

The background of the slide is a light gray gradient. It is decorated with numerous realistic water droplets of various sizes. Some droplets are clustered in the top left corner, while others are scattered across the bottom right. The droplets have highlights and shadows, giving them a three-dimensional appearance.

WATER TREATMENT

M2X9623 – ENVIRONMENTAL MONITORING & REMEDIATION



WATER TREATMENT

- GOAL: CLEAN WATER
 - SOURCE: (CONTAMINATED) SURFACE WATER
 - SOLUTION: SEPARATE CONTAMINANTS FROM WATER
 - HOW?
- 



PROCESSES

- REMOVE PARTICLES
 - REMOVE DISSOLVED CHEMICALS
 - REMOVE/INACTIVATE PATHOGENS
-
- SCREENING, SEDIMENTATION, FILTRATION
 - COAGULATION, FLOCCULATION
 - CHLORINATION, UV-DISINFECTION
- 



WATER TREATMENT PROCESSES

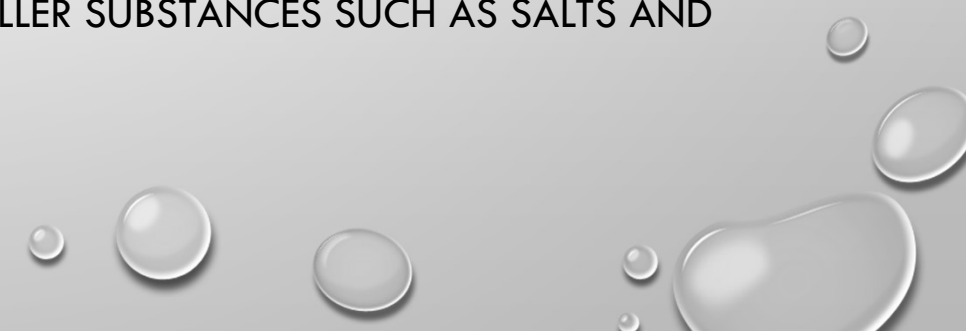
PHYSICAL PROCESSES

- SCREENS – THESE ARE USED TO FILTER THE WATER AND ARE USUALLY USED AT THE BEGINNING OF THE PURIFICATION PROCESS. THEY REMOVE SOLID PARTICLES FROM THE WATER AND THEIR SHAPE DEPENDS ON WHICH PARTICLES THEY HAVE BEEN DESIGNED TO FILTER.
 - SAND FILTRATION – THE FILTER IN THIS CASE IS MADE OF A MULTIPLE LAYER OF SAND THAT VARIES IN SIZE. WHEN THE WATER FLOWS THROUGH THE SAND, SOLID PARTICLES ARE FILTERED OUT. MANY PARTICLES ARE NOT FILTERED OUT USING THIS METHOD, SO SECONDARY FILTRATION IS OFTEN REQUIRED.
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WATER TREATMENT PROCESSES

FILTRATION PROCESSES 1

- CROSS FLOW FILTRATION – THIS METHOD USES A PERMEABLE MEMBRANE TO FILTER OUT SALTS AND SOME DISSOLVED MATTER. THERE ARE SEVERAL MEMBRANE FILTRATION METHODS DEPENDING ON THE CONTAMINANT THAT IS TO BE REMOVED FROM THE WATER:
 - MICRO FILTRATION – THIS TYPE OF FILTRATION IS DESIGNED TO REMOVE VERY SMALL PARTICLES FROM THE WATER THAT RANGE IN SIZE FROM 0.1 TO 1.5 MICRONS. IT IS ABLE TO FILTER OUT SUSPENDED MATTER AND SOME MICROORGANISMS.
 - ULTRA FILTRATION – THIS TYPE OF FILTRATION REMOVES EVEN SMALLER PARTICLES FROM THE WATER THAT RANGE IN SIZE FROM 0.005 TO 0.1 MICRONS. NOT ONLY DOES IT REMOVE SUSPENDED PARTICLES BUT IT CAN REMOVE OTHER SMALLER SUBSTANCES SUCH AS SALTS AND PROTEINS.
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WATER TREATMENT PROCESSES

FILTRATION PROCESSES 2

- NANO FILTRATION – THIS TYPE OF FILTRATION REMOVES PARTICLES FROM THE WATER THAT RANGE IN SIZE FROM 0.0001 TO 0.005 MICRONS. THIS MEANS IT IS EFFECTIVE AT FILTERING OUT VIRUSES, HERBICIDES AND PESTICIDES FROM THE WATER.
 - REVERSE OSMOSIS – THIS TYPE OF FILTRATION IS EFFECTIVE AT REMOVING THE SMALLEST OF PARTICLES WITH A SIZE OF UP TO 0.001 MICRONS. IT CAN REMOVE METAL ION PARTICLES AND DISSOLVED SALT.
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WATER TREATMENT PROCESSES

CHEMICAL PROCESSES 1

- CHEMICAL ADDITION – CERTAIN CHEMICALS CAN BE ADDED TO WATER TO COMBAT SPECIFIC PROBLEMS. YOU CAN ADD CHELATING AGENTS TO PREVENT HARD WATER PROBLEMS. OXIDISING AGENTS ARE EFFECTIVE AT KILLING CERTAIN MICROORGANISMS AND REDUCING AGENTS CAN BE ADDED TO NEUTRALISE THE OXIDISING AGENTS TO PREVENT HARM TO HUMANS. THEY PREVENT EROSION OF PURIFICATION MEMBRANES AND NEUTRALISE SUBSTANCES SUCH AS CHLORINE AND OZONE.
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WATER TREATMENT PROCESSES

CHEMICAL PROCESSES 2

- CLARIFICATION – THIS PROCESS REMOVES SUSPENDED SOLIDS THROUGH A NUMBER OF DIFFERENT PROCESSES. COAGULANTS ARE FIRST ADDED TO REDUCE ION CHARGES, CAUSING SMALLER PARTICLES TO STICK TOGETHER TO CREATE BIGGER ONES. THESE LARGER PARTICLES ARE THEN REMOVED THROUGH A GRAVITY FILTER. THIS METHOD IS EFFECTIVE AT REMOVING LARGE PARTICLES BUT MAY NOT FILTER OUT ALL OF THEM, FURTHER TREATMENT MAY BE NEEDED.
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WATER TREATMENT PROCESSES

