ES 200 ENVIRONMENTAL STUDIES

Module-C

Anthropogenic effects on ecosystem, water quality & health, water & wastewater treatment

Lecture-5

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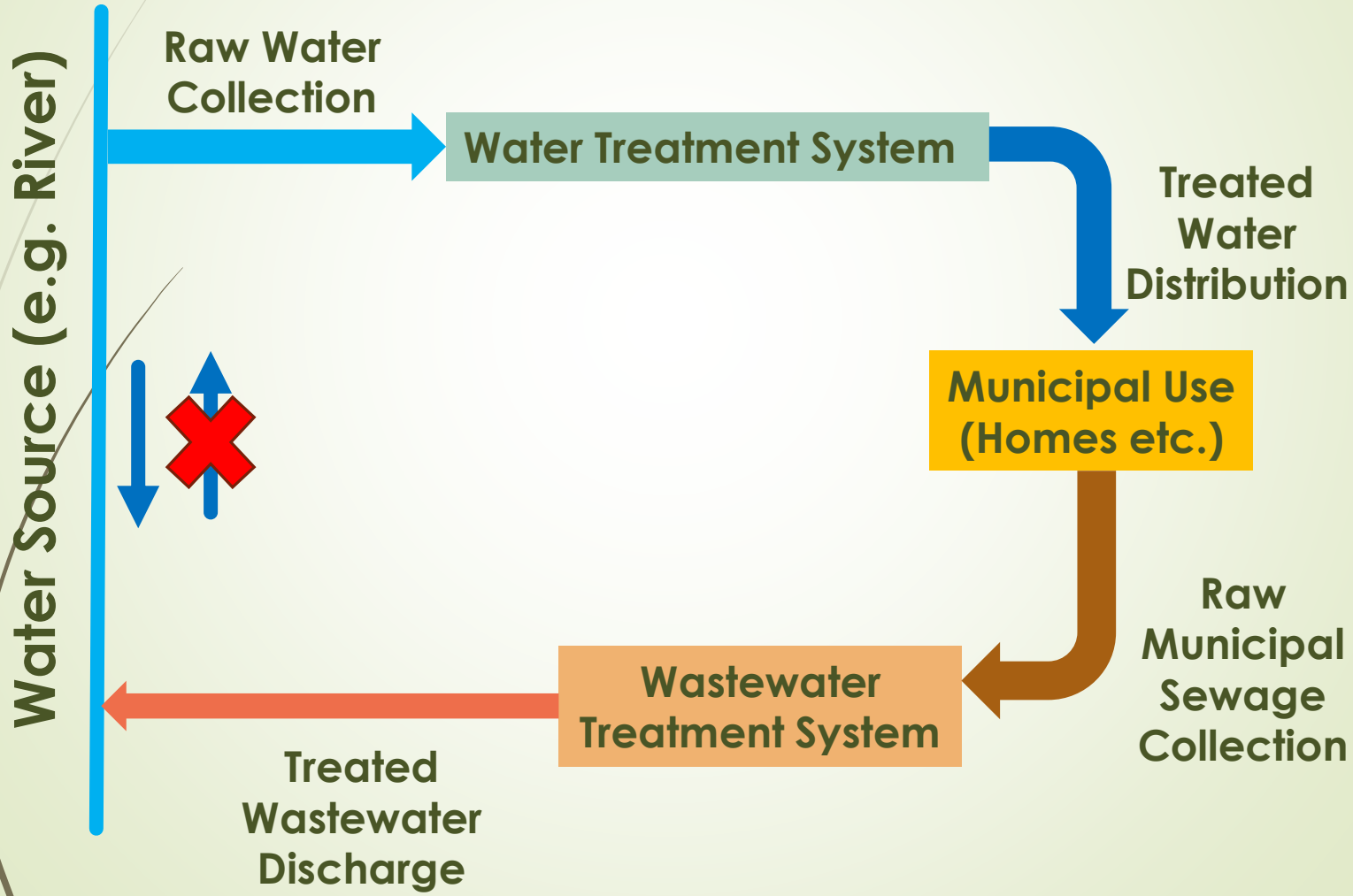
Learning Objectives

Conventional Surface Water Treatment System

- Water collection, treatment, and distribution

Typical Water Use Pattern



Municipal Water Treatment

- **The purpose of municipal water treatment is to bring raw water up to potable water quality.**
- **Most of the raw water sources are either surface water (rivers, lakes) or groundwater.**
- **Depending on the source, characteristics of the raw water vary and so do the treatment options.**

Reading Assignment

What are the major differences in the quality of surface water and groundwater?

