of the constituents in wastewater are measured by laboratory tests.
- Some typical parameters tested are:
  - ***TN*** - Total Nitrogen.
  - ***TAN*** – Total Ammonia Nitrogen. Measured in secondary effluent.
  - ***TP*** - Total Phosphorus.
  - ***TSS*** - Total Suspended Solids.



Raw Sewage Constituents

- Typical parameters (cont'd):
  - ***BOD*** - Biochemical Oxygen Demand. Measures how fast organisms use oxygen in water, and indicates amount of organic material in raw wastewater and primary effluent.
  - ***CBOD*** – Carbonaceous Biochemical Oxygen Demand. Does not include oxygen demand of nitrifying bacteria. Measured in secondary effluent.
  - Other constituents.

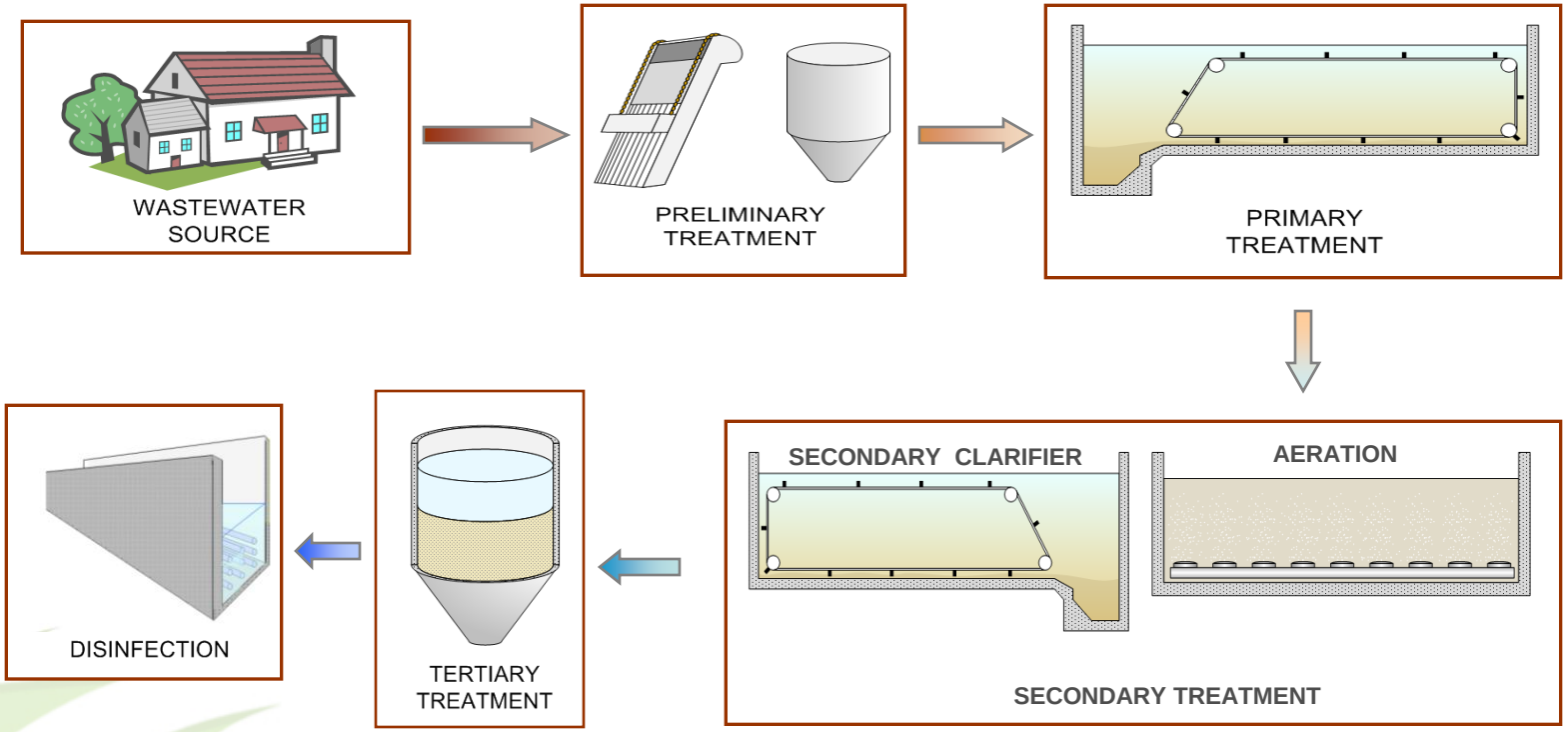
Raw Sewage Quality

Parameter	Typical Concentration in Raw Wastewater[1] (mg/L)	Ontario Typical Effluent Compliance Limits[2,3] (mg/L)
Total Suspended Solids (TSS)	150 - 200	<25
Carbonaceous Biological Oxygen Demand ($CBOD_5$)	150 - 200[2]	<25
Total Ammonia Nitrogen (TAN)	20 - 25	-
Total Phosphorus (TP)	6 - 8	<1

1. Design Guidelines for Sewage Works. 2008. Ministry of the Environment (MOE).
2. Value is for BOD_5. Assumed BOD_5 and $CBOD_5$ are the same in raw wastewater for this table.
3. Ontario compliance limits are decided on a case by case basis. These values are for WPCP secondary treatment which is considered the normal level of treatment in Ontario.

WPCP Conventional Wastewater Treatment

Overview



Preliminary Treatment

- Mechanical screens remove materials like rags, sticks, etc.
- Grit removal processes remove grit, sand and granular materials.

Channels conveys flow through screens

Wastewater flowing into parshall flumes and grit removal systems

Preliminary Treatment Screening

- Coarse screens (12 - 50 mm) are used to remove large debris like rags, sticks, rocks, and plastic.
- Fine screens (2 - 6 mm) capture smaller items such as cigarette butts and some fecal matter.
- Screens have to be cleaned often; this can be automated or manual.

Mechanical Screen

Preliminary Treatment
Grit Removal

- Grit removal is the forced separation of gritty material (gravel, sand, egg shells, seeds, etc.) from wastewater.
- If not removed, this material could accumulate in the treatment system and cause damage to or abrasion of pipes and equipment.