CHEMICAL PROCESSES 3

- DEIONISATION AND SOFTENING – ION EXCHANGE SYSTEMS ABSORB CERTAIN ANIONS AND CATIONS IN ORDER TO DEIONISE THE WATER. THE CATIONS AND ANIONS ARE REPLACED BY COUNTER-IONS UNTIL THE TANK IS SATURATED WITH IONS. THE ION-EXCHANGING DEVICE THEN NEEDS TO BE REGENERATED WITH THE USE OF CERTAIN CHEMICALS. WATER SOFTENERS ARE OFTEN USED AS ION EXCHANGERS; THEY WORK BY REMOVING CALCIUM AND MAGNESIUM IONS FROM THE WATER, AND THEN REPLACES THEM WITH POSITIVELY CHARGED IONS. THIS REDUCES THE HARDNESS OF THE WATER.
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WATER TREATMENT PROCESSES

DISINFECTANT PROCESSES 1

- DISINFECTANTS ARE USED TO KILL ANY REMAINING MICROORGANISMS IN THE WATER; IT IS AN IMPORTANT PROCESS OF WATER TREATMENT AS IT CAN PREVENT PATHOGENIC MICROORGANISMS FROM CAUSING HUMAN DISEASE. THERE ARE MANY WAYS TO DISINFECT WATER.
 - CHLORINE DISINFECTION – CHLORINE IS CAPABLE OF KILLING MANY MICROORGANISMS, BUT WHEN IT REACTS WITH SUBSTANCES THAT MAY BE PRESENT IN THE WATER, DANGEROUS CARCINOGENIC CHEMICALS MAY BE FORMED. THIS PROBLEM CAN BE OVERCOME BY USING CHLORINE DIOXIDE WHICH IS EFFECTIVE AT LOW CONCENTRATIONS.
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WATER TREATMENT PROCESSES

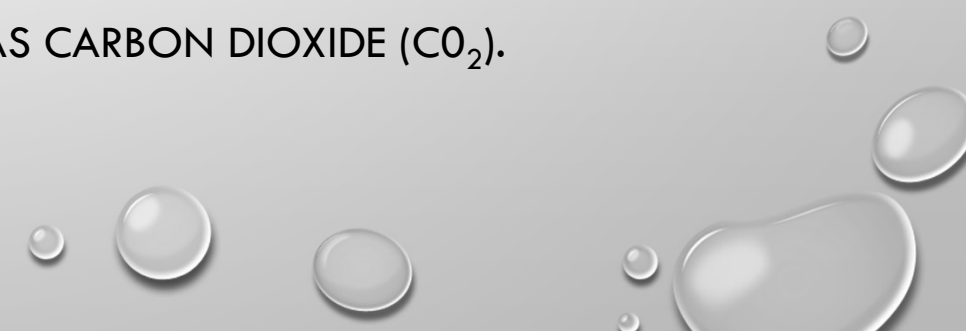
DISINFECTANT PROCESSES 2

- OZONE DISINFECTION – THIS TYPE OF DISINFECTION WORKS BY USING OXYGEN ATOMS TO DESTROY PARTICLES THROUGH OXIDISATION. THIS IS AN EFFECTIVE METHOD TO KILL MICROORGANISMS AND IS NOT HARMFUL TO HUMAN HEALTH.
 - UV-RADIATION – THIS TYPE OF DISINFECTION IS GROWING IN POPULARITY. IT IS MORE NATURAL IN ITS WAY OF KILLING MICROORGANISMS AS IT USES UV RAYS TO KILL GERMS.
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WATER TREATMENT PROCESSES

BIOLOGICAL PROCESSES 1

- WATER PURIFICATION CAN ALSO BE DONE BIOLOGICALLY USING MICROORGANISMS SUCH AS BACTERIA. THESE MICROORGANISMS DECOMPOSE ORGANIC MATTER WITHIN THE WATER AND THEREFORE REDUCE THE AMOUNT OF ORGANIC SUSPENDED MATTER. THERE ARE TWO TYPES OF TREATMENT THAT USE EITHER ANAEROBIC OR AEROBIC BACTERIA.
 - IN **AEROBIC DECOMPOSITION**, LIVING ORGANISMS, WHICH USE OXYGEN, FEED UPON THE ORGANIC MATTER. THEY USE THE NITROGEN, PHOSPHORUS, SOME OF THE CARBON, AND OTHER REQUIRED NUTRIENTS. MUCH OF THE CARBON SERVES AS A SOURCE OF ENERGY FOR THE ORGANISMS AND IS BURNED UP AND RESPIRED AS CARBON DIOXIDE (CO₂).
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WATER TREATMENT PROCESSES