Municipal Surface Water Treatment

Characteristic pollutants in raw surface water

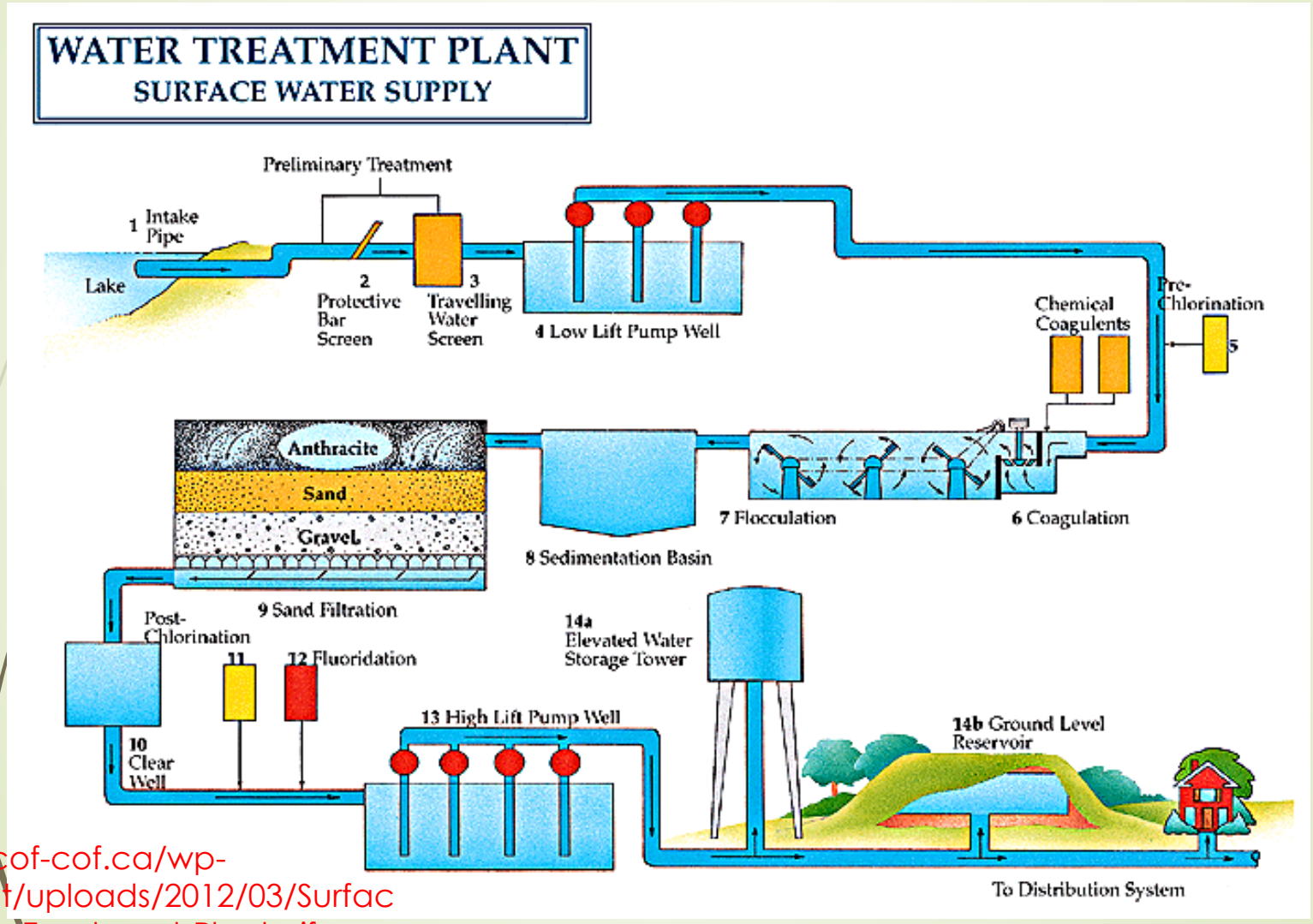
- Large floating matter (e.g. leaves, plastic etc.)
- Dissolved and suspended solids/particles (organic and inorganic)
- Biological agents (e.g. pathogens)