Preliminary Treatment

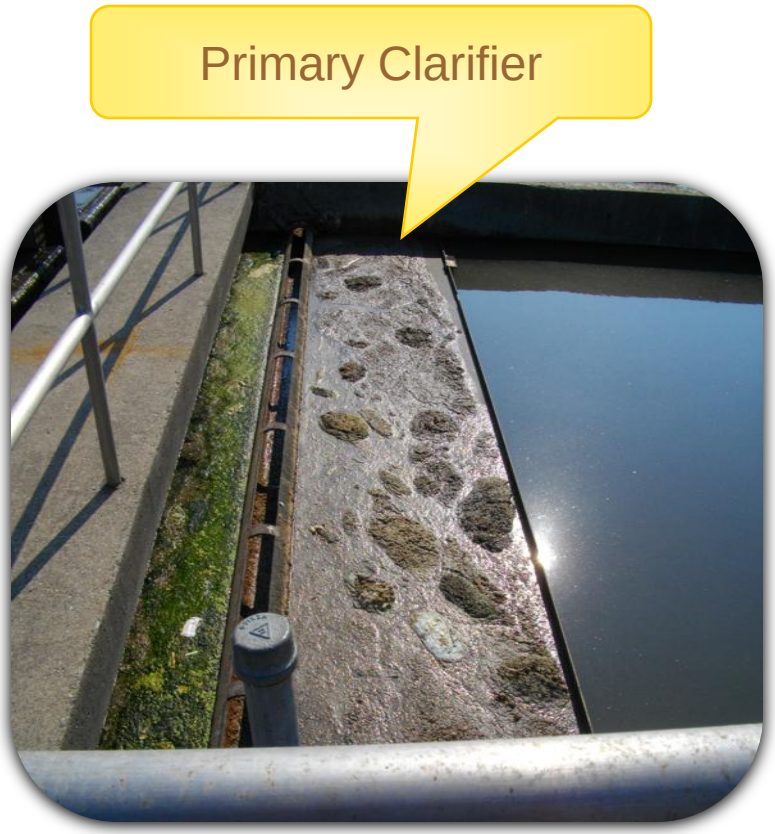
What happens to the screenings & grit?

Screenings & Grit Removal

- Screenings and grit are stored at the WPCP.
- Typically, these screenings and grit are eventually sent to a landfill for disposal.

Primary Treatment

- Removes a portion of the suspended solids and organic matter from the wastewater.
- It is considered the first stage of wastewater treatment.



Primary Treatment
Primary Sedimentation

- ***Primary sedimentation*** is the oldest and most widely used form of wastewater treatment.
- Sedimentation describes the tendency of floating or suspended particles to settle to the bottom of the tank by gravity.

Primary Treatment
Primary Sedimentation

- Wastewater enters the tank and is held there long enough to let easily settleable particles reach the bottom of the tank.
- The settled material is called ***primary sludge***.

Primary Treatment
Enhanced Primary Sedimentation

Coagulants tanks

- Sometimes chemicals are added to improve or enhance settling during primary sedimentation.
- These chemicals are called ***coagulants*** and promote ***flocculation*** (clumping) of particles so they settle more easily.
- Enhanced primary treatment also helps to remove phosphorus.

Primary Treatment

What do you do with primary sludge?

- Sludge is scraped from the bottom of the tank into a ***hopper*** (funnel-like structure), and is pumped from the tank for processing.
- Raw sludge contains a lot of water. Usually, some water is removed before further processing.

Primary Treatment Water Quality

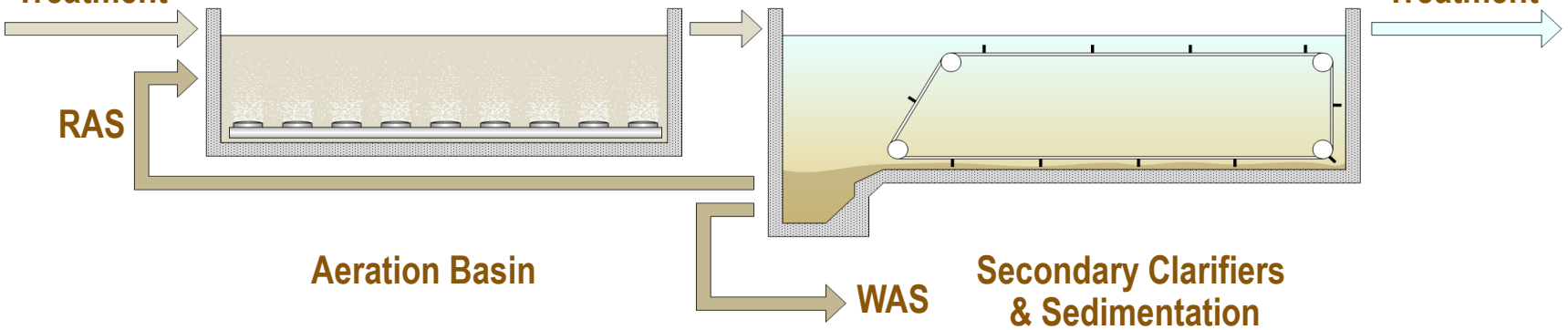
Primary treatment removes significant amounts of TSS, BOD and TP!

Parameter	Removal in Primary Treatment[1] (%)	
	Conventional	*Enhanced*
Total Suspended Solids (TSS)	40 - 70	60 - 90
Biological Oxygen Demand (BOD)	25 - 40	40 - 70
Total Phosphorus (TP)	5 - 10	70 - 90

1. Design of Municipal Wastewater Treatment Plants, 4th Edition (WEF Manual of Practice 8/ASCE Manual and Report on Engineering Practice No. 76. 1998. Water Environment Federation and American Society of Civil Engineers.

Secondary Treatment Biological Treatment

Suspended Growth Biological Treatment



Secondary Treatment Biological Treatment

- Biodegradable organic matter is removed by microorganisms (biomass).
- This is considered the second stage of wastewater treatment.

