WASTEWATER TREATMENT PLANTS: DESIGN AND OPERATION ASPECTS

November 2017

Version 1.4

THE PROBLEM

What challenges might occur from insufficient wastewater treatment?

Brainstorm as a group and take notes in your workbook, exercise (22-1).

LEARNING OUTCOME & RESOURCES

Learning Outcome

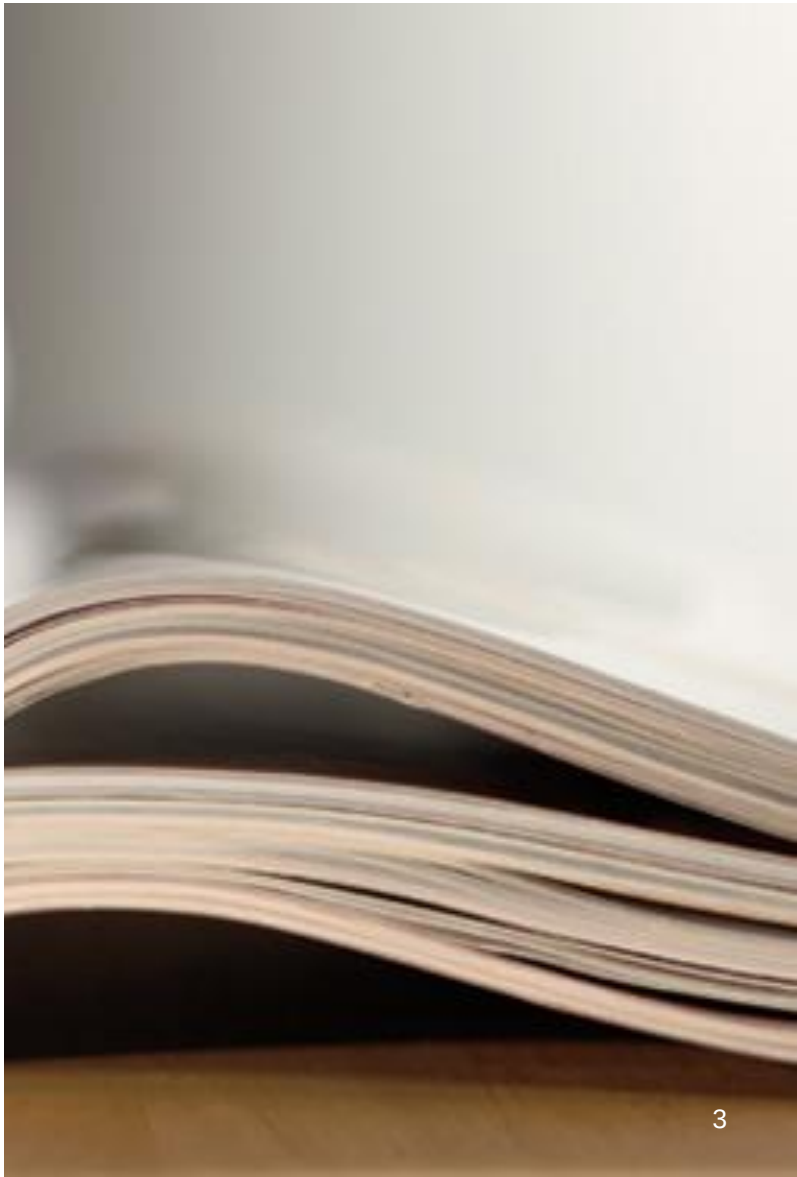
- Understanding of WWTP designs, treatment technologies and the sequence of treatments.
- Knowledge of the mapping of these technologies against the chemicals and processes involved in WPU and the control measures to undertake.

Resources

- ZDHC Wastewater Guideline.

Workbook

Refer to complimentary excercises in your workbook.



Introduction To Wastewater Treatment

TERMS

Term	Description
Anaerobic	Without oxygen
Aerobic	With oxygen, e.g. in activated sludge plants or in aerobic ponds
Anaerobic digestion/degradation/treatment	terms used interchangeably and mean “breaking down anaerobic matter”
Digestate/ digester residue/ digested organic matter	Effluent from a digester, the liquid product of the anaerobic digestion process
Biogas	Gas produced by microorganisms in anaerobic process (typically 66% methane content)
Biogas digester/ anaerobic digester	A covered vessel (or reactor) in which anaerobic digestion occurs

COD (Chemical Oxygen Demand) LOAD THROUGH VARIOUS TEXTILE PROCESSES

Process	COD content in mg O2/l
De-sizing	3.000 – 80.000
Bleaching	3.000 – 10.000
Scouring	2.000 – 6.000
Exhausted dye liquors reactive dyeing	400 – 2.000
Exhausted dye liquors dispersing dyes or vat dyes	5.000 – 10.000
Residual dyeing liquors	10.000 – 100.000
Residual finishing padding baths	5.000 – 200.000
Residual printing pastes	50.000 – 300.000

Wastewater Treatment Plants

WASTEWATER TREATMENT PROCESS

Wastewater Treatment

Total water treatment system, employed to treat the waste/effluent water from industry.

(Image: courtesy of wikipedia)

Pre-Treatment

Removal of insoluble particles from reaching treatment zone, which may hinder treatment operation.

1) Grit removal, 2) flow equalisation, 3) Fat and grease removal

(Image: Courtesy of Hydro International)

Primary Treatment

Based on the effluent the primary treatment is to remove the total suspended solids by suspending in to coagulant - results in sludge.

(image: Courtesy of ovivo)

Secondary Treatment

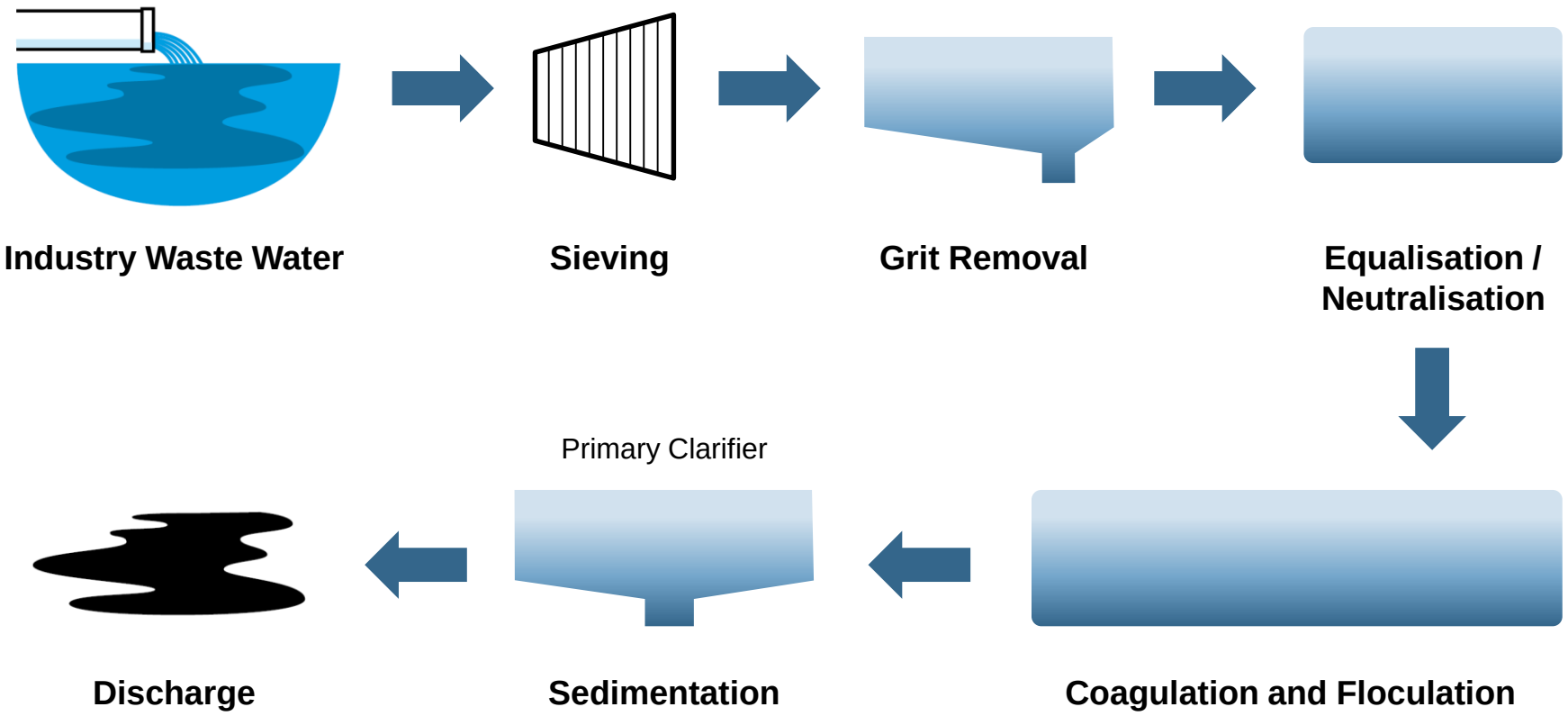
Reduction of chemicals either by aerobic, (with oxygen) or anaerobic, (without oxygen) reactions - results in sludge.

(Image: Courtesy of Apa Heuristic)

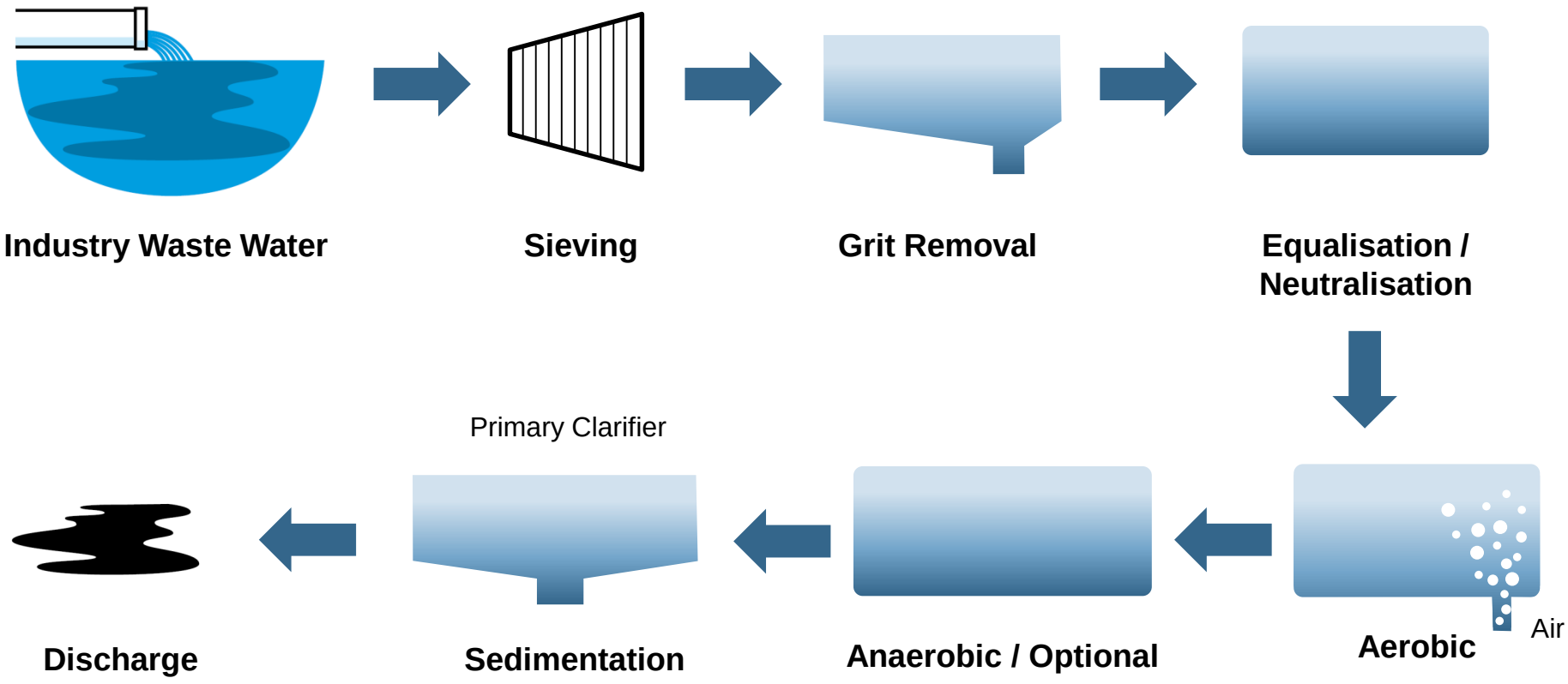
Tertiary treatment

Removal of residual components like colour, sludge remains and resulting clear water with the specification to meet the environmental requirement (*Image courtesy- Pure aqua*)

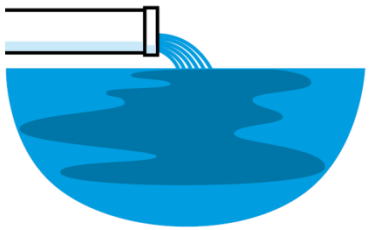
WASTEWATER TREATMENT PLANT – TYPE 1



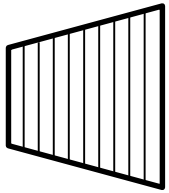
WASTEWATER TREATMENT PLANT – TYPE 2



WASTEWATER TREATMENT PLANT – TYPE 3



Industry Waste Water



Sieving

Grit Removal

Equalisation / Neutralisation

Aerobic

Anaerobic / Optional

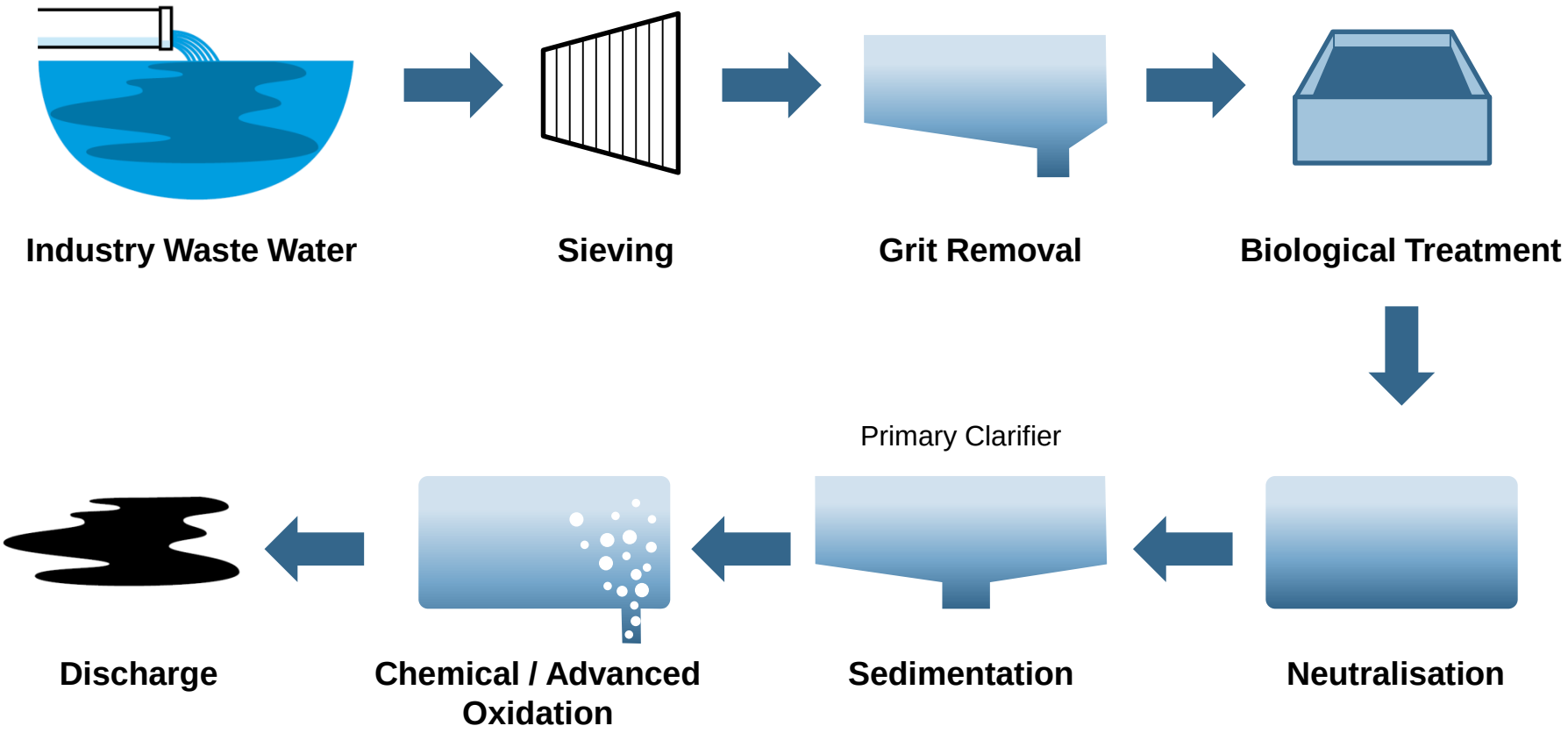
Primary Clarifier

Sedimentation