Municipal Surface Water Treatment

Unit Processes

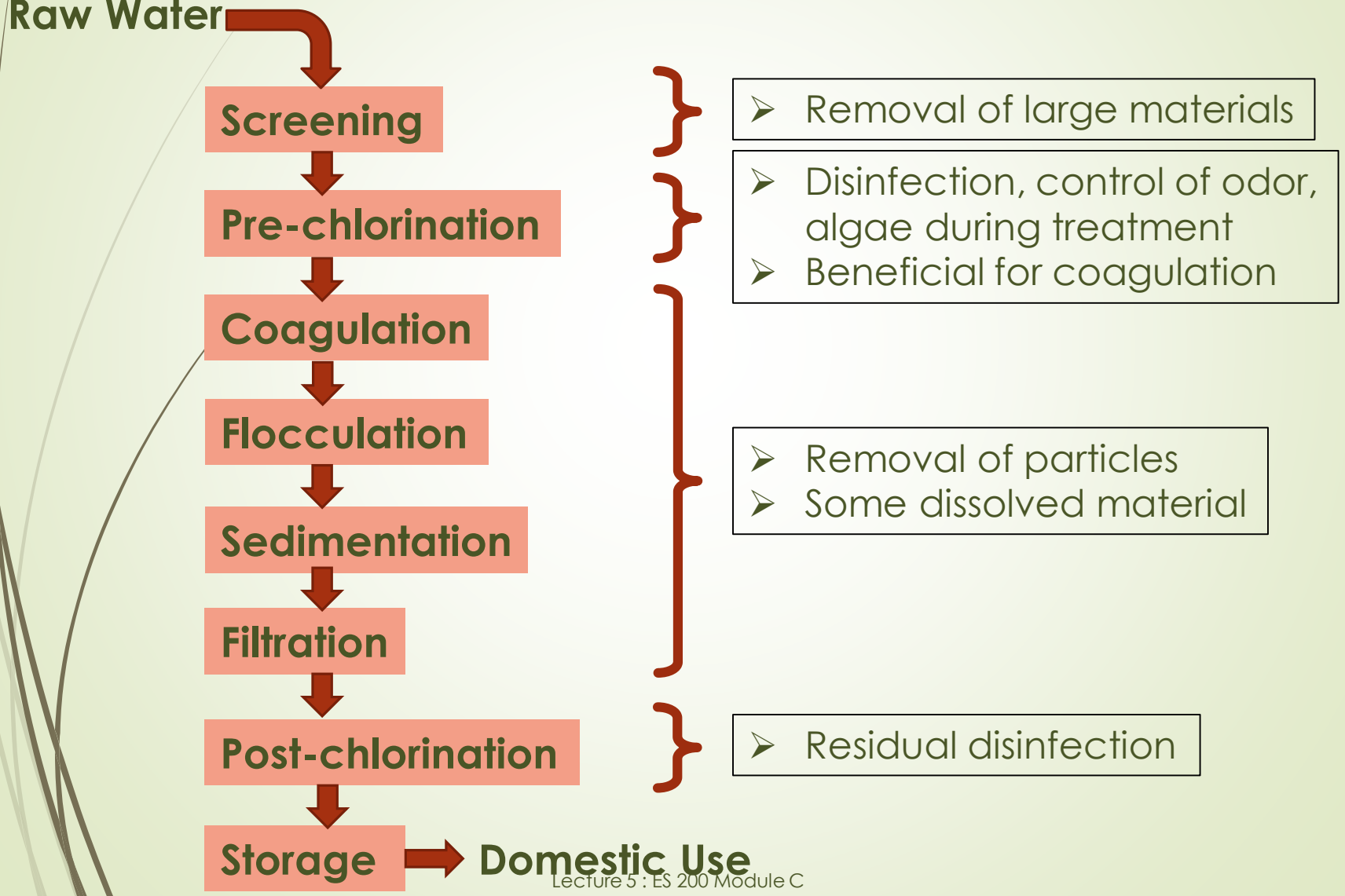
- As the pollutants differ widely in their properties, a single treatment process is not feasible/efficient for all of them.
- Multiple unit processes targeted for some specific pollutant/group of pollutants are designed and used.
- A sequential operation of these unit processes is called as the treatment train, and which results in comprehensive treatment of the water.