Secondary Treatment (secondary clarifier)

Secondary Treatment Biological Treatment

Suspended Growth Biological Treatment

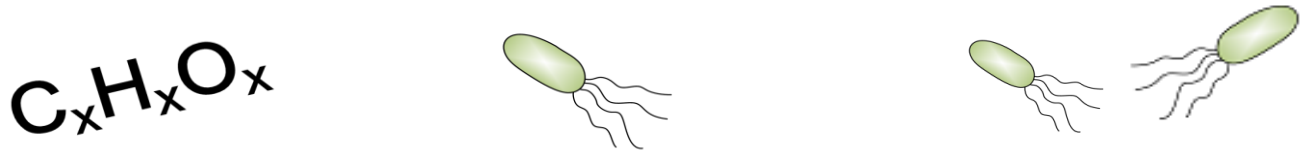
- Secondary treatment is usually accomplished by a process called ***suspended growth biological treatment.***
- The term “suspended” is used because the biomass floats freely in the liquid.

Aeration Basin

Secondary Treatment Biological Treatment

Suspended Growth Biological Treatment

- Wastewater and biomass are mixed in a reactor. The content of the reactor is called ***mixed liquor***, and the solids portion of the mixed liquor is called ***mixed liquor suspended solids***.
- Microorganisms remove biodegradable organic material from the wastewater by converting it into a new cell mass through growth and reproduction.



ORGANIC MATERIAL + O_2 + NUTRIENTS + MICROBES → NEW MICROBES + CO_2 + H_2O

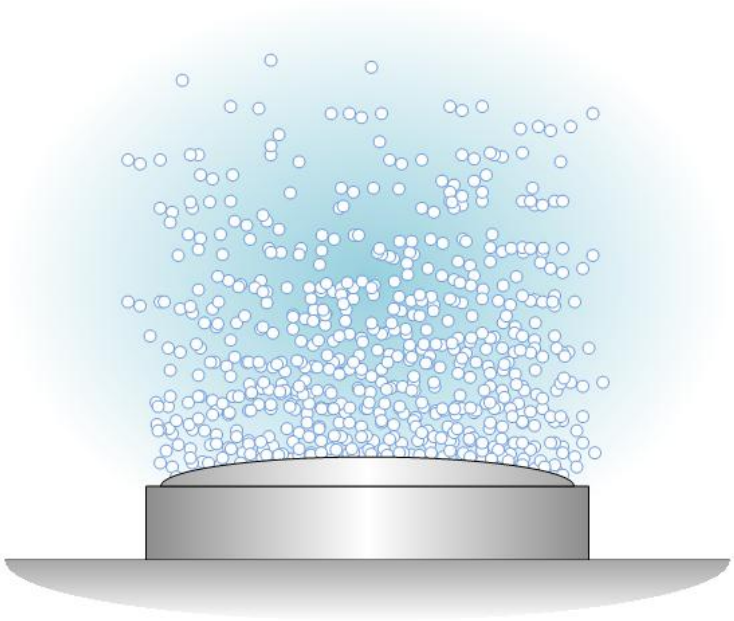
Secondary Treatment Biological Treatment

Suspended Growth Biological Treatment

- The microorganisms need oxygen to do their work, so air is forced into the reactor.
- This process is called aeration, and this is why the reactor is also called an ***aeration basin***.

Secondary Treatment Biological Treatment

Suspended Growth Biological Treatment



- Aeration is often accomplished by ***blowers*** that pull air in and force it through ***diffusers***, which are distributed evenly on the bottom of the basin.
- The diffusers create small air bubbles that flow up through the mixed liquor.

Secondary Treatment
Secondary Clarification

- After enough time for the biological reactions, ***mixed liquor suspended solids*** **(MLSS)** is sent to a settling basin for separation of the **MLSS** from the treated wastewater.
- The separation process is called ***secondary clarification***, and it is very similar to ***primary sedimentation***.

Secondary Clarifier

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Secondary Treatment

What happens to secondary sludge?

Return Activated Sludge Conveyance System

- Settled ***mixed liquor suspended solids*** is called ***activated sludge*** because it contains so many living organisms.
- Some of the activated sludge (return activated sludge - ***RAS***) is sent back to the aeration basin to maintain a high biomass concentration which is needed to achieve adequate treatment.

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Secondary Treatment

What happens to secondary sludge?

- The rest of the waste activated sludge - ***WAS*** is removed from the treatment system so the biomass concentration doesn't get too high.
- WAS is sometimes thickened before further processing.

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Secondary Treatment Water Quality

Parameter	Typical Concentration in Secondary Effluent[1,2] (mg/L)	Ontario Typical Effluent Compliance Limits[2,3] (mg/L)
Total Suspended Solids (TSS)	15	<25
Carbonaceous Biological Oxygen Demand ($CBOD_5$)	15	<25
Total Ammonia Nitrogen (TAN)	3	-
Total Phosphorus (TP)	<1	<1

1. These values are for conventional activated sludge with nitrification and phosphorus (P) removal, extended aeration with P removal and biological nutrient removal processes.
2. Design Guidelines for Sewage Works. 2008. Ministry of the Environment (MOE).
3. Ontario compliance limits are decided on a case by case basis. These values are for WPCP secondary treatment which is considered the normal level of treatment in Ontario.