BIOLOGICAL PROCESSES 2

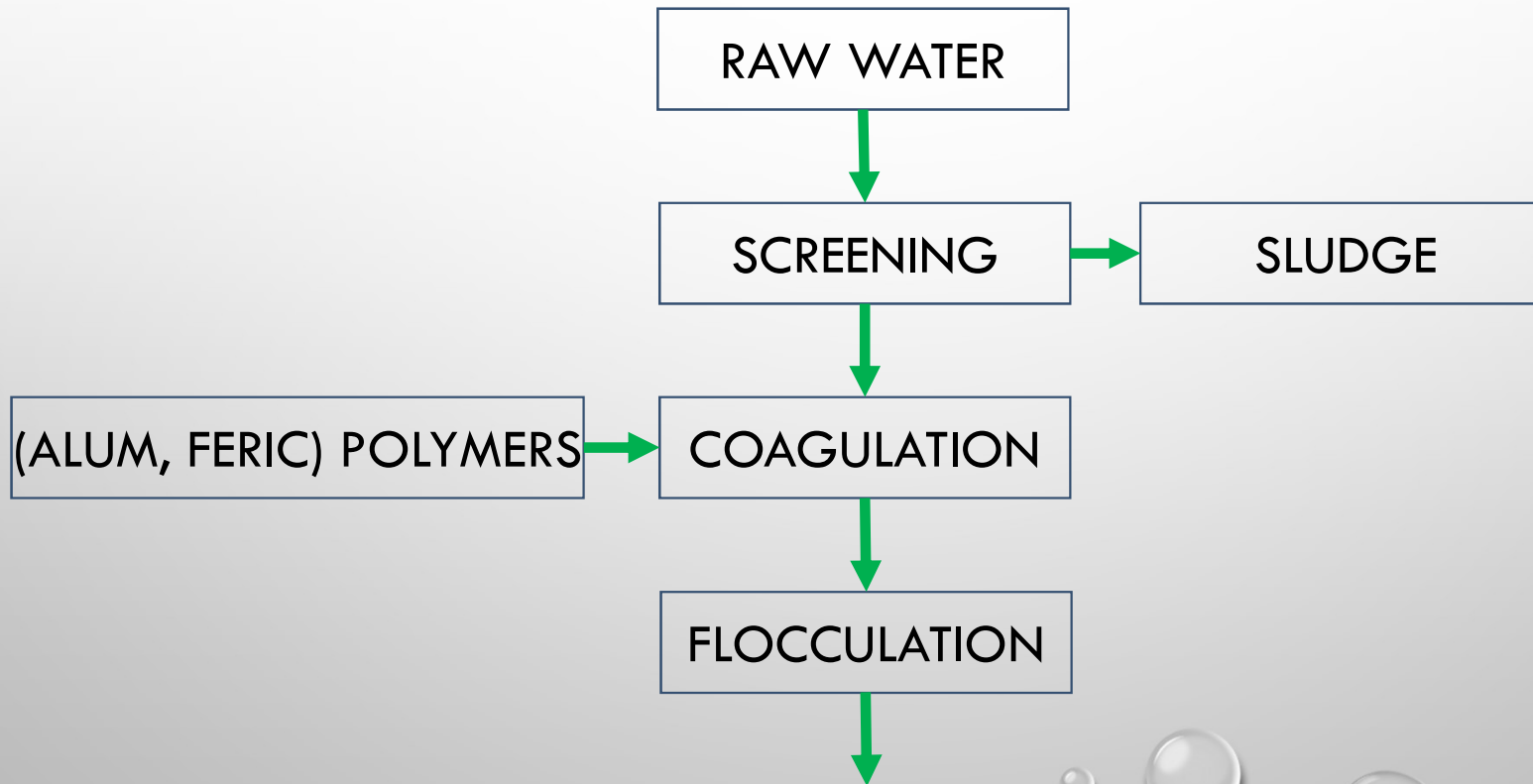
- **ANAEROBIC DIGESTION** IS A SEQUENCE OF PROCESSES BY WHICH MICROORGANISMS BREAK DOWN BIODEGRADABLE MATERIAL IN THE ABSENCE OF OXYGEN. THE PROCESS IS USED FOR INDUSTRIAL OR DOMESTIC PURPOSES TO MANAGE WASTE OR TO PRODUCE FUELS. MUCH OF THE FERMENTATION USED INDUSTRIALLY TO PRODUCE FOOD AND DRINK PRODUCTS, AS WELL AS HOME FERMENTATION, USES ANAEROBIC DIGESTION.
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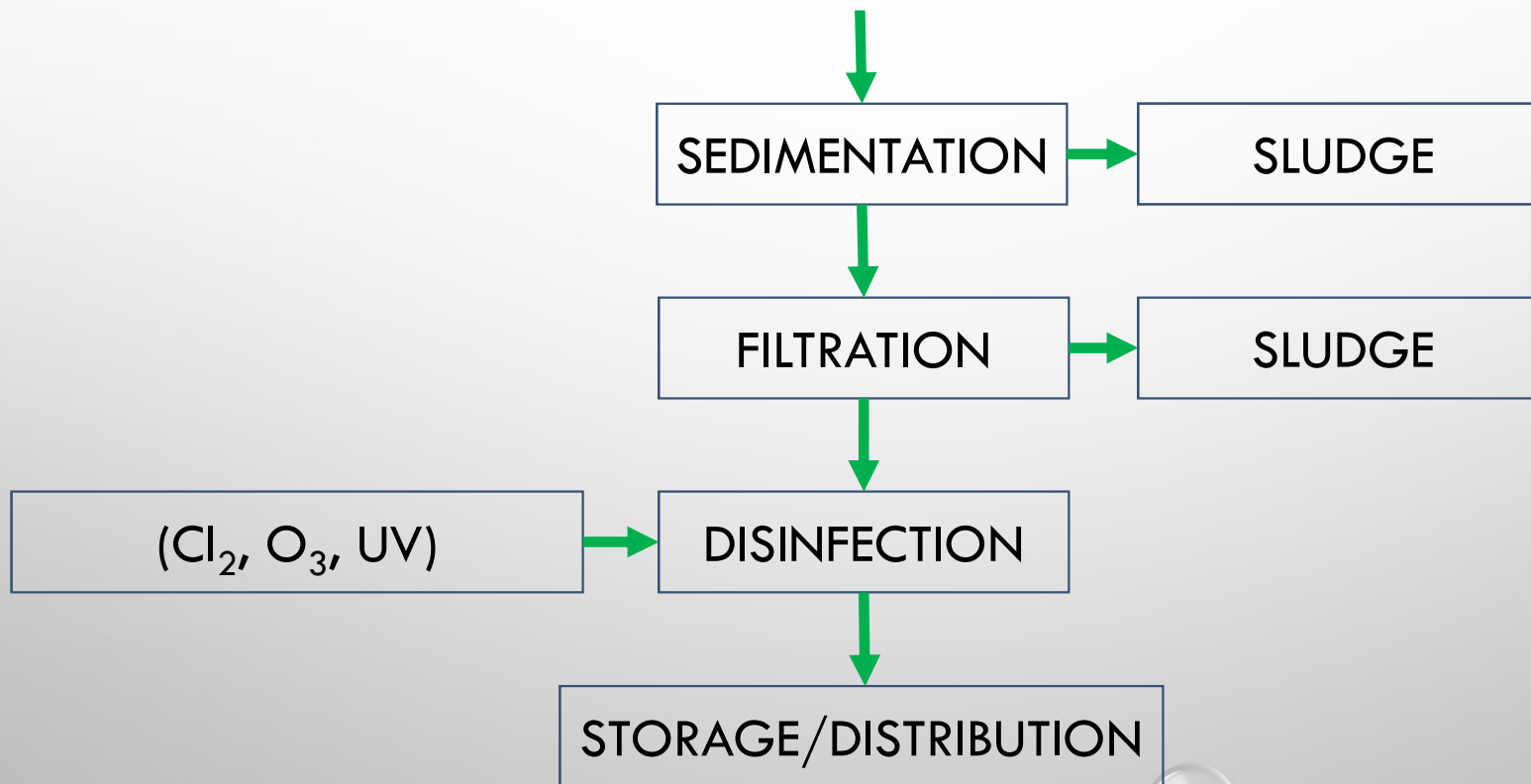
WATER TREATMENT PLANTS

- SCREENING
 - SEDIMENTATION
 - COAGULATION/FLOCCULATION
 - FILTRATION
 - SLOW SAND FILTERS
 - RAPID SAND FILTERS
 - DIATOMACEOUS EARTH FILTERS
 - MEMBRANE FILTERS
- 

