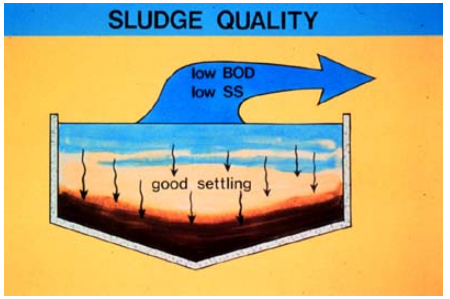



# ENVE 422
# TREATMENT AND DISPOSAL OF WATER AND WASTEWATER
# SLUDGE


**Prof.Dr. F.Dilek SANİN**

# SLUDGE CONDITIONING

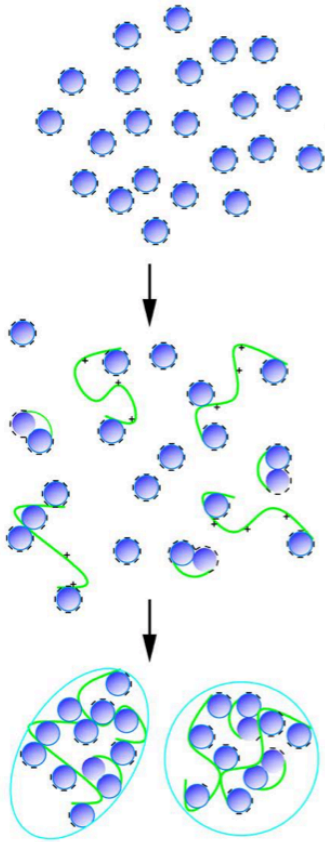
Conditioning is a chemical, physical or thermal process used to improve the efficiency of thickening or dewatering operations. The improvements of sludge properties upon conditioning are in:

- Increased thickening and dewatering,
- Increased sterilization with some systems,
- Odor control.

Note: Conditioning does not reduce the water content of solids; it alters the physical properties of solids to help the release of water during thickening and dewatering. Mechanical thickening and dewatering would not be economical without solids conditioning beforehand.

# TYPES OF CONDITIONING

- Chemical
  - Inorganic coagulants
  - Organic polymers
- Thermal
  - Heating
  - Freeze/thaw process
- Physical
  - Ash from thermic power plants or incinerators
  - Elutriation



## FACTORS AFFECTING CONDITIONING

- Source of sludge
- Solids concentration
- Particle size and distribution
- pH and alkalinity
- Surface charge and degree of hydration
- Other physical factors

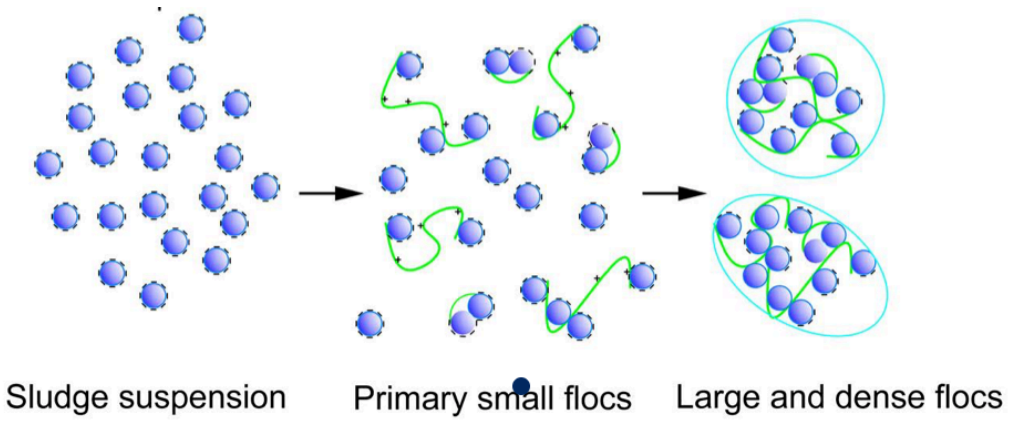
## Chemical Conditioning

Types of chemicals used

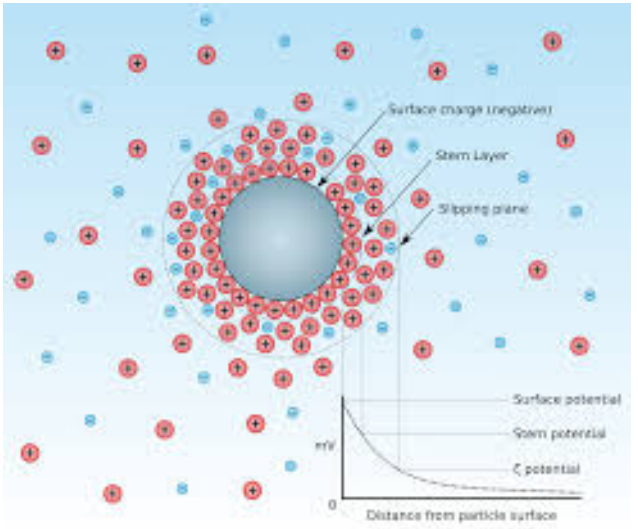
- Inorganic coagulants (such as alum, iron compounds, lime)
- Organic polymers (polyelectrolytes)

Two mechanisms are behind the chemical conditioning

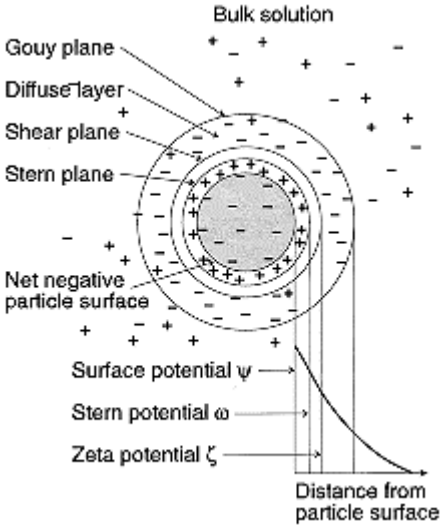
- Charge neutralization, and
- Bridging of the particles



**Charge Neutralization:** Most particles including **bacteria**, or **other colloids** as well as sludge flocs are all negatively charged on the surface. So they will collect a layer of **positive charges** around them when they are suspended in an **ionic medium**.




The concentration of these positive ions will decrease as we go away from the particle surface. This phenomenon will form a region around the particle of varying ionic concentration. If we were to plot potential versus the distance from the surface the potential will decrease as we move away from the surface.