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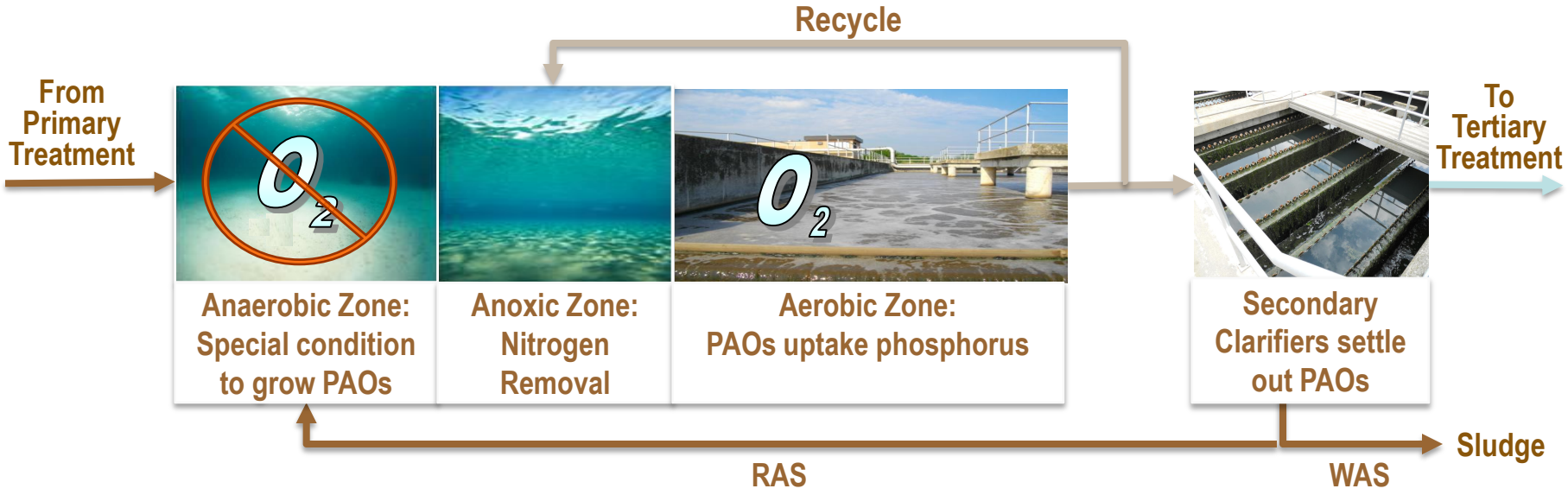
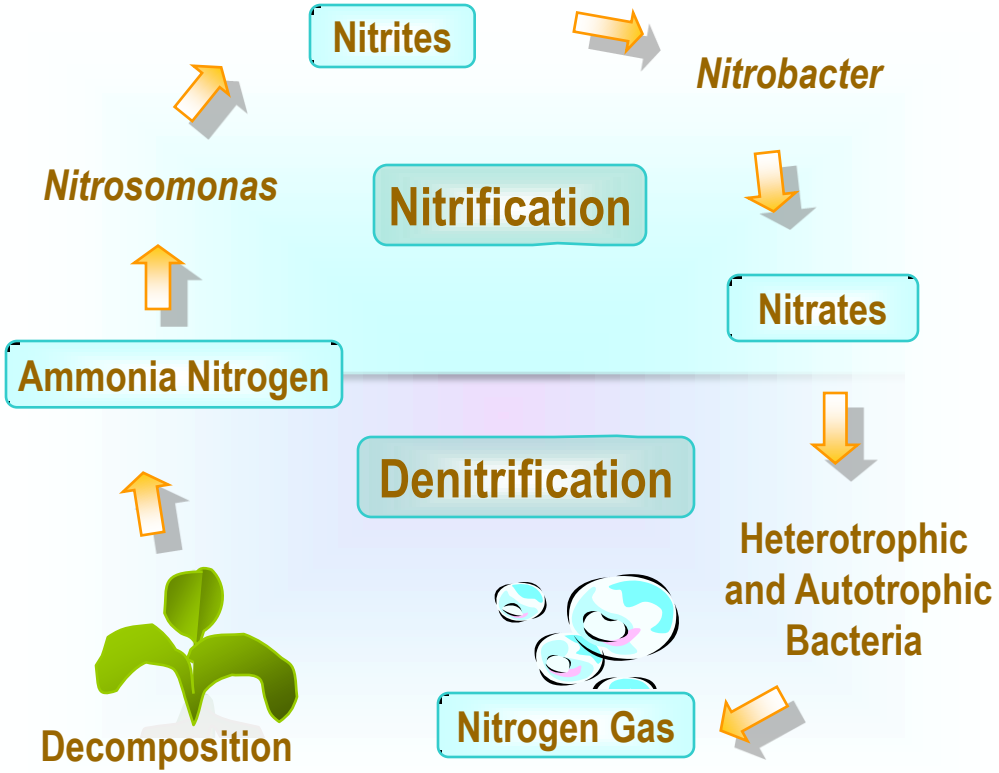
Secondary Treatment Phosphorus Removal

- About 10-30% of influent phosphorus is used by microorganisms during the breakdown of organic material. As in primary sedimentation, coagulants may be added to remove greater amounts of phosphorus.
- ***Enhanced biological phosphorus removal*** is an alternative to chemical addition. It involves the creation of special conditions that allow certain microorganisms known as Phosphorus Accumulating Organisms (PAOs) to grow more easily than others. These microorganisms can uptake 2.5 - 4 times more phosphorus than other microorganisms.



Secondary Treatment Nitrogen Removal

- Some nitrogen is taken up as a nutrient during the breakdown of organic material, but large amounts can only be removed by two processes called ***nitrification*** and ***denitrification***.