Municipal Surface Water Treatment



http://cof-cof.ca/wp-content/uploads/2012/03/Surface-Water-Treatment-Plant.gif

Municipal Surface Water Treatment



Municipal Surface Water Treatment

Screening

- **Removes large solids**
  - Logs
  - Branches
  - Rags
  - Fish
- **Simple process**
  - Trash removal can be manual or mechanized
- **Protects pumps and pipes in WTP**

https://webpages.uidaho.edu/larc380/new380/assets/images/waterTreatment/images/CC/BarScreenFrankVincentzCC-BY-SA-3jpg.jpg

Municipal Surface Water Treatment

Coagulation – Flocculation – Sedimentation

- Smaller particles still remain in the water, which need to be removed.
- Basic and oldest mechanism for their removal is gravitational settling (or sedimentation) as per Stokes' Law.
- However, some particles are either too small to settle, or have some electrostatic charge (e.g. dust/soil particles are in general negatively charged) due to which they repel each other and do not settle efficiently **(called as Colloids)**.
- One basic process to remove such particles is by some how bringing them together, so as to increase their effective size (and thus weight) leading to better settling properties.
- It requires the understanding of **particle-particle interactions**.

Municipal Surface Water Treatment

Coagulation – Flocculation – Sedimentation

Particle-Particle Interaction

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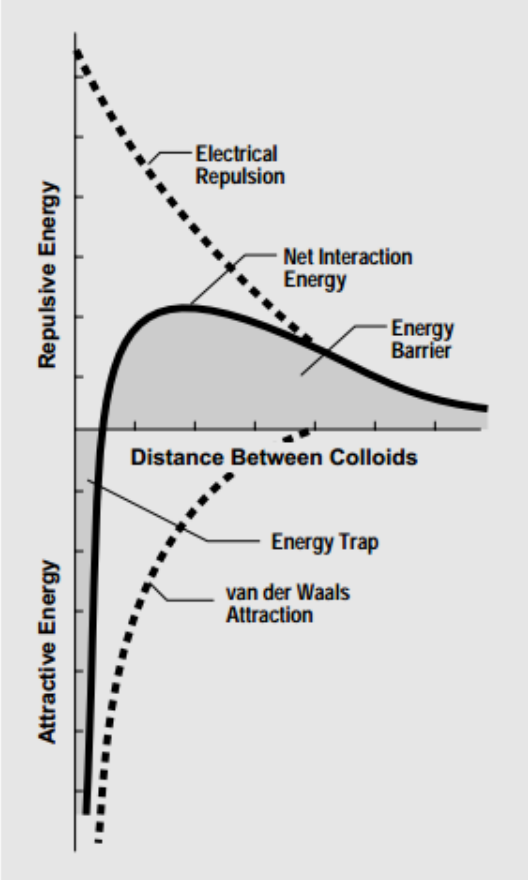


An **Energy Barrier** is to be crossed if two particles in a colloid are to come together.

- ✓ Increase the energy of the particles *(e.g. increase the temperature or stirring etc.)*
- ✓ Lower the Energy Barrier *(e.g. remove the charges on particles, add particles with opposite charges etc.)* Destabilizing the particles

Municipal Surface Water Treatment

Coagulation – Flocculation – Sedimentation

Coagulation is the process of destabilizing the particles.