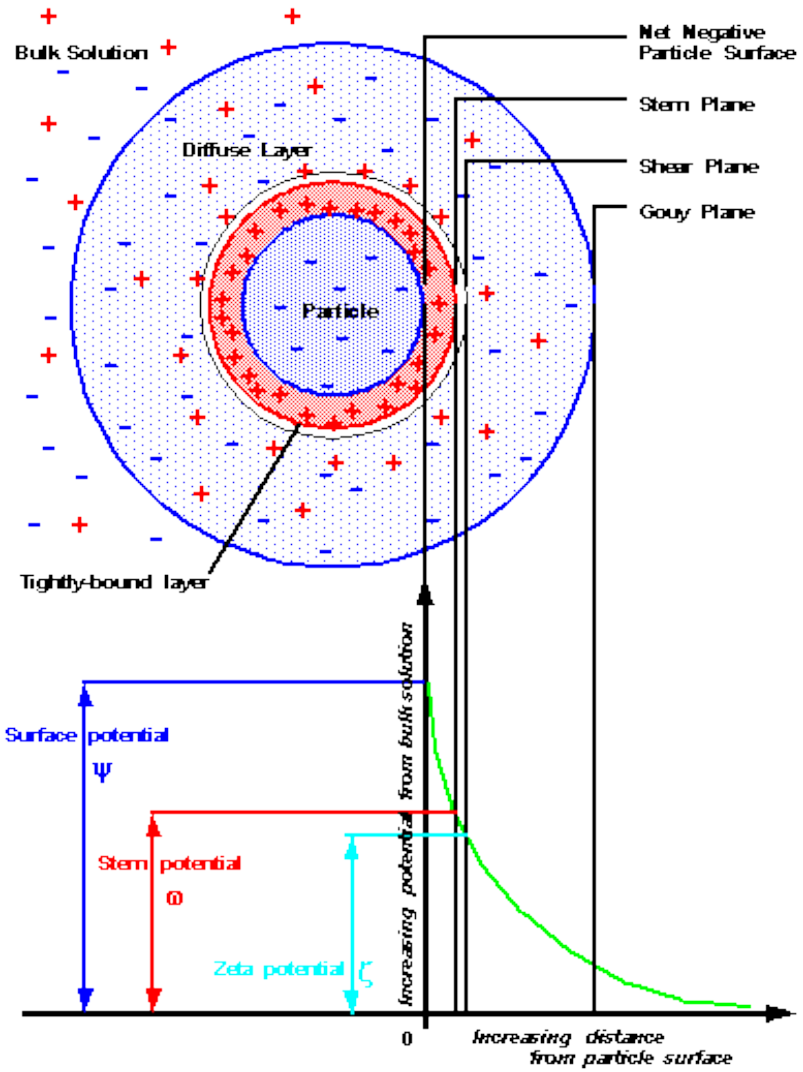
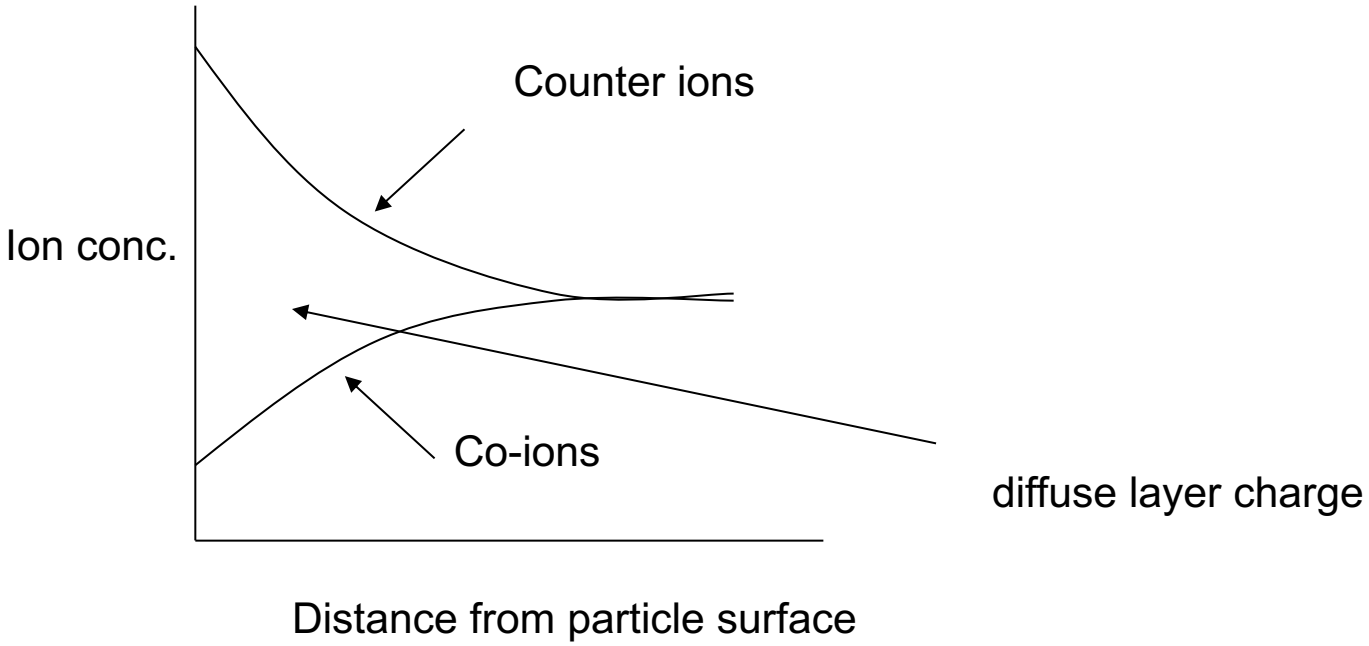