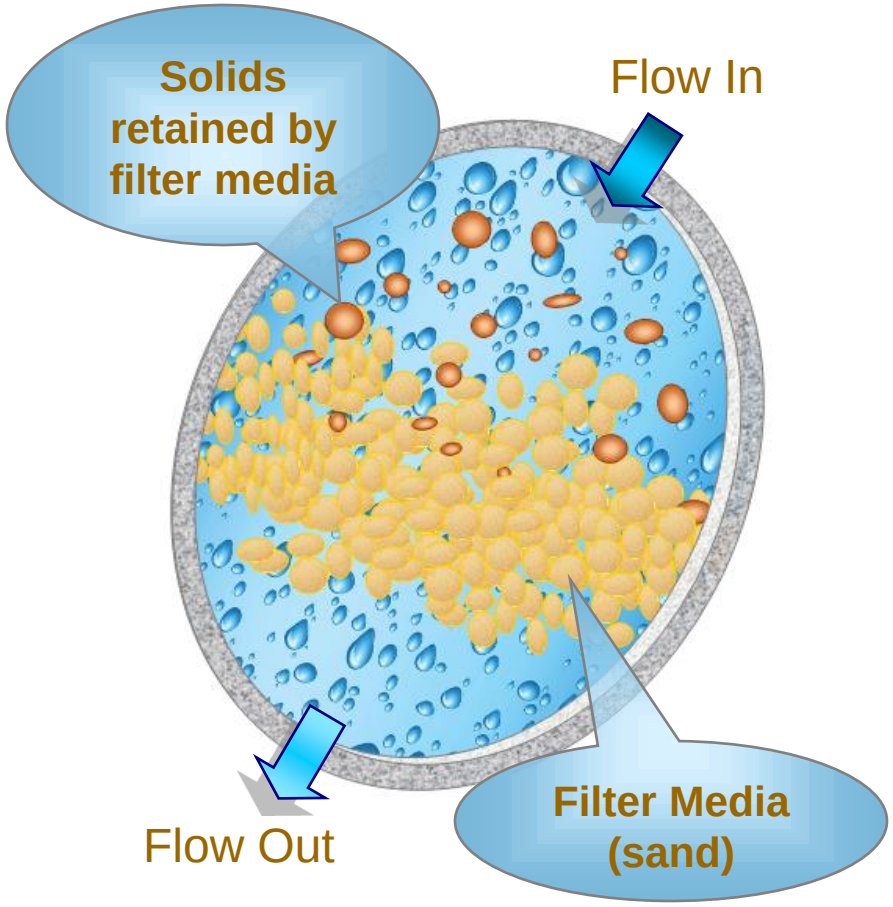
- The types of microorganisms responsible for nitrification and denitrification are different from those that remove organic material, and they are not always present in the treatment system.
- Special conditions can be created that will allow these microorganisms to grow.

Tertiary Treatment

- Removal of residual suspended solids following secondary treatment.
- Considered the third stage of wastewater treatment.

Tertiary Treatment

- Filtration is the most common method of tertiary treatment; it involves removal of remaining (residual) solids by passing the wastewater through a bed of granular media/material.
- Chemicals are added prior to filtration to convert soluble (dissolved) components, such as phosphate, to a solid (particulate) that can then be removed by filtration.



Tertiary Treatment Filtration

- After a while, solids build up in the filter media. To remove them, filtered water is forced backwards through the media. This process is called ***backwashing***.
- The backwash is recycled to an earlier stage in the treatment process.

- Wastewater enters the filter and flows through the filter media (usually sand).
- Solids, including organic material and particulate phosphorus, are caught in the sand. Filtered water moves on to the next stage of the treatment process.

Tertiary Treatment Water Quality

Parameter	Typical Concentration in Tertiary Effluent[1] (mg/L)	Ontario Typical Effluent Compliance Limits[1,2] (mg/L)
Total Suspended Solids (TSS)	5	<25
Carbonaceous Biological Oxygen Demand ($CBOD_5$)	5	<25
Total Phosphorus (TP)	0.1-0.3	<1

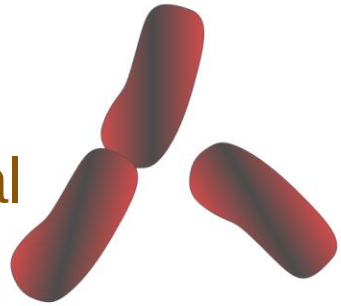
1. Design Guidelines for Sewage Works. 2008. Ministry of the Environment (MOE).
2. Ontario compliance limits are decided on a case by case basis. These values are for WPCP secondary treatment which is considered the normal level of treatment in Ontario.

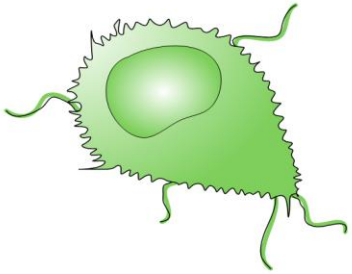
Disinfection

- Kills potentially infectious organisms, or makes them unable to reproduce or cause infection in humans.
- Depending on the level of treatment required, disinfection is provided as a part of either secondary or tertiary treatment.

Disease-Causing Organisms

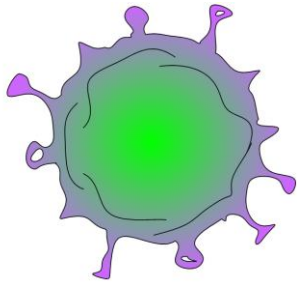
- Bacteria - Many types of bacteria are excreted in human feces and some, like *Salmonella* and *E. coli,* have the potential to cause disease.





- Protozoa - Disease-causing protozoa like *Cryptosporidium* and *Giardia* may be found in wastewater.

- Viruses - More than 100 different types of viruses capable of causing disease are excreted by humans.

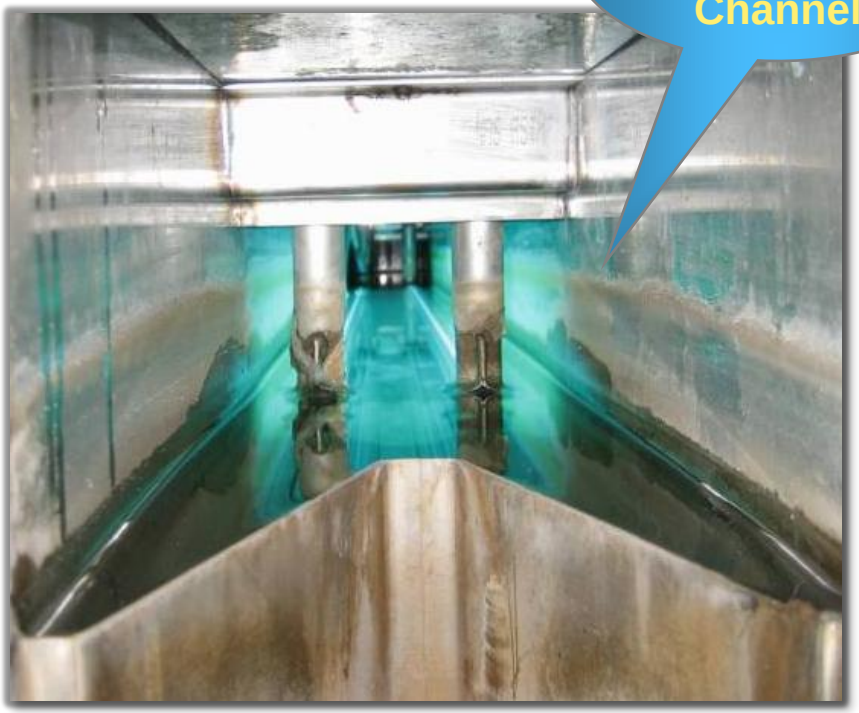


Disinfection Chlorination

- Chlorine may be applied as a gas (Cl_2) or a liquid (hypochlorite)
- Chlorine disinfects by damaging the cell envelope (or viral coat) and/or nucleic acids (DNA) of the organisms.
- Chlorine remaining after disinfection is usually removed by a process called ***dechlorination***.