- Change the property of Media so that repulsion does not start even when particles are brought much closer (reduce the thickness of counter ions)
- Change the properties of Particles so that their charges are neutralized (reduce the overall repulsion)
- Provide external bridges (e.g. precipitates) to connect the far located particles

Municipal Surface Water Treatment

Coagulation – Flocculation – Sedimentation

Some common coagulants:

Alum [$Al_2(SO_4)_3 \cdot 18H_2O$]

$FeCl_3$

These coagulants can either produce active species that neutralize the charge on the particles (e.g. $Al(OH)_2^+$, $AlOH^{2+}$ etc.) or produce flocs (e.g. $Al(OH)_3$) that entrap the colloid particles.

Coagulation requires very rapid mixing of coagulants with the particles for short duration (1-2 minutes)

Municipal Surface Water Treatment

Coagulation – Flocculation – Sedimentation

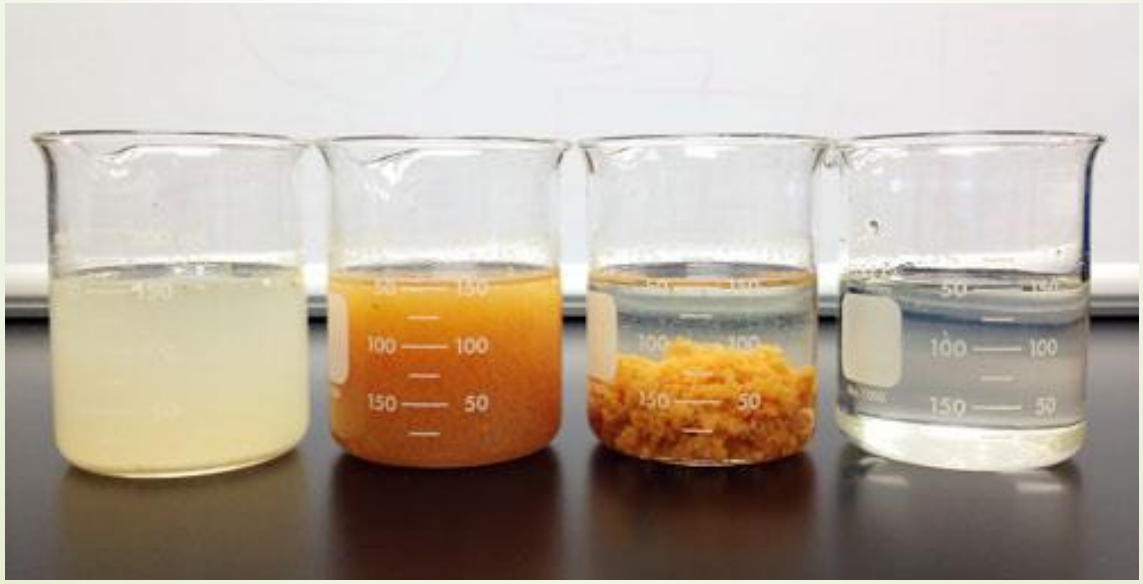
Flocculation is the process of getting the destabilized particles to collide with each other so that they could form flocs (or larger/heavier particles).

- Require some relative motion between particles
- Gentle mixing for long time (1 – 2 hours)

Municipal Surface Water Treatment

Coagulation – Flocculation – Sedimentation

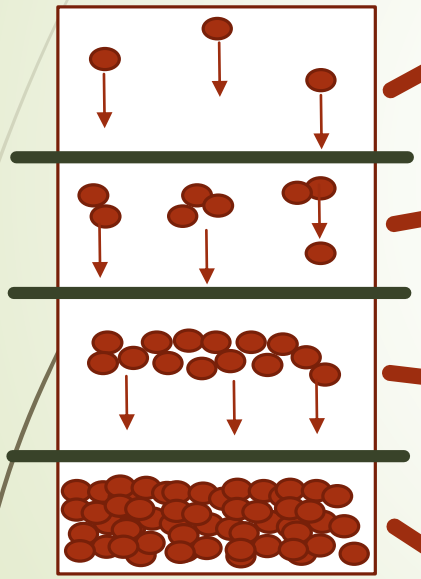
Once sufficiently large flocs are formed, they are allowed to settle by gravity. The process is called as sedimentation or settling.



http://www.ecologixsystems.com/images/chemical-jar-tests.jpg

Municipal Surface Water Treatment

Coagulation – Flocculation – Sedimentation



Type I: *Discrete particle settling* - Particles settle individually without interaction with neighbouring particles.