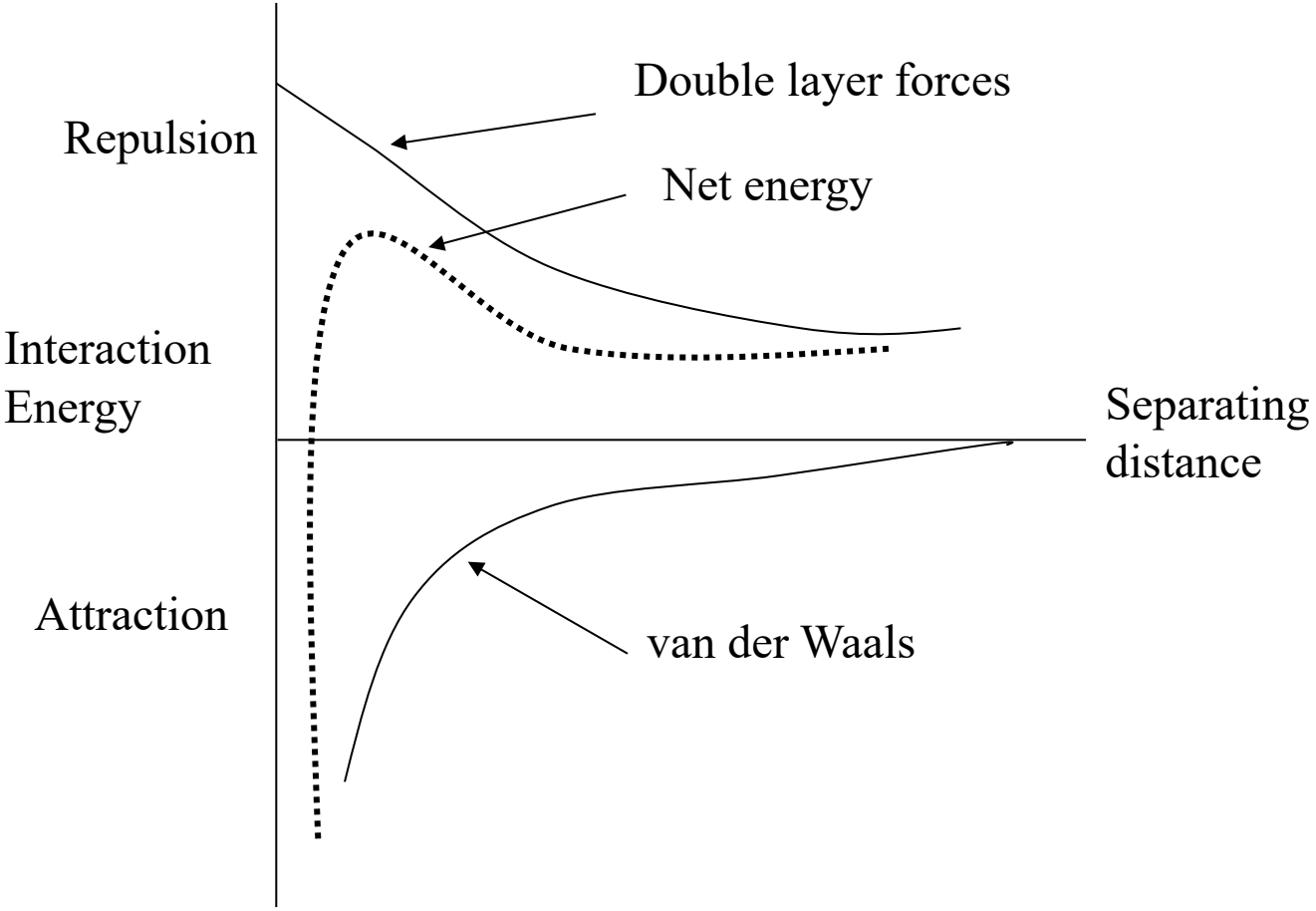

*Figure 1: Double layer model of a particle suspended in water.*

**Electrical Potential** is like the electrical pressure that must be applied to bring a unit charge of the same sign as the primary particle to within a given distance from the particle surface.

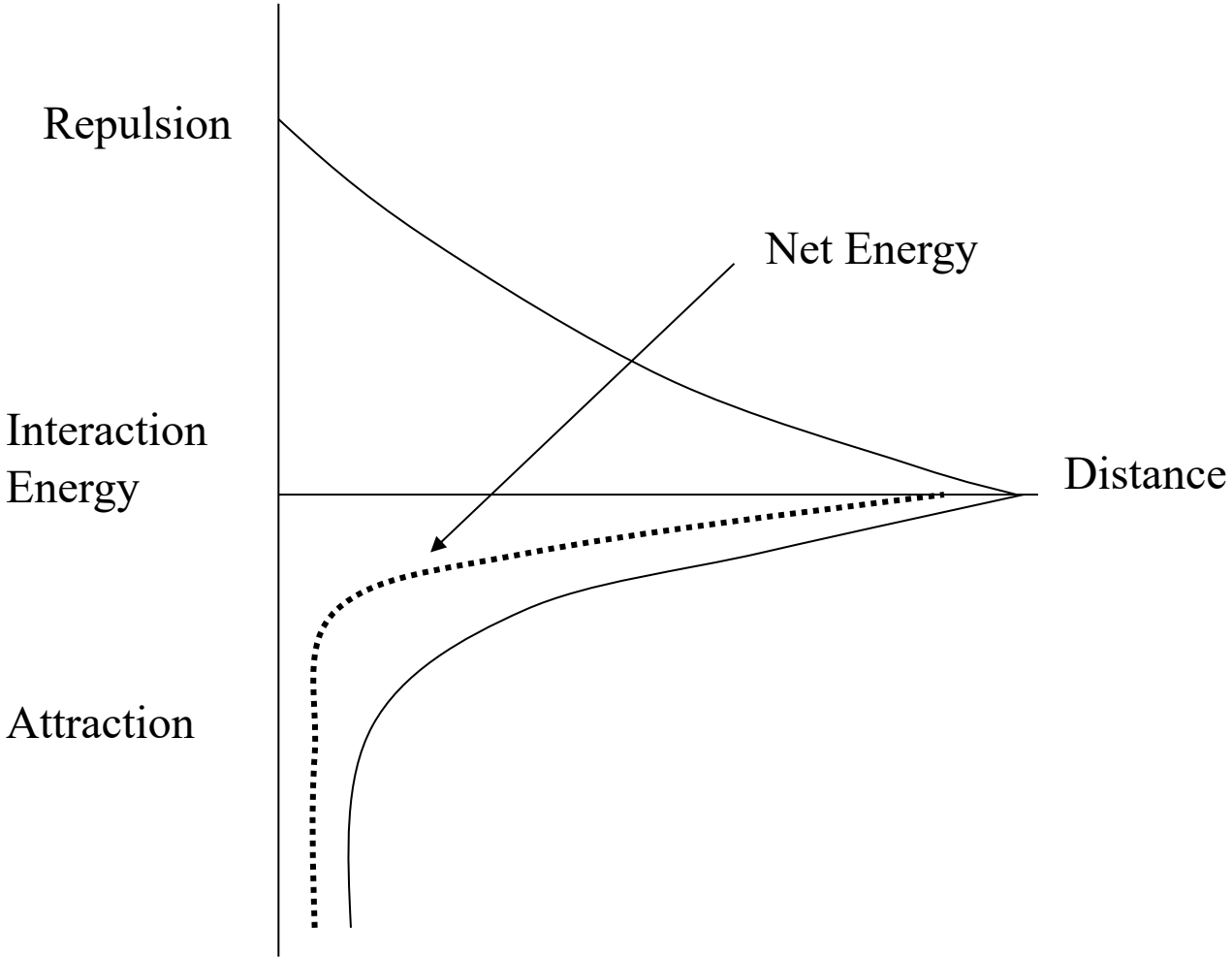
If we look at the variation of concentration of ions with distance:



# Interaction energy graph before conditioning



# Interaction energy graph after conditioning



## Inorganic Chemical Conditioners

- Most commonly used ones are aluminum (III) and iron (III) species. The initial belief was that when aluminum (III) or iron (III) is added to the solution, they go to the surface of the negatively charged particles and be attracted there and help neutralizing the charges via this mechanism.
- This is only in part true. Because these ions in water form complexes rather than staying as Al(III) or Fe(III). The complexes are like $Fe(H_2O)_6^{3+}$ or $Al(H_2O)_6^{3+}$. If the Fe(III) and Al(III) concentration exceeds the solubility limit of these salts, then a precipitate will form such as $Fe(OH)_3$ or $Al(OH)_3$.