Disinfection Ultraviolet (UV)

- Ultraviolet light inactivates microorganisms by damaging their nucleic acids.



Disinfection Ultraviolet (UV)

- UV lamps are filled with argon and mercury vapour, and covered with a clear sleeve for protection.
- The lamps are suspended in a channel through which wastewater flows, and the lamps are fully submerged.

Beyond Conventional Treatment…

Advanced/Quaternary Treatment

- Quaternary and sometimes tertiary treatment are classed as advanced treatment.
- Removal of dissolved and suspended materials remaining after conventional treatment stages.
- Advanced treatment is not always required.

Membrane Filtration

Reverse Osmosis

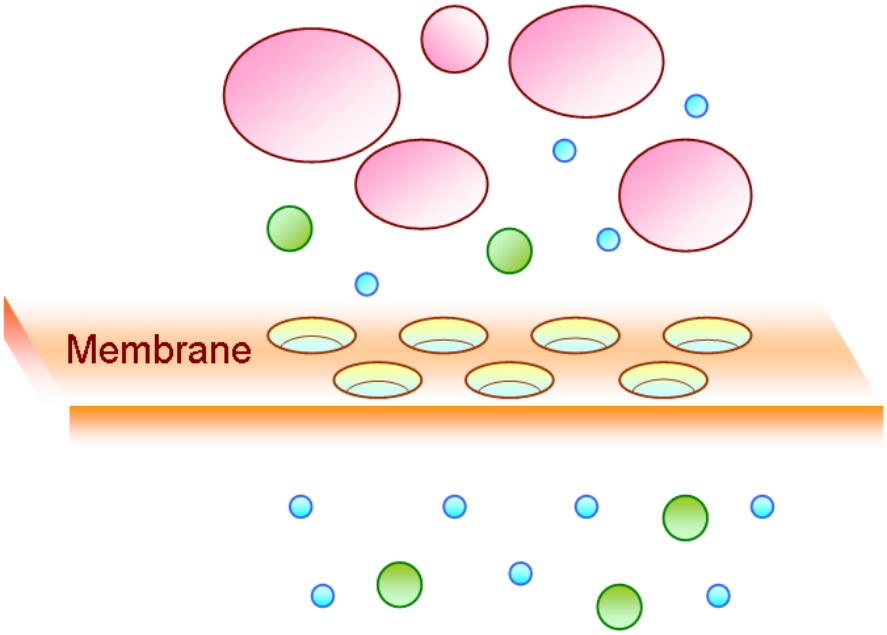
Advanced Treatment

- A wide variety of treatment technologies are available for removal of residual constituents in treated water.
- Technologies include membrane filtration and reverse osmosis.

NOTE: Tertiary treatment for removal of residual suspended solids may also be considered advanced treatment.

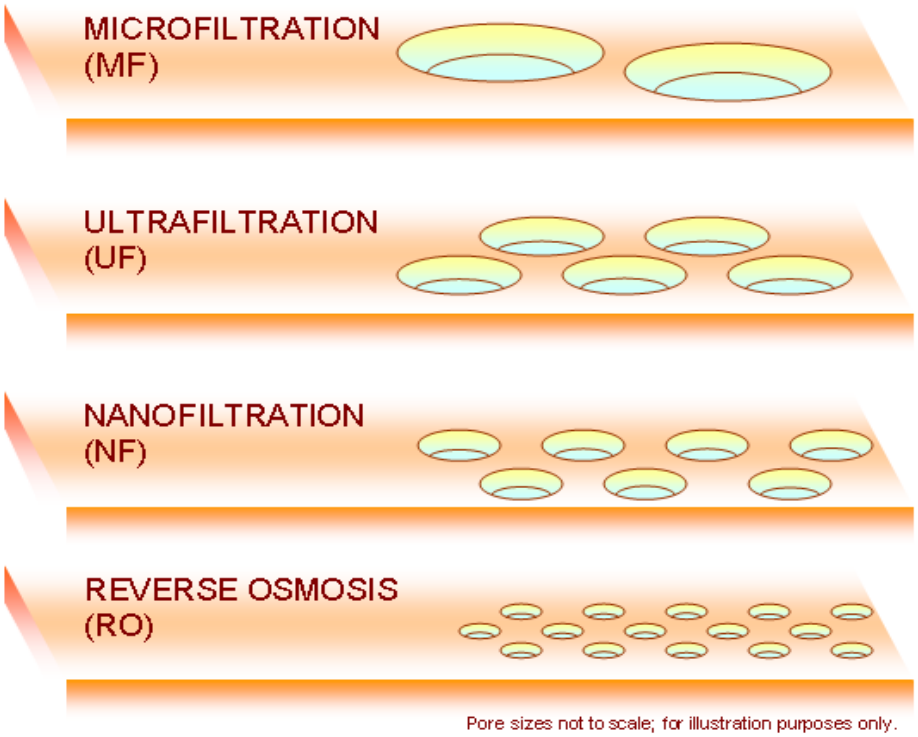
Advanced Treatment Membrane Filtration

- A membrane is a thin, ***semi-permeable*** layer of material.
- It has very small pores that stop some particles from passing through. Other particles, like water, are allowed to pass through the membrane.