Type II: *Flocculent particles settling* – Flocculation causes the particles to increase in mass and settle at a faster rate.

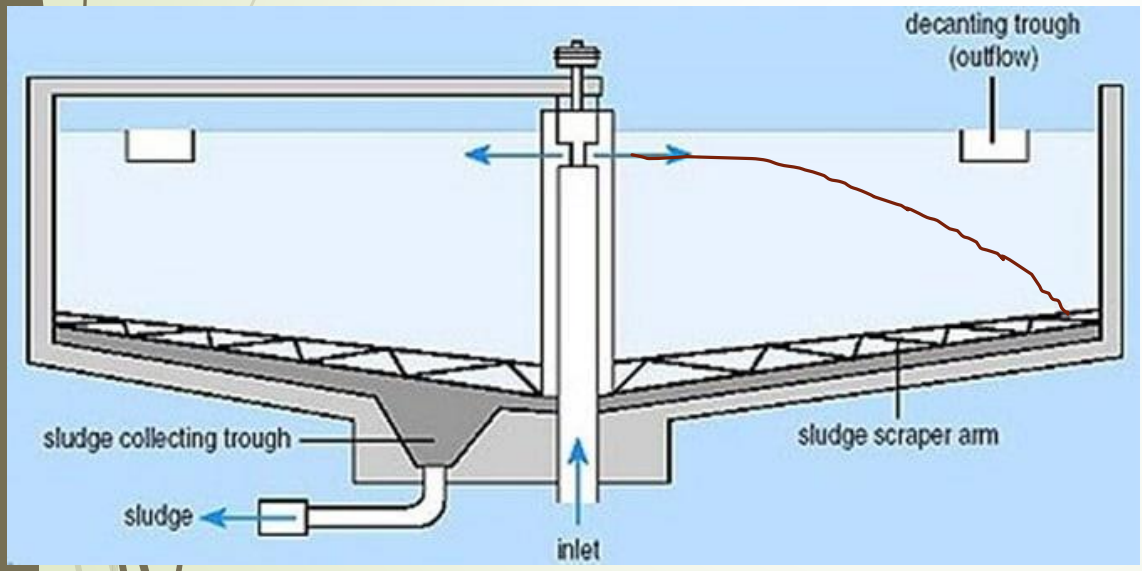
Type III: *Hindered or Zone settling* –The mass of particles tends to settle as a unit with individual particles remaining in fixed positions with respect to each other.

Type IV: *Compression settling* – The concentration of particles is so high that sedimentation can only occur through compaction of the structure.

Municipal Surface Water Treatment

Coagulation – Flocculation – Sedimentation

Municipal Surface Water Treatment: Discrete Settling



https://theconstructor.org/wp-content/uploads/2016/12/types-of-sedimentation-tank.jpg

- Stokes Law
- Circular or Rectangular Channel

https://ak2.picdn.net/shutterstock/videos/4148686/thumb/1.jpg?i10c=img.resize(height:160)

Municipal Surface Water Treatment

Filtration: Rapid Sand Filter

Some flocs still resist settling

	Size (mm)	Depth (cm)
Water		
Anthracite	0.70	30
Sand	0.45-0.55	45
Gravel	5-60	45

Depth can vary depending on various factors

Municipal Surface Water Treatment

Filtration: Rapid Sand Filter

- Removes the flocs that resist settling
- Filtration due to **Mechanical Straining** and **Adsorption**
- Effluent ~ 0.5 NTU
- Requires frequent backwashing (with treated water) as huge head loss is encountered after ~12 hours of operation

Reading Assignment
What is Slow Sand Filtration?