WATER TREATMENT PLANTS 1



WATER TREATMENT PLANTS 2



SCREENING

- REMOVES LARGER SOLIDS
 - LOGS/BRANCHES
 - RAGS
 - FISH
- MAY INCORPORATE A MECHANIZED TRASH REMOVAL SYSTEM
- PROTECTS PUMPS AND PIPES IN THE TREATMENT PLANT



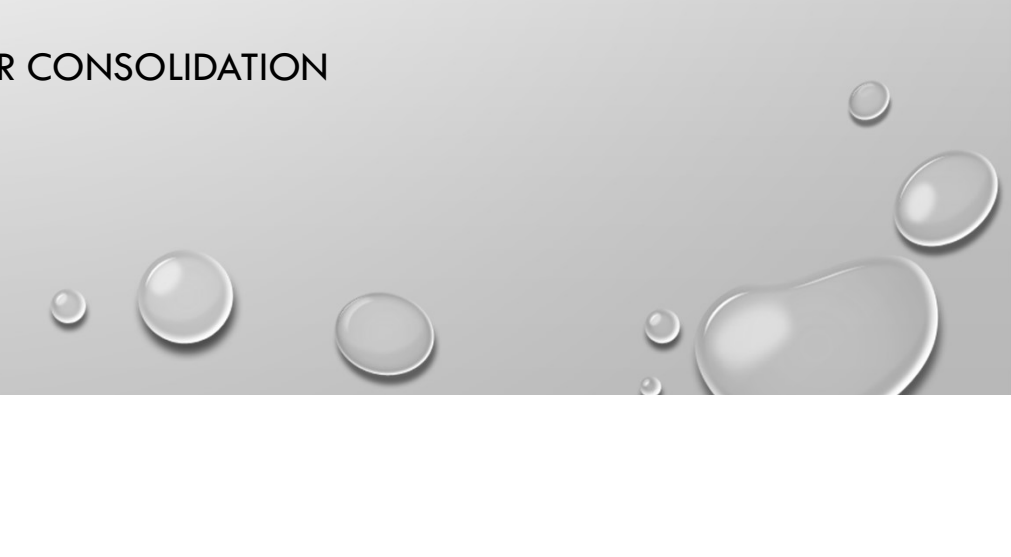
SEDIMENTATION

- OLDEST FORM OF WATER TREATMENT
- USES GRAVITY TO SEPARATE PARTICLES FROM WATER
- OFTEN FOLLOWS COAGULATION AND FLOCCULATION

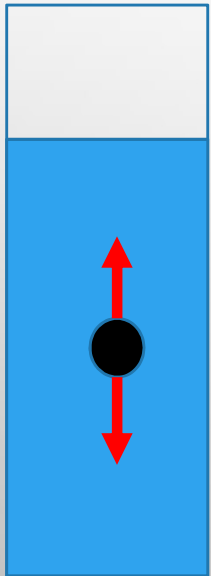




SEDIMENTATION

- DILUTE SUSPENSIONS
 - PARTICLES ACT INDEPENDANTLY
 - CONCENTRATED SUSPENSIONS
 - PARTICLE TO PARTICLE INTERACTIONS ARE SIGNIFICANT
 - PARTICLES MAY COLLIDE AND STICK TOGETHER (FORM FLOCS)
 - PARTICLE FLOCS MAY SETTLE MORE QUICKLY
 - PARTICLE TO PARTICLE FORCES MAY PREVENT FURTHER CONSOLIDATION
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SETTLING OF PARTICLES IN DILUTE SUSPENSIONS



- UPWARD FORCES:

- BUOYANCY – F_B $\longrightarrow F_B = \rho_W V_P g$

- DRAG – F_D $\longrightarrow F_D = C_D A_P \rho_W \frac{V_t^2}{2}$

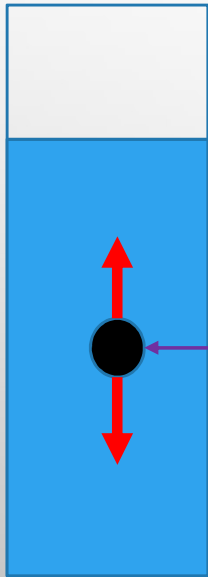
- DOWNWARD FORCES:

- GRAVITY – F_G $\longrightarrow F_G = \rho_P V_P g$

- WHERE:

- ρ_W – DENSITY OF WATER
- V_P – VOLUME OF PARTICLE
- g – ACCELERATION (GRAVITY)
- C_D – COEFFICIENT OF DRAG
- A_P – PLAN AREA OF PARTICLE
- V_t – TERMINAL VELOCITY OF PARTICLE
- ρ_P – DENSITY OF PARTICLE

SETTLING OF PARTICLES IN DILUTE SUSPENSIONS



- UPWARD FORCES:

$$F_B = \rho_W V_P g$$

$$F_D = C_D A_P \rho_W \frac{v_t^2}{2}$$

- DOWNWARD FORCES:

$$F_G = \rho_P V_P g$$

- ASSUME SPHERICAL

$$A_P = \pi r^2$$

$$V_P = \frac{4}{3} \pi r^3$$

$$\left. \begin{array}{l} A_P = \pi r^2 \\ V_P = \frac{4}{3} \pi r^3 \end{array} \right\} \frac{V_P}{A_P} = \frac{4}{3} r = \frac{2}{3} d \rightarrow$$

$$F_D = F_G - F_B$$

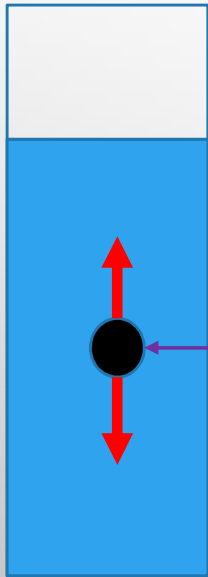
$$C_D A_P \rho_W \frac{v_t^2}{2} = \rho_P V_P g - \rho_W V_P g$$

$$v_t^2 = \frac{2(\rho_P V_P g - \rho_W V_P g)}{C_D A_P \rho_W}$$

$$v_t = \sqrt{\frac{2V_P g(\rho_P - \rho_W)}{C_D A_P \rho_W}}$$

$$v_t = \sqrt{\frac{4dg(\rho_P - \rho_W)}{3C_D \rho_W}}$$

SETTLING OF PARTICLES IN DILUTE SUSPENSIONS



- UPWARD FORCES:

$$F_B = \rho_W V_P g$$

$$F_D = C_D A_P \rho_W \frac{v_t^2}{2}$$

- DOWNWARD FORCES:

$$F_G = \rho_P V_P g$$

- ASSUME SPHERICAL

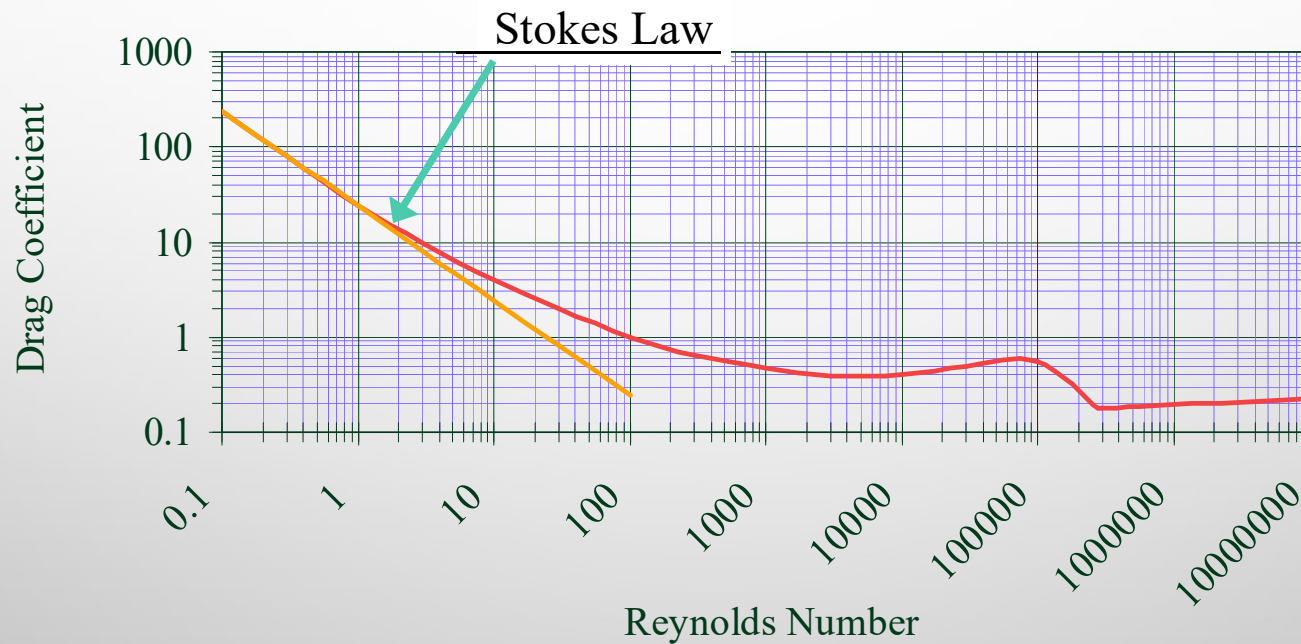
$$\left. \begin{aligned} A_P &= \pi r^2 \\ V_P &= \frac{4}{3} \pi r^3 \end{aligned} \right\} \frac{V_P}{A_P} = \frac{4}{3} r = \frac{2}{3} d$$

$$v_t = \sqrt{\frac{4dg(\rho_P - \rho_W)}{3C_D\rho_W}}$$

TO INCREASE THE TERMINAL VELOCITY:

- INCREASE PARTICLE DIAMETER (SIZE)
- INCREASE PARTICLE COEFFICIENT OF DRAG (SIZE)

SETTLING OF PARTICLES IN DILUTE SUSPECSIONS



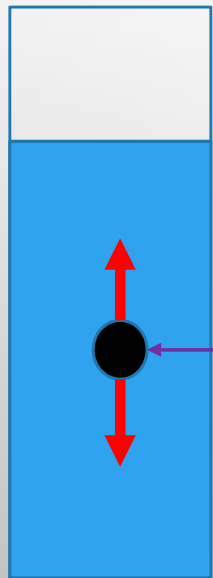
$$R_e = \frac{V_t d \rho_w}{\mu}$$

μ = VISCOSITY

Laminar flow

Turbulent flow

SETTLING OF PARTICLES IN DILUTE SUSPENSIONS



- UPWARD FORCES:

$$F_B = \rho_W V_P g$$

$$F_D = C_D A_P \rho_W \frac{V_t^2}{2}$$

- DOWNWARD FORCES:

$$F_G = \rho_P V_P g$$

- ASSUME SPHERICAL

$$\left. \begin{array}{l} A_P = \pi r^2 \\ V_P = \frac{4}{3} \pi r^3 \end{array} \right\} \frac{V_P}{A_P} = \frac{4}{3} r = \frac{2}{3} d$$

$$V_t = \sqrt{\frac{4dg(\rho_P - \rho_W)}{3C_D\rho_W}} \rightarrow V_t^2 = \frac{4dg(\rho_P - \rho_W)}{3C_D\rho_W}$$

$$Re = \frac{V_t d \rho_W}{\mu}$$

FOR LAMINAR FLOW:

$$C_D = \frac{24}{Re} = \frac{24\mu}{V_t d \rho_W}$$

$$V_t^2 = \frac{4dg(\rho_P - \rho_W)}{3 \frac{24\mu}{V_t d \rho_W} \rho_W} \rightarrow V_t = \frac{d^2 g (\rho_P - \rho_W)}{18 \mu}$$

SEDIMENTATION TANK SURFACE AREAS

- RETENTION TIME:

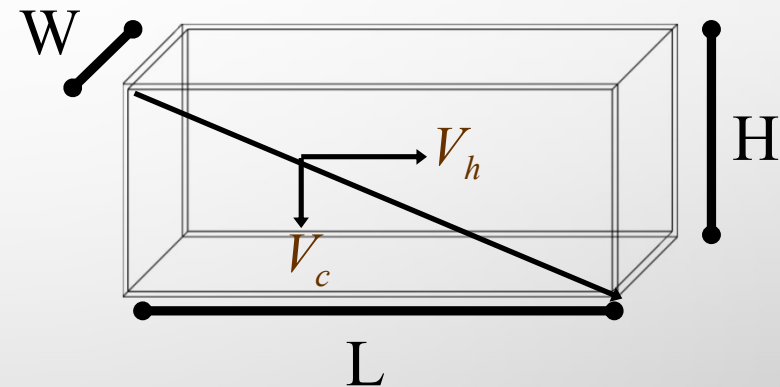
$$T = \frac{VOLUME}{FLOW} = \frac{V}{Q} = \frac{WHL}{Q}$$