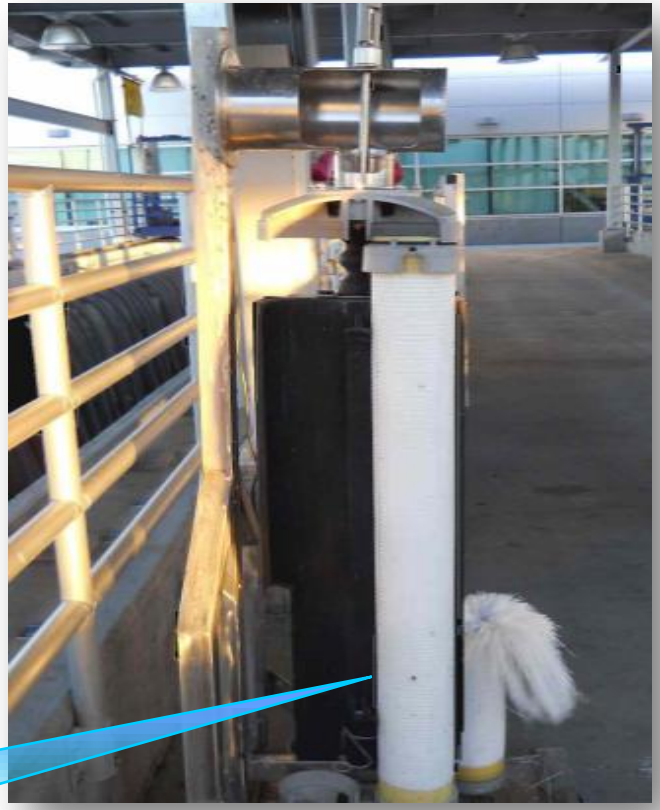
Advanced Treatment Membrane Filtration

- The constituents that are allowed to pass through the membrane depend on:
  - The size of the pores (barrier)
  - Applied pressure (hydrostatic)



Advanced Treatment Membrane Filtration

- Because membranes are so thin, they are usually attached to a thicker support structure.
- There are many different membrane configurations, including tubes, spirals, or flat sheets.



Microfiltration membrane

Advanced Treatment Membrane Filtration

- Membranes are cleaned frequently by ***backpulsing***.
- Occasionally, chemicals are used to remove build-up on the membrane.
- The concentrated reject captured by membrane filtration is often recycled to an earlier stage in the wastewater treatment process for another cycle of treatment.

Advanced Treatment Reverse Osmosis

- Reverse osmosis (RO) is a type of membrane filtration that allows the removal of very small molecules.
- Constituents are trapped on one side of the membrane while clean water is continuously forced through to the other side.

Reverse Osmosis membrane

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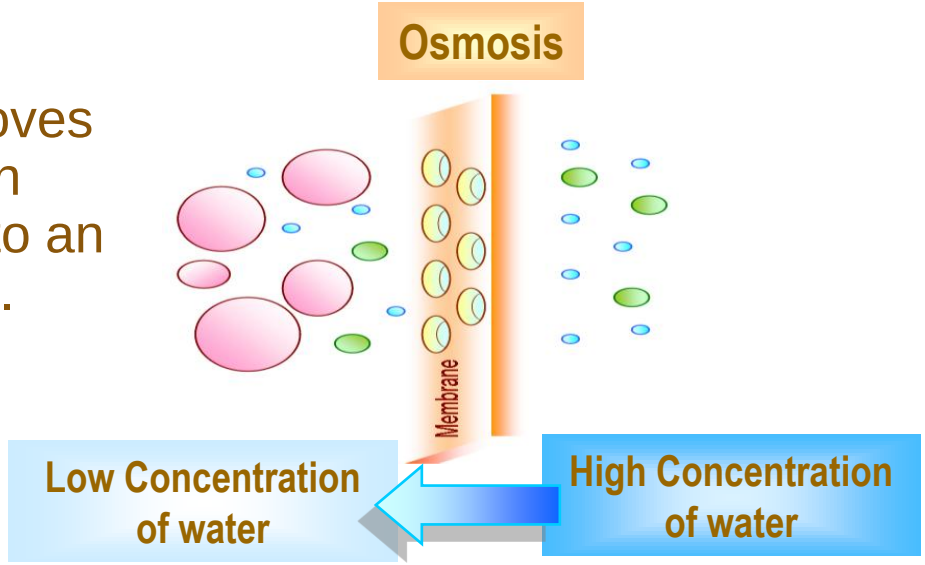
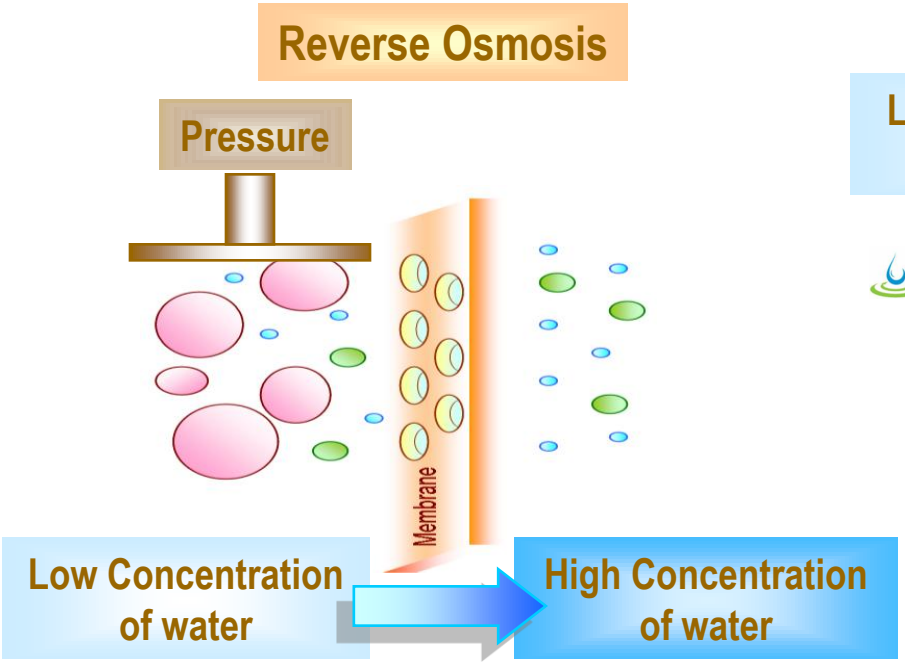
Advanced Treatment Reverse Osmosis Explained

- ***Osmosis*** is when water moves across a membrane from an area of high concentration to an area of lower concentration.