Municipal Surface Water Treatment

Disinfection by Chlorination

- **Primary disinfection:** To kill any pathogens in the water
- **Secondary (or Residual) disinfection:** To prevent pathogen regrowth in the water during the period before use

Free Chlorine Disinfection

$$Cl_{2(aq)} + H_2O \rightarrow \mathbf{HOCl} + H^+ + Cl^-$$
$$\mathbf{HOCl} \rightarrow \mathbf{OCl^-} + H^+$$

HOCl : Hypochlorous acid
OCl^- : Hypochlorite Ion

Municipal Surface Water Treatment

Disinfection by Chlorination

- Free chlorine oxidizes the bacterial cell, thus killing them.
- Free available residual chlorine: [HOCl] + [OCl^-] helps in residual disinfection; however they have short life time in water.
- Ammonia is added to react with free chlorine and form chloramines (NH_2Cl, $NHCl_2$, and NCl_3).
- Chloramines are less effective oxidants, but more persistent in water, and thus can provide residual disinfection in distribution systems for longer durations.
- Problem with chlorination occurs due to the formation of Disinfection byproducts (DBPs), many of which are carcinogenic.

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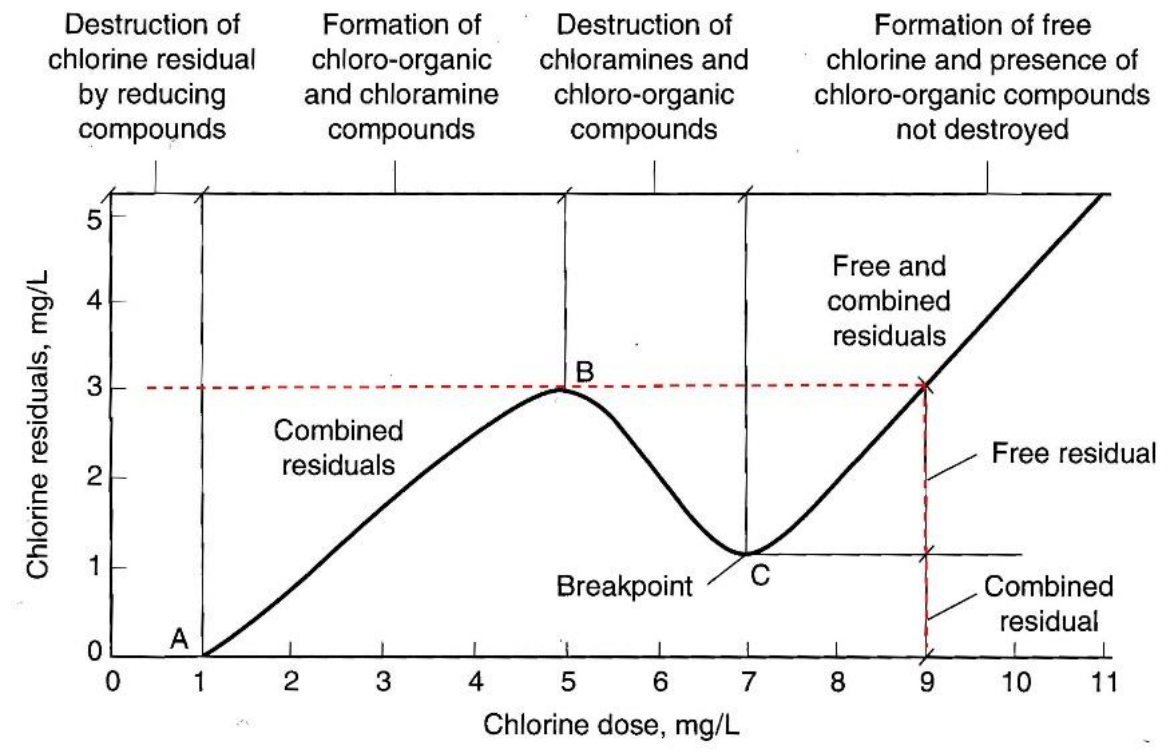
Disinfection by Chlorination