- HORIZONTAL VELOCITY:

$$V_h = \frac{FLOW}{AREA} = \frac{Q}{WH}$$

- VERTICAL VELOCITY:

$$V_c = \frac{FLOW}{AREA} = \frac{Q}{WL} \quad \text{COMPARE WITH}$$



$$v_t = \sqrt{\frac{4dg(\rho_P - \rho_W)}{3C_D\rho_W}} = \frac{d^2g(\rho_P - \rho_W)}{18\mu}$$

SEDIMENTATION OF SMALLER PARTICLES

- INCREASED THE DIAMETER
- INCREASE GRAVITY (CENTRIFUGE)
- INCREASE DENSITY DIFFERENCE (DISSOLVED AIR)
- DECREASE VISCOSITY (INCREASE TEMPERATURE)

$$V_t = \frac{d^2 g (\rho_P - \rho_W)}{18\mu}$$

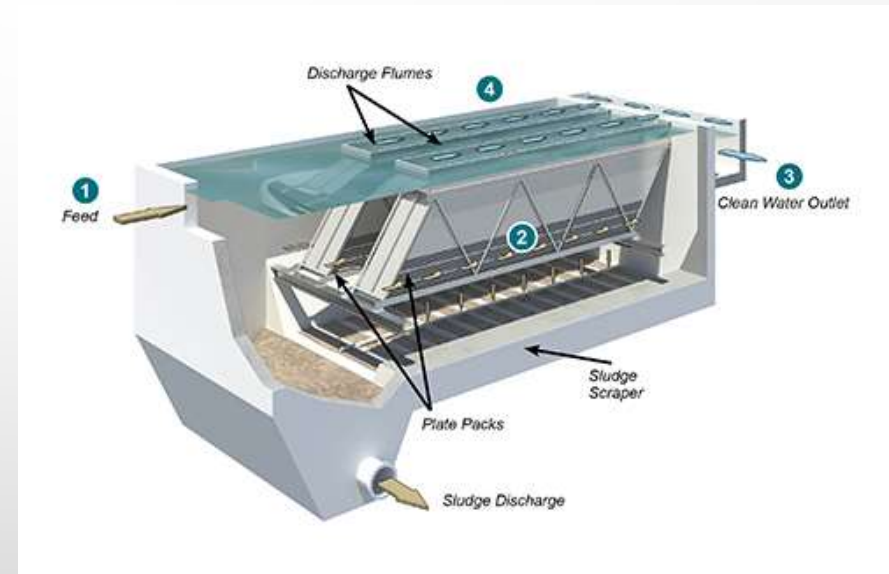


DESIGN CRITERIA

- MINIMAL TURBULENCE (INLET BAFFLES)
 - UNIFORM VELOCITY
 - NO SCOUR OF SETTLED PARTICLES
 - SLOW MOVING PARTICLE SCRAPER SYSTEMS
 - OVERFLOW RATE (VERTICAL VELOCITY) SHOULD BE SMALL TO GIVE ENOUGH RETENTION FOR SMALLER PARTICLES TO SETTLE
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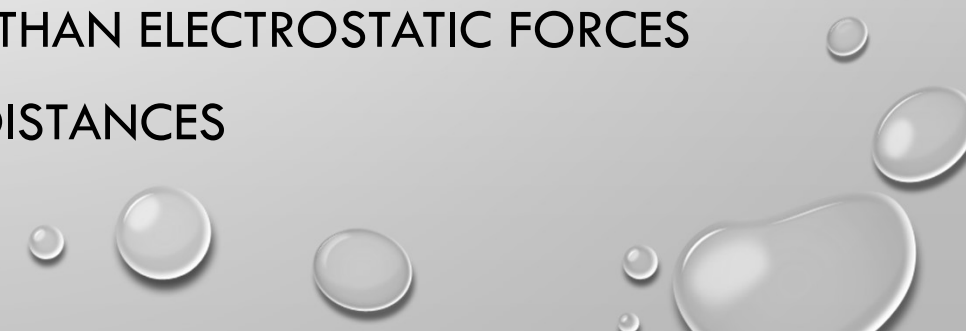
LAMELLA

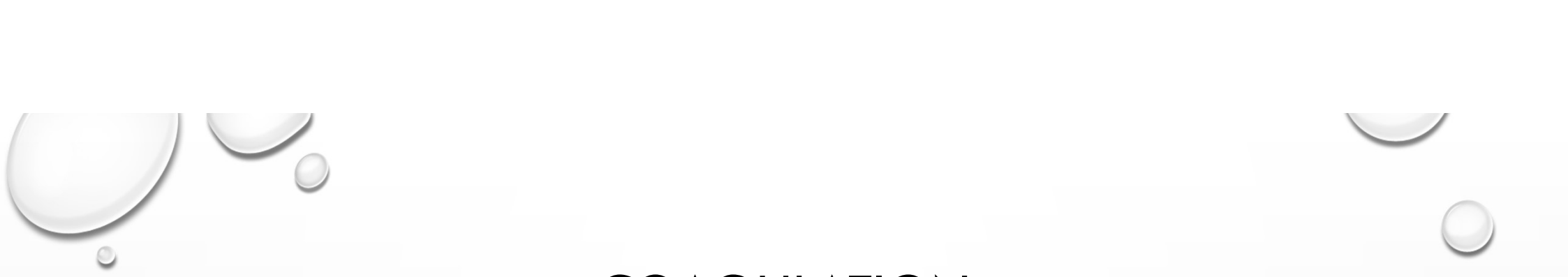
- SEDIMENTATION TANKS ARE USUALLY DIVIDED INTO LAYERS OF SHALLOW TANKS (LAMELLA)
- LAMELLA DECREASE THE DISTANCE PARTICLE HAS TO FALL IN ORDER TO BE REMOVED
- THE FLOW RATE CAN THUS BE INCREASED WHILE STILL OBTAINING GOOD PARTICLE REMOVAL