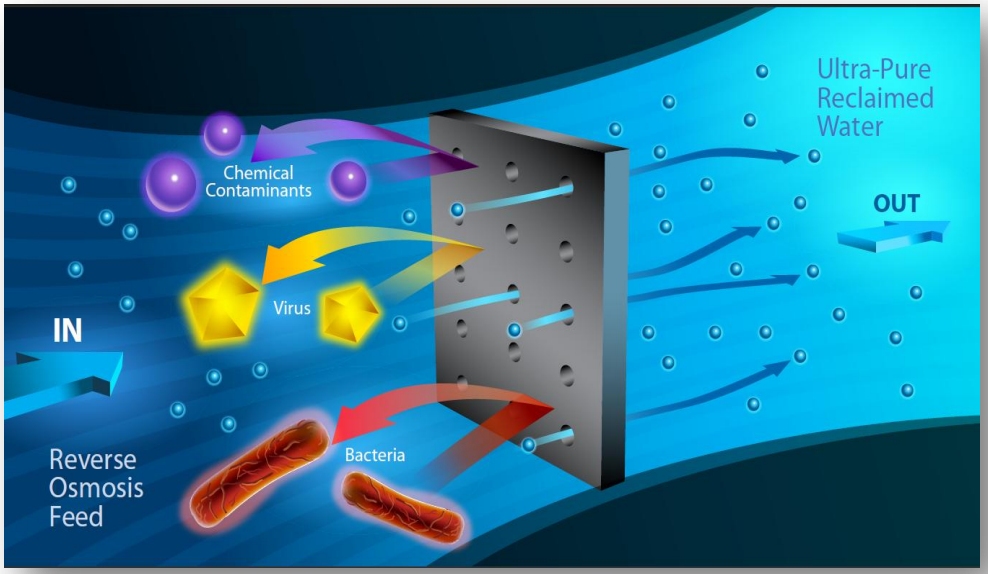




- In ***reverse osmosis***, water is forced across a membrane in the opposite direction, from an area of low concentration to an area of higher concentration.

Advanced Treatment Reverse Osmosis

- To protect reverse osmosis filters (much smaller pore size) from damage and excessive fouling, microfiltration is usually required before reverse osmosis.



- Reverse osmosis produces a high purity water that is suitable for applications such as groundwater recharge and industrial uses.

Advanced Treatment Water Quality

- Membrane filtration and reverse osmosis reduce constituents to very low levels; and remove many constituents not removed during conventional treatment.

Parameter	MF Effluent[1] (% Reduction)	RO Effluent[1] (% Reduction)
Total Suspended Solids (TSS)	95 – 98%	95 – 100%
Biological Oxygen Demand (BOD)	70 – 95%	30 – 60%
Ammonia as Nitrogen (NH_3-N)	5 – 15%	90 – 98%
Nitrates as Nitrogen (NO_3-N)	0 – 2%	65 – 85%
Phosphates (PO_4^-)	0 – 2%	95 – 99%

1. **Metcalf & Eddy (2003). *Wastewater Engineering: Treatment and Reuse, 4th Edition.***

Sludge Processing

Handling & Managing the Solids

- Includes a number of treatment steps that may be used alone or in combination to prepare wastewater sludge for reuse or disposal.

What is Sludge?

Protect our Environment!

- Sludge is solid material removed from primary sedimentation tanks and secondary clarifiers.
- Other sludge components may include chemical precipitates and backwash solids from tertiary filters or other processes.

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Sludge Processing Thickening

Raw sludge is usually more than 95% water!

Sludge Thickeners

- Thickening the sludge:
  - Reduces water
  - Reduces volume to be processed
  - Occurs with and without chemical addition
  - Increases sludge solids concentration from 3% to 8%

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Sludge Processing Stabilization

- ***Stabilization*** – process that reduces pathogens and sludge odours.
- ***Biosolids*** are Stabilized sludge.
- Biological stabilization is called ***digestion***.

Sludge Processing Stabilization

- ***Aerobic digestion*** is a suspended growth process with oxygen present for stabilization.

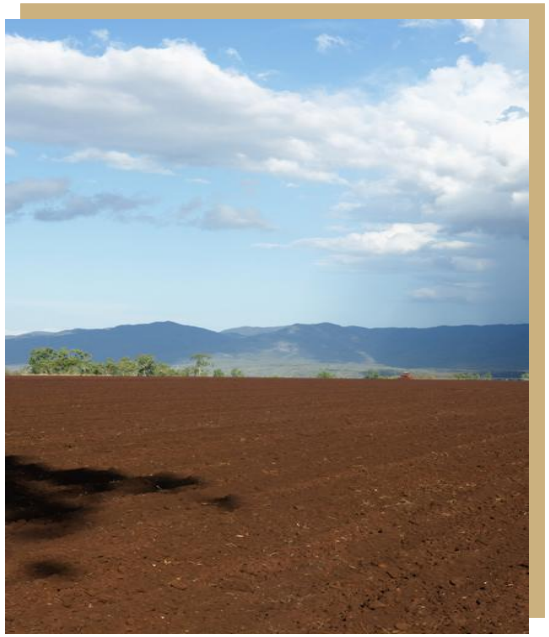
- ***Anaerobic digestion*** involves the decomposition of organic and inorganic matter in the absence of oxygen.

Sludge Processing Dewatering

- Biosolids dewatering reduces the water content of biosolids to the 20 to 30% range.
- At this dryness level, it is often called Sludge Cake.

Sludge Processing Biosolids

- In Ontario, utilization of biosolids in land as a nutrient is common. This is a beneficial reuse practice.
- Biosolids are incorporated into the soil. Available nutrients are taken up by plants for growth.
- If land application is not possible, biosolids may be disposed of in a landfill, composted or incinerated.
- Further processes exist to convert biosolids to a marketable fertilizer.



Thank You for Visiting !

York Region