Free Chlorine Disinfection: Break Point Chlorination



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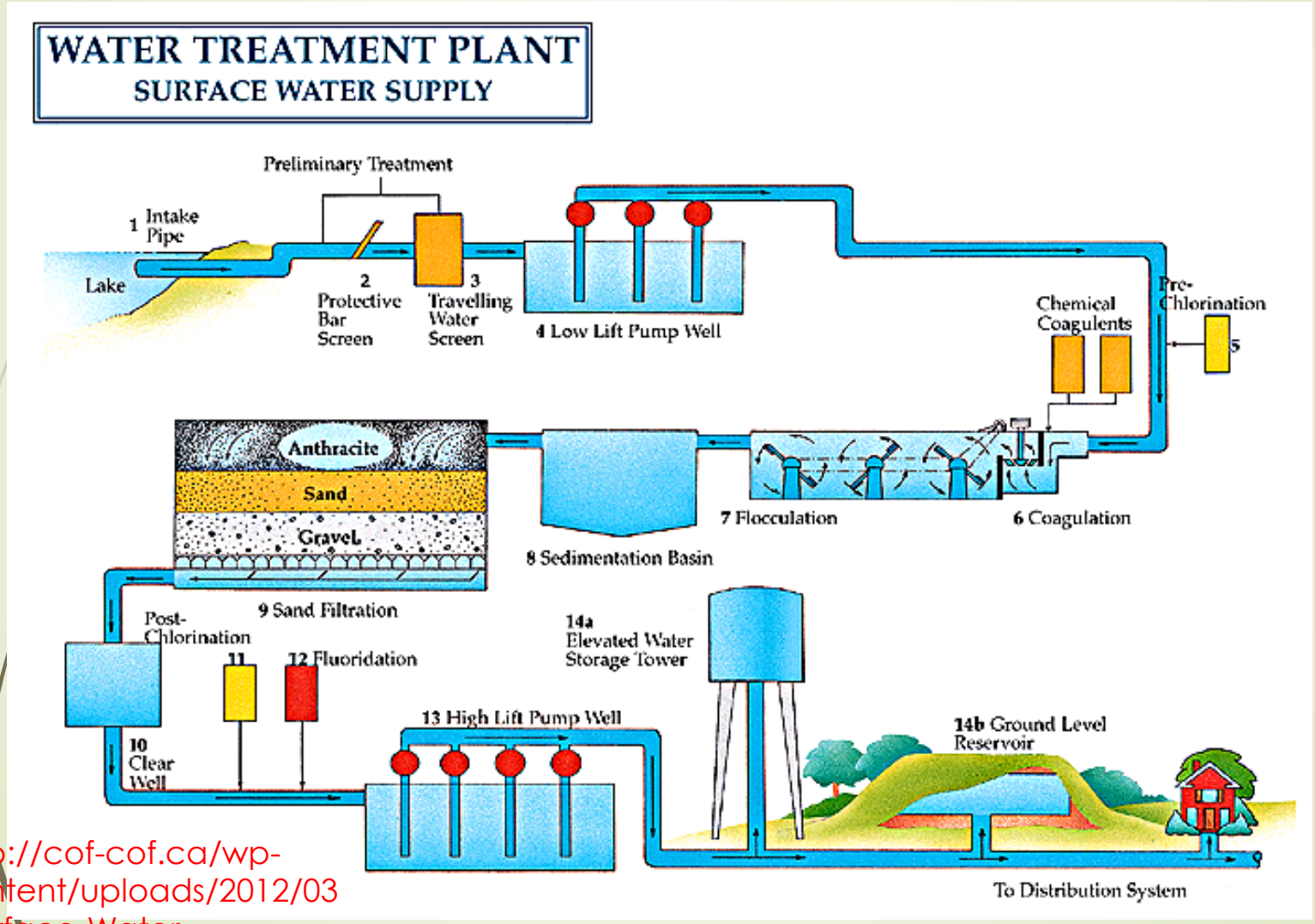
Municipal Surface Water Treatment



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Next Lecture:

Conventional Municipal Wastewater Treatment System