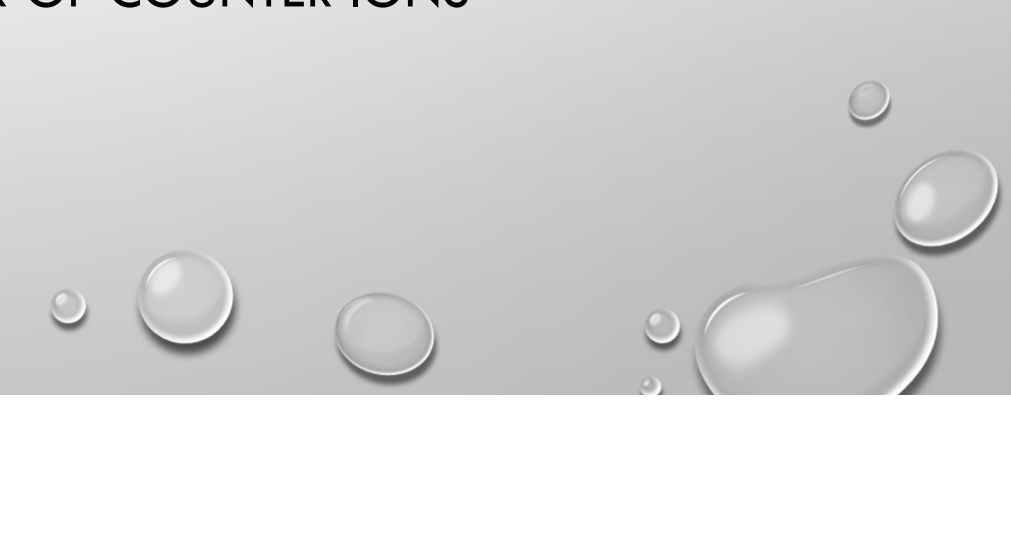


PARTICLE TO PARTICLE INTERACTIONS

- ELECTROSTATIC REPULSION
 - IN MOST SURFACE WATERS PARTICLE SURFACES ARE NEGATIVELY CHARGED
 - LIKE CHARGES REPEL EACH OTHER (STABLE SUSPENSION)
 - VAN DER WAALS FORCES
 - AN ATTRACTIVE FORCE
 - DECAYS MORE RAPIDLY WITH DISTANCE THAN ELECTROSTATIC FORCES
 - IS A STRONGER FORCE AT VERY CLOSE DISTANCES
- 



COAGULATION

- COAGULATION IS A PHYSICAL+CHECMICAL PROCESS WHEREBY PARTICLES ARE DESTABILIZED
 - SEVERAL MECHANISMS
 - ADSORPTION OF CATIONS ONTO NEGATIVELY CHARGES PARTICLES
 - DECREASE THE THICKNESS OF THE LAYER OF COUNTER IONS
 - SWEEP COAGULATION
 - INTERPARTICLE BRIDGING
- 

COAGULATION CHEMISTRY

- THE STANDARD COAGULANT FOR WATER SUPPLY IS ALUM [$\text{Al}_2(\text{SO}_4)_3 \cdot 14.3\text{H}_2\text{O}$]
- TYPICALLY 5 MILLIGRAMS/LITRE TO 50 MILLIGRAMS/LITRE ALUM IS USED
- THE CHEMISTRY IS COMPLEX WITH MANY POSSIBLE SPECIES FORMED SUCH AS AlOH^{+2} , $\text{Al}(\text{OH})_2^+$, AND $\text{Al}_7(\text{OH})_{17}^{+4}$
- THE PRIMARY REACTION PRODUCES $\text{Al}(\text{OH})_3$