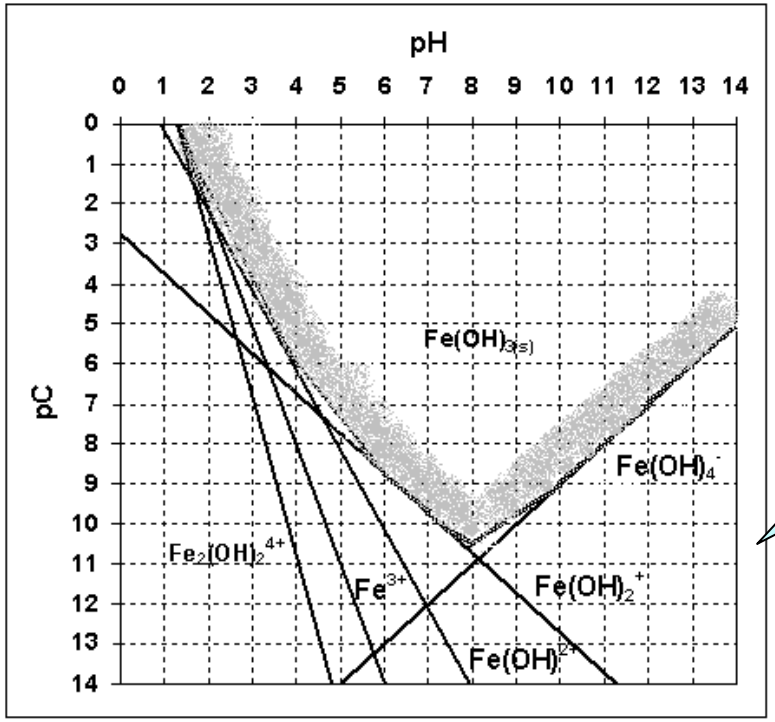
- Between the $Fe(H_2O)_6^{3+}$ and $Al(H_2O)_6^{3+}$ complexes, and their insoluble precipitate ($Fe(OH)_3$ and $Al(OH)_3$) formation, there are a variety of polymers formed, these polymers act as the destabilizing agents, go adsorb to the particle surfaces and neutralize the charges and also can act as bridges.

$$Fe(H_2O)_6^{3+} + H_2O \rightarrow Fe(H_2O)_5(OH)^{2+} + H_3O^+$$

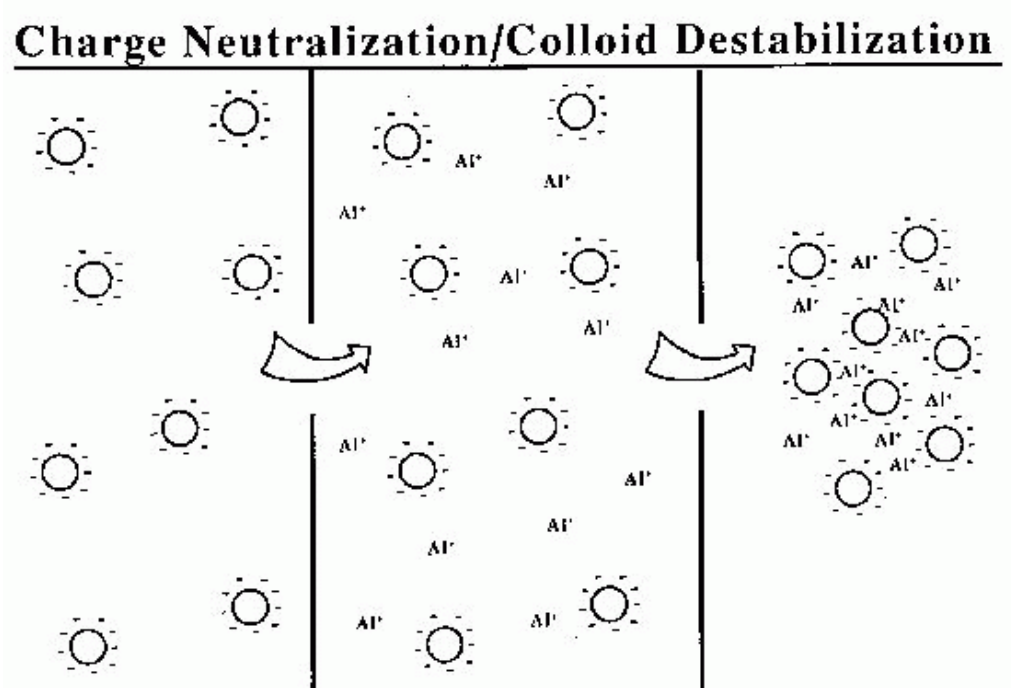
$$Fe(H_2O)_5(OH)^{2+} + H_2O \rightarrow Fe(H_2O)_4(OH)^{+} + H_3O^+$$

.
.
.

Once the solubility limit is exceeded, $Fe(OH)_3$ and $Al(OH)_3$ are formed, these insoluble species are soluble at both high and low pH values. So it is important to adjust the pH range where they are minimum soluble. These insoluble species also help to bring the particles of sludge together in a big floc network.



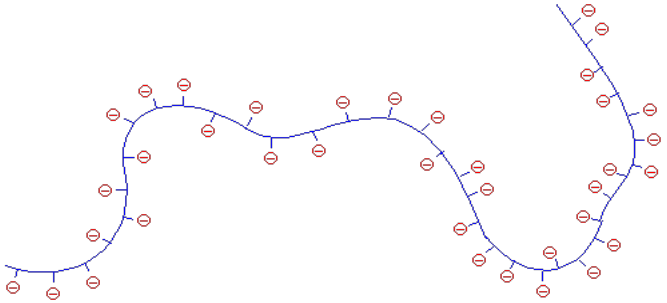

Do you remember this graph from earlier courses? ENVE 102 was one of them and we learned how to plot this graph.




Conditioning with only **charge neutralization**, works well with clay suspensions and for some inorganic sludges. However, it is not enough for organic sludges. For these sludges, flocculation with polymers using the **bridging mechanism** is necessary for the formation of large flocs.

# Organic Chemical Conditioners – Polymers/Polyelectrolytes

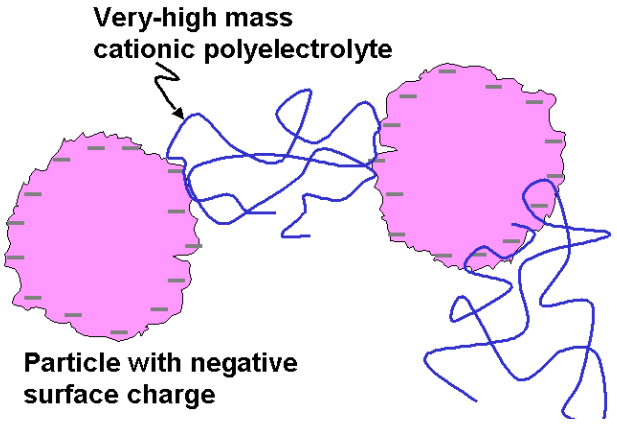
- Polymers are built up by monomers of one kind or repeating different kinds, mostly the same type of monomer. These monomers also do have functional groups, i.e., charged sites attached. These could be carboxylic, hydroxylic or amine groups.
  - These ionizable groups are actually the reaction sites. If these groups carry (+) charge, then the polymer is called a "**cationic**" polymer.
  - If they have (-) charges, polymers are called "**anionic**" polymers and if they have no charge polymers are called as "**non-ionic**" polymers.

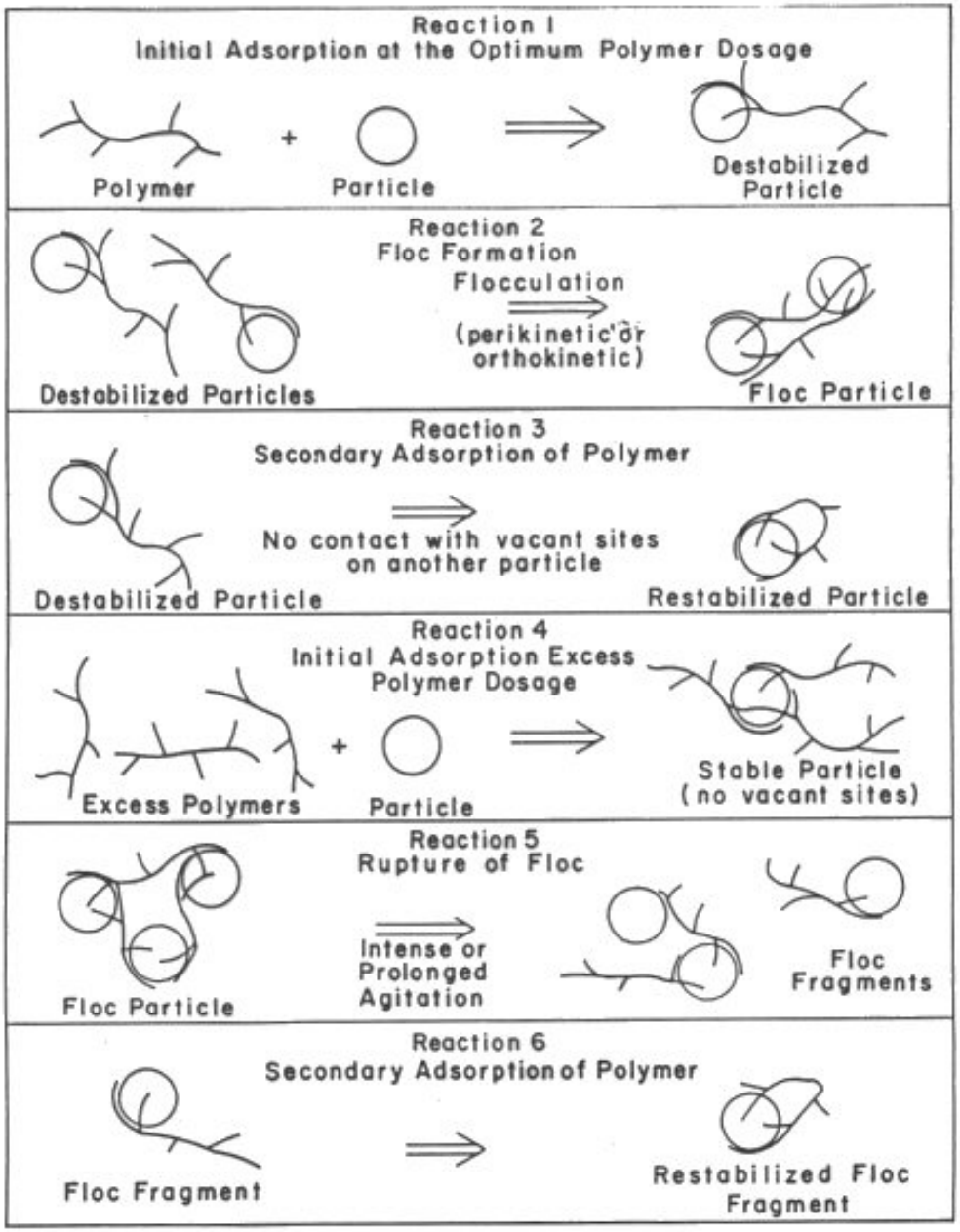


perform the same two things:

- Charge neutralization
- Bridging of the particles

- In bridging by either the metal hydroxide polymers or the organic polyelectrolytes, long molecular chain length extends and bridge the gap between the particles.
- Particles attach themselves by physical and chemical means to the polymers and otherwise individual particles will be attached to the same polymer at the end of the bridging process.
- Polymers, apart from bringing the particles together, also hold the particles together; imparting strength to the floc structure and a lattice system that dewaters easily.



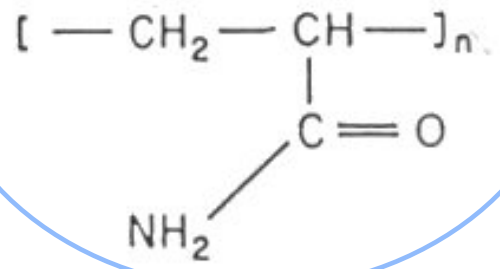



From: Weber, 1972

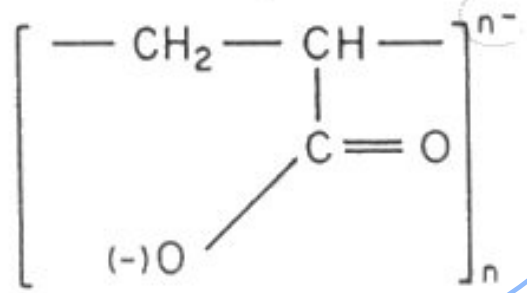
- Because sludge surfaces are negatively charged, the most commonly used type of polymers are cationic polymers. The positive charge on the polymers nicely matches the negatively charged surfaces in flocculation. This bridging is simple and effective.
- Same thing is not valid for anionic and non-ionic polymers. Anionic polymers can effectively be used only when certain cations are also added to the system. To achieve this $H^+$ ions are added to reduce the electrostatic repulsion between the polymer and the particle.
- Since anionic polymers are less expensive than the other types, it may be worthwhile to decrease the pH and use an anionic polymer.

Non-ionic

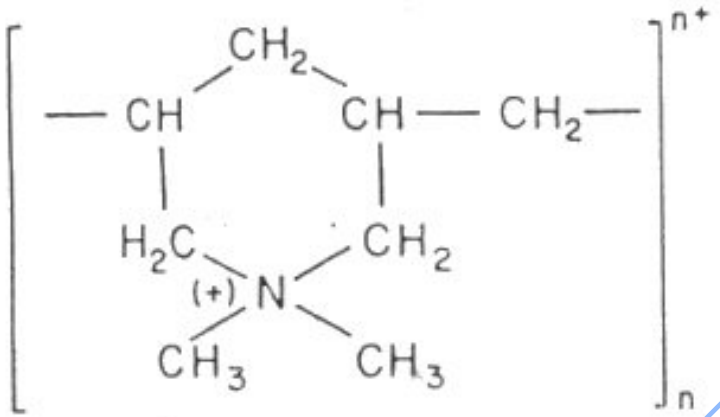
Polyacrylamide (PAM)



Polyacrylic Acid (PAA)



Polydiallyldimethylammonium (PDADMA, Cat-Floc)



Anionic

Cationic

## How are the Polymers used?

**Polymers come as liquid, powder or pellets.**

- In most cases a dilute dose will be effective enough (0.01%) for conditioning.
- Polymers at dilute concentrations have good solubility since they have a chance to stretch out.
- A powdered polymer should not be directly added to the system to be flocculated because it will form a gel and it won't act as a flocculant.
- A stock of 1-5% is prepared and polymer is dosed from there to the system to be flocculated.

Polymers are more advantageous than inorganic conditioners because of:

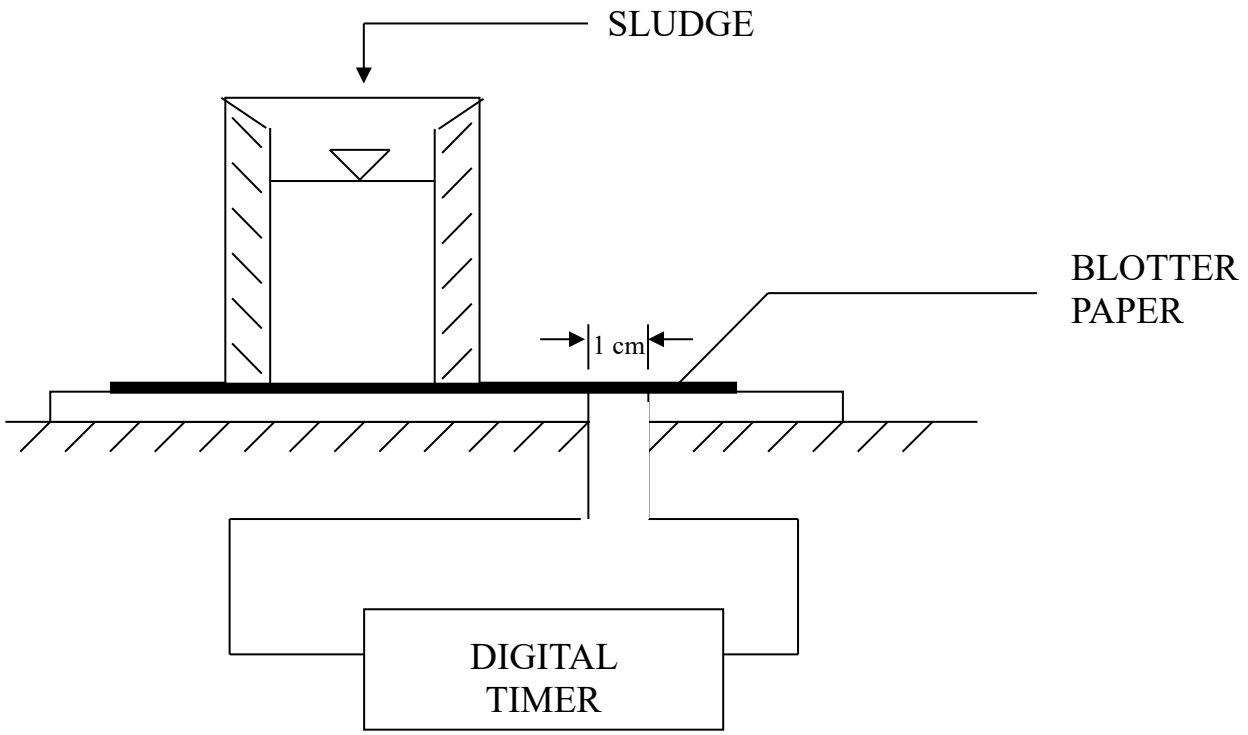
- easy operation,
- safe handling,
- better thermal characteristics (since organics)

**Other advantages are:** they are typically dosed at a much smaller concentration. Unlike inorganic conditioners they do not increase the sludge volume significantly.

## How to Select the Best Polymer for Conditioning?

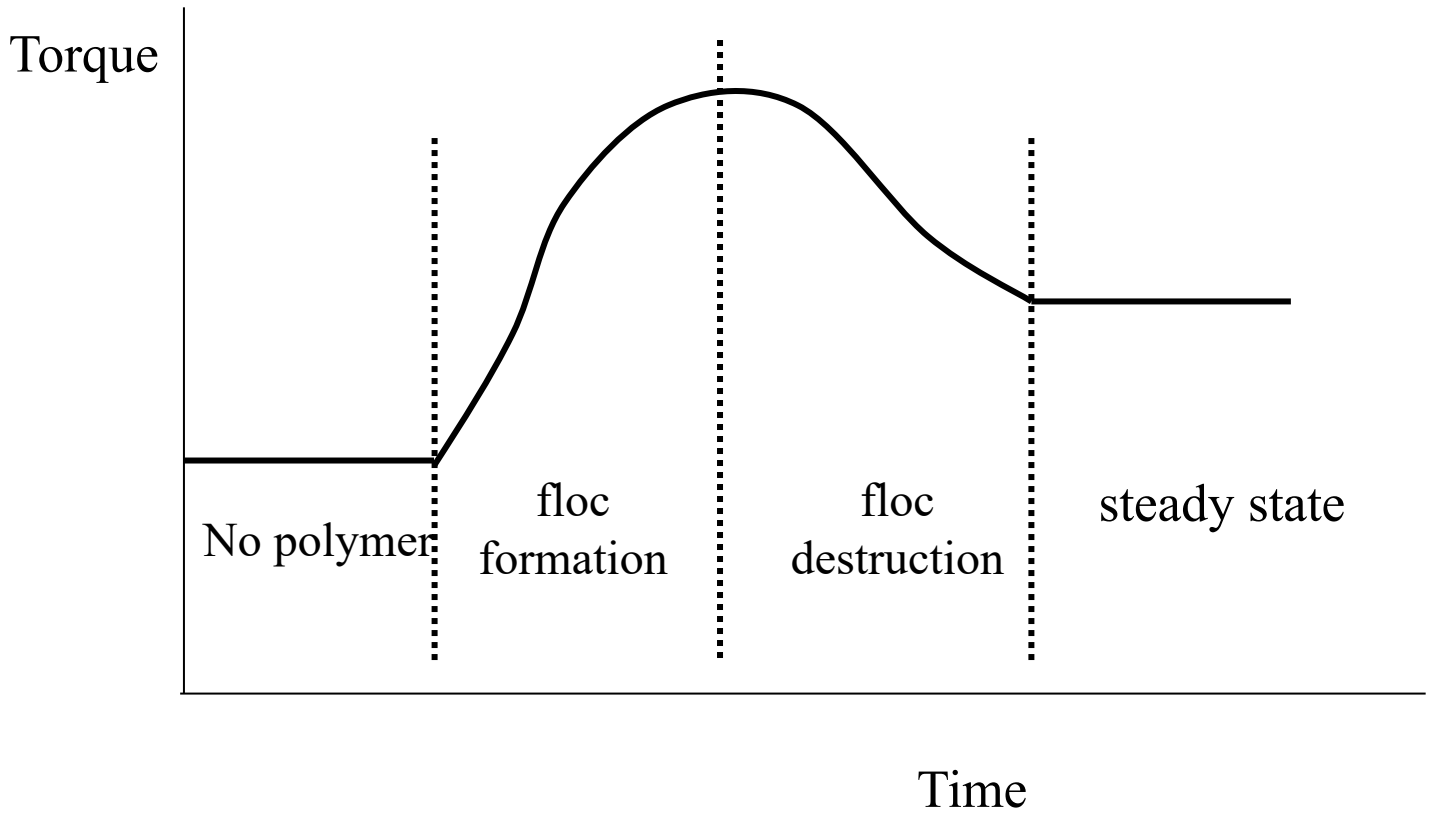
Best way is to try in a full-scale treatment plant (expensive).
There are quick and easy tests that can be conducted to gain an idea:

- ***CST***: simple test that takes only a few seconds, try different polymers, find the one with the best performance,



- ***Jar test:*** Try different polymers at different concentrations in a jar test set-up. Add polymer; mix rapidly, then slowly, the flocs form. Following settlement, the clarity of the liquid and the appearance of the flocs will give qualitative information.

- ***Rotational viscometers***: In paddle type of viscometer as the spindle rotates in sludge, a polymer is introduced. The torque measurement will show something like below:




From this graph, the rate of floc formation and the floc strength information can be gathered.

## Thermal Conditioning

## Heat treatment conditioning

**Porteus Process:** Early in 1900's they tried to heat the sludge up with the purpose of easy separation of sludge solids from the liquid. This process is batch and it was not very successful in its first applications. It was not applied again until 1950's.

**Ferrer System:** Turned the Porteus process into a continuous system. It is being marketed now.

Heat conditioning is based on applying heat to sludge for a certain time. This destroys the cells and frees up the **bound water** within the cells. Then the solids can be concentrated up to a certain solids concentration.

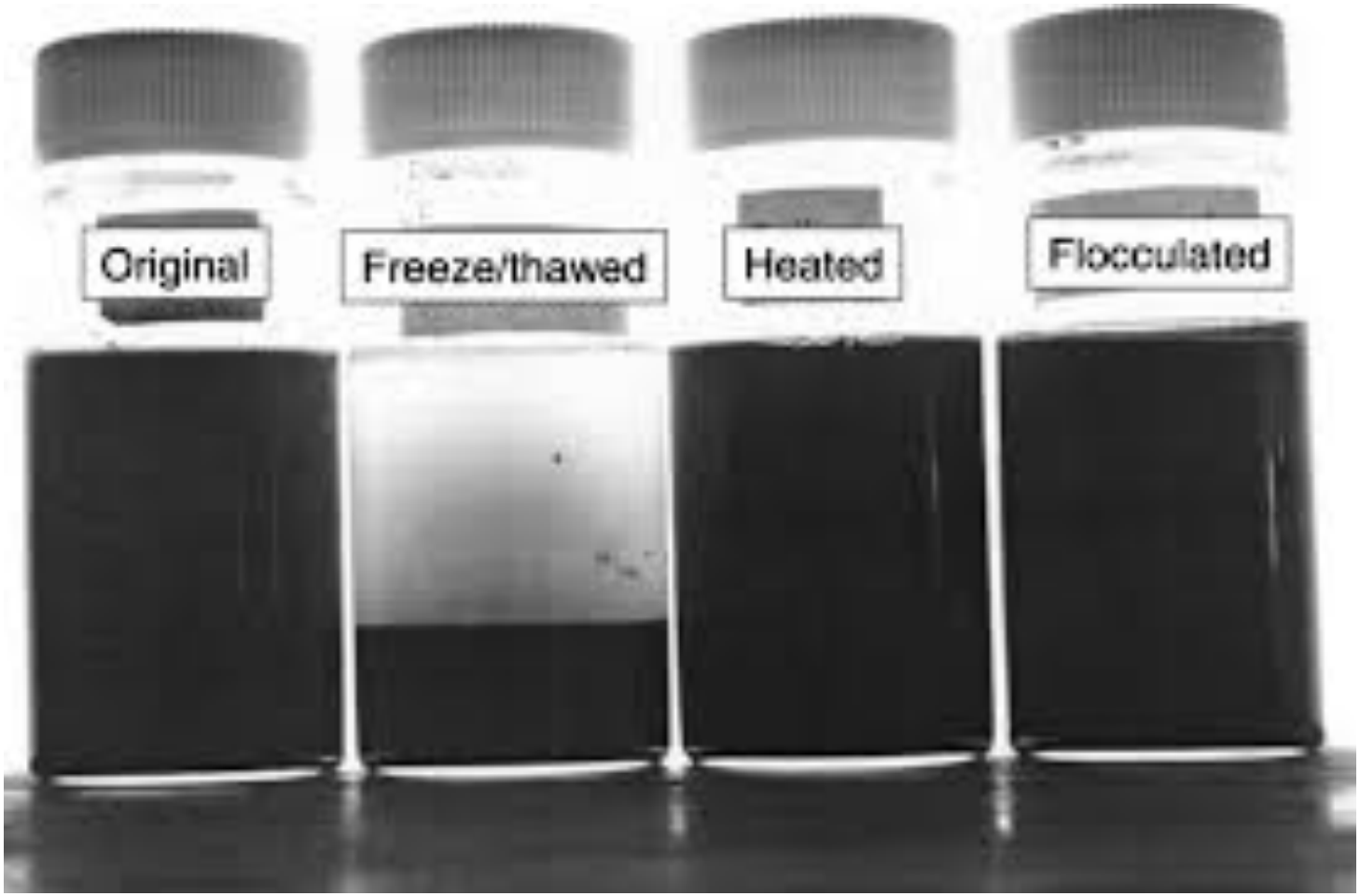
Two variables of the process:

- **Temperature:** ranges from 180-200$^{o}$C, and
- **Time:** 20-30 minutes

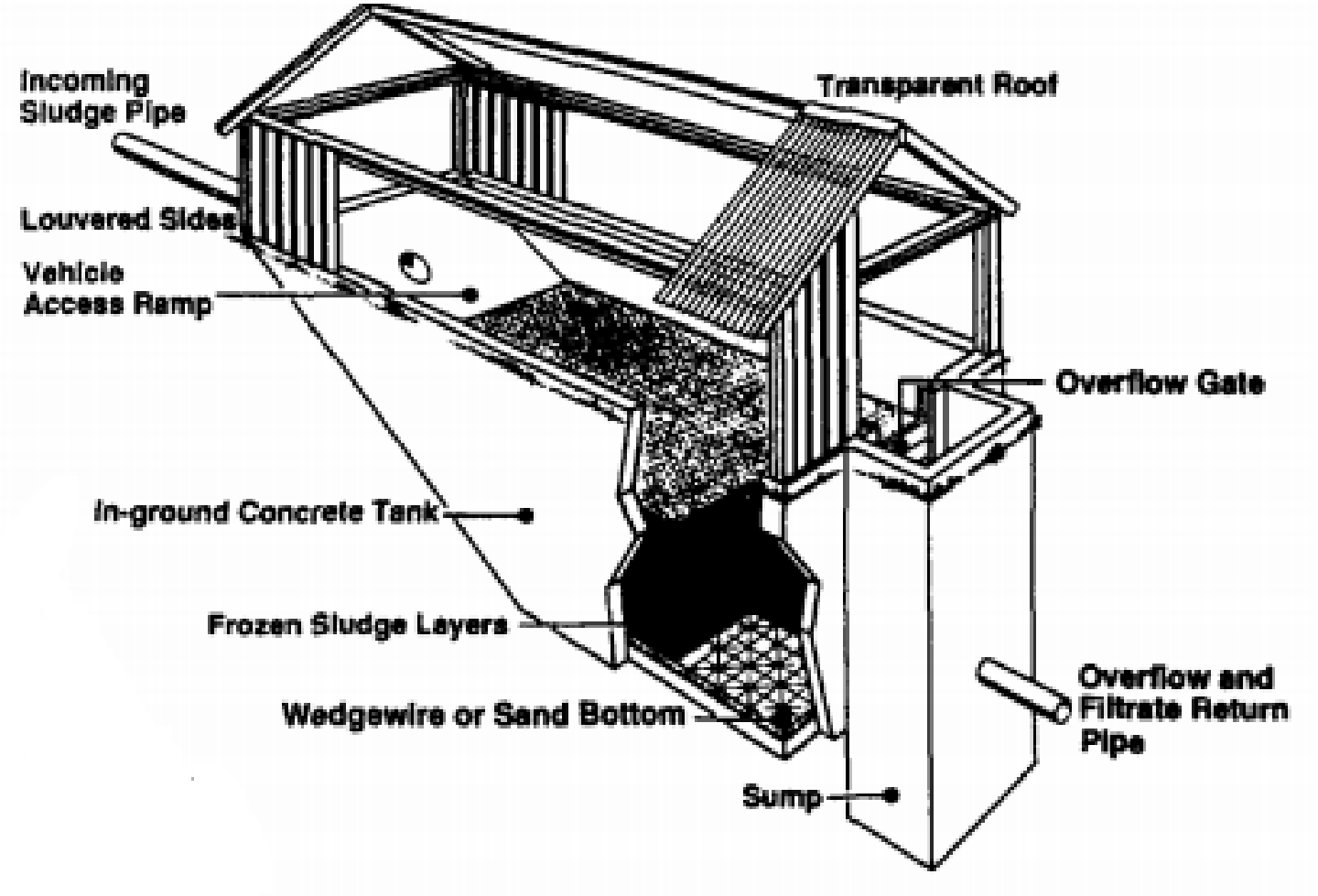
The problem with heat treatment is the quality of effluent produced. The effluent will be very high in COD, i.e., 6000mg/L for every 1% feed solids. When this effluent is recycled back to the head of the treatment plant, it is a substantial load. Typically for domestic wastewater treatment plants about 15% capacity increase is suggested to accommodate this load.

## Freeze/thaw sludge conditioning

- A very effective system of sludge conditioning. This is applied in sludge freezing beds.
- Sludge is frozen slowly whole winter and then it is thawed when spring comes. Slow freezing pushes all the particles towards each other in front of the advancing ice front. This way particles are brought together and they form larger flocs. If the freezing is too fast, this process will not work.
- Freeze thaw sludge conditioning has also good pathogen reduction capabilities, so can provide sludge for agricultural use.
- The only problem with this system is that you cannot apply it in southern countries where the cold winters are not present. Freezing sludge applying cooling externally is very expensive. So the process remains applicable in northern countries. There are applications of this system in north US and Canada.


Original
Freeze/thawed
Heated
Flocculated

# Sludge Freezing Bed



## Physical Conditioning

## Elutriation

It is not a conditioning process. It is done to help the conditioning. It can be defined as washing of sludge to remove constituents that would interfere with the dewatering operation. Normally elutriation lowers the alkalinity and removes the fine solids, so it lowers the chemical demand for sludge conditioning (up to 50% $FeCl_3$ dose for example).

Carried out in tanks like thickeners. Washwater to sludge ratio is 2 to 1. The problem with this system is too many fine particles are washed away and have to be returned to head of the treatment plant.

**THAT'S ALL FOLKS FOR THIS PART!**

**BYE FOR NOW** 👋👋👋👋👋