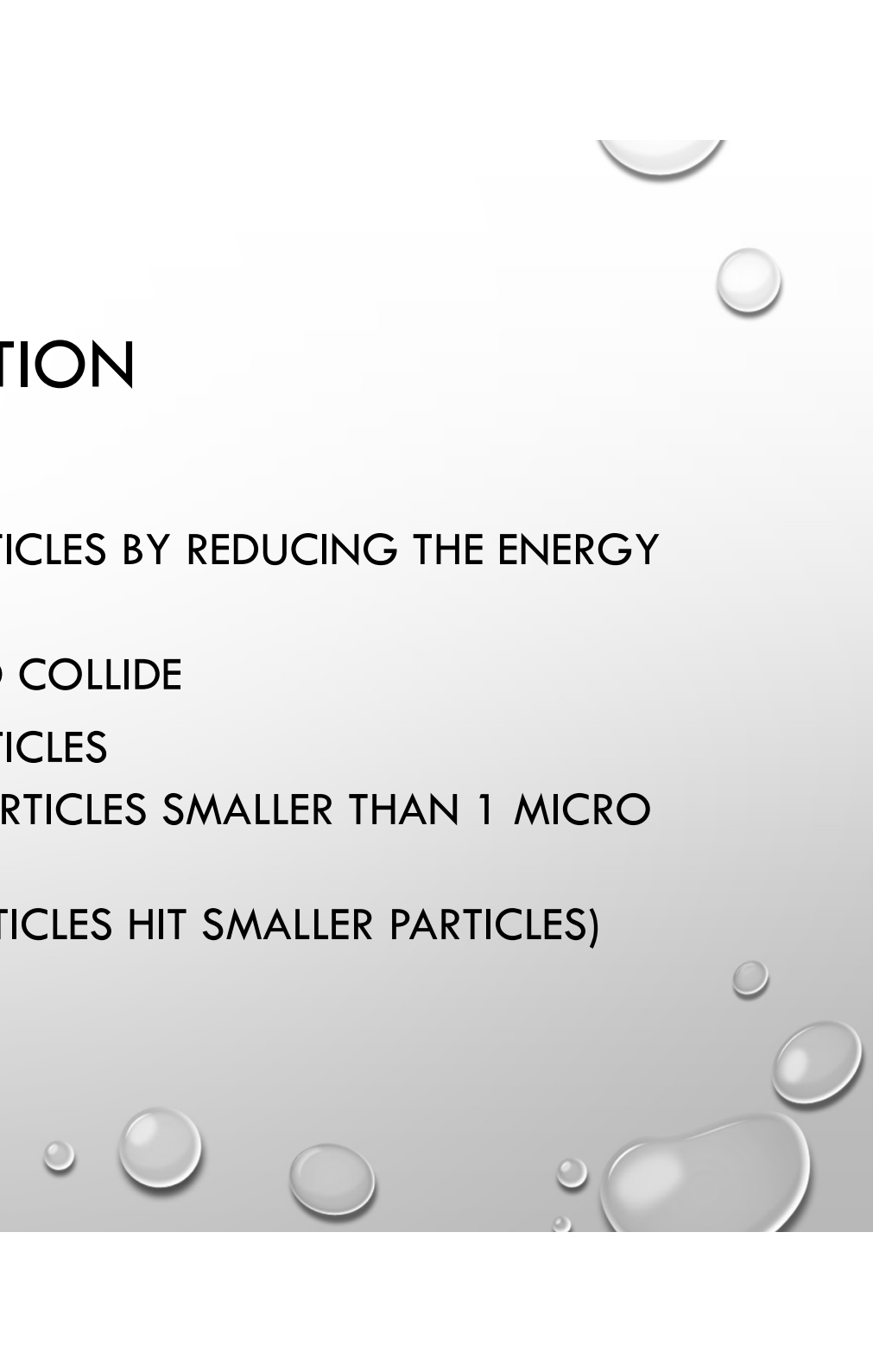
$$\text{pH} = -\log[\text{H}^+]$$

COAGULATION CHEMISTRY

- ALUMINUM HYDROXIDE $[\text{Al}(\text{OH})_3]$ FORMS AMORPHOUS, GELATINOUS FLOCS THAT ARE HEAVIER THAN WATER. THE FLOCS LOOK LIKE SNOW IN WATER
- THESE FLOCS ENTRAP PARTICLES AS THE FLOCS SETTLE (SWEEP COAGULATION)
- THE COAGULANT MUST BE MIXED WITH THE WATER. RETENTION TIMES IN THE MIXING ZONE ARE TYPICALLY BETWEEN 1 AND 10 SECONDS
- TYPES OF RAPID MIX UNITS
 - PUMPS
 - HYDRAULIC JUMPS
 - FLOW-THROUGH BASINS WITH MANY BAFFLES
 - IN-LINE BLENDERS
 - IN-LINE STATIC MIXERS



FLOCCULATION

- COAGULATION HAS DESTABILIZED THE PARTICLES BY REDUCING THE ENERGY BARRIER
 - NOW WE WANT TO GET THE PARTICLES TO COLLIDE
 - WE NEED RELATIVE MOTION BETWEEN PARTICLES
 - BROWNIAN MOTION(EFFECTIVE FOR PARTICLES SMALLER THAN 1 MICRO METRES)
 - DIFFERENTIAL SEDIMENTATION (BIG PARTICLES HIT SMALLER PARTICLES)
 - SHEAR
- 

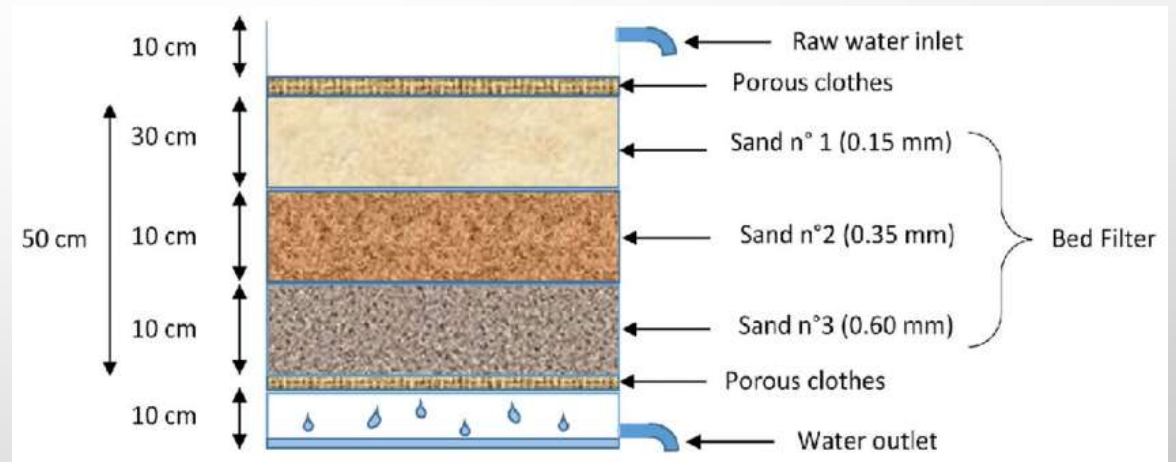


FILTRATION

- SLOW SAND FILTERS
 - DIATOMACEOUS EARTH FILTERS
 - MEMBRANE FILTERS
 - RAPID SAND FILTERS
- 

SLOW SAND FLITRATION

- FIRST FILTERS TO BE USED ON A WIDESPREAD BASIS
- FINE SAND WITH AN EFFECTIVE SIZE OF 0.2 MILLI METRES
- LOW FLOW RATES (10 - 40 CUBIC METRES/HOUR)
- FILTER CAKE FORMS ON TOP OF THE FILTER
 - CAUSES HIGH HEAD LOSS
 - MUST BE REMOVED PERIODICALLY
- USED WITHOUT COAGULATION/FLOCCULATION





DIATOMACEOUS EARTH FILTERS

- DIATOMACEOUS EARTH (DE) IS MADE OF THE SILICA SKELETONS OF DIATOMS
 - DE IS ADDED TO WATER AND THEN FED TO A SPECIAL MICRO-SCREEN
 - THE DE ALREADY ON THE MICRO-SCREEN STRAINS PARTICLES AND DE FROM THE WATER
 - THE CONTINUOUS DE FEED PREVENTS THE GRADUALLY THICKENING DE CAKE FROM DEVELOPING EXCESSIVE HEAD LOSS
- 



MEMBRANE FILTERS

- MUCH LIKE THE MEMBRANE FILTERS USED TO ENUMERATE COLIFORMS
 - MUCH GREATER SURFACE AREA
 - PRODUCE VERY HIGH QUALITY WATER (EXCELLENT PARTICLE REMOVAL)
 - CLOG RAPIDLY IF THE INFLUENT WATER IS NOT OF SUFFICIENTLY HIGH QUALITY
 - MORE EXPENSIVE THAN SAND AND DE FILTERS
- 



PARTICLE REMOVAL MECHANISMS IN FILTERS

- TRANSPORT
 - MOLECULAR DIFFUSION
 - INERTIA
 - GRAVITY
 - INTERCEPTION
 - ATTACHMENT
 - STRAINING
 - SURFACE FORCES
- 



DISINFECTION

- DISINFECTION: OPERATIONS AIMED AT KILLING OR INACTIVATING PATHOGENIC MICROORGANISMS
 - IDEAL DISINFECTANT;
 - TOXIC TO PATHOGENS
 - NOT TOXIC TO HUMANS
 - FAST RATE OF KILL
 - RESIDUAL PROTECTION
 - ECONOMICAL
- 



DISINFECTION

- CHLORINE
 - CHLORINE GAS
 - SODIUM HYPOCHLORITE (BLEACH)
 - OZONE
 - IRRADIATION WITH ULTRAVIOLET LIGHT
 - SONIFICATION
 - ELECTRIC CURRENT
 - GAMMA-RAY IRRADIATION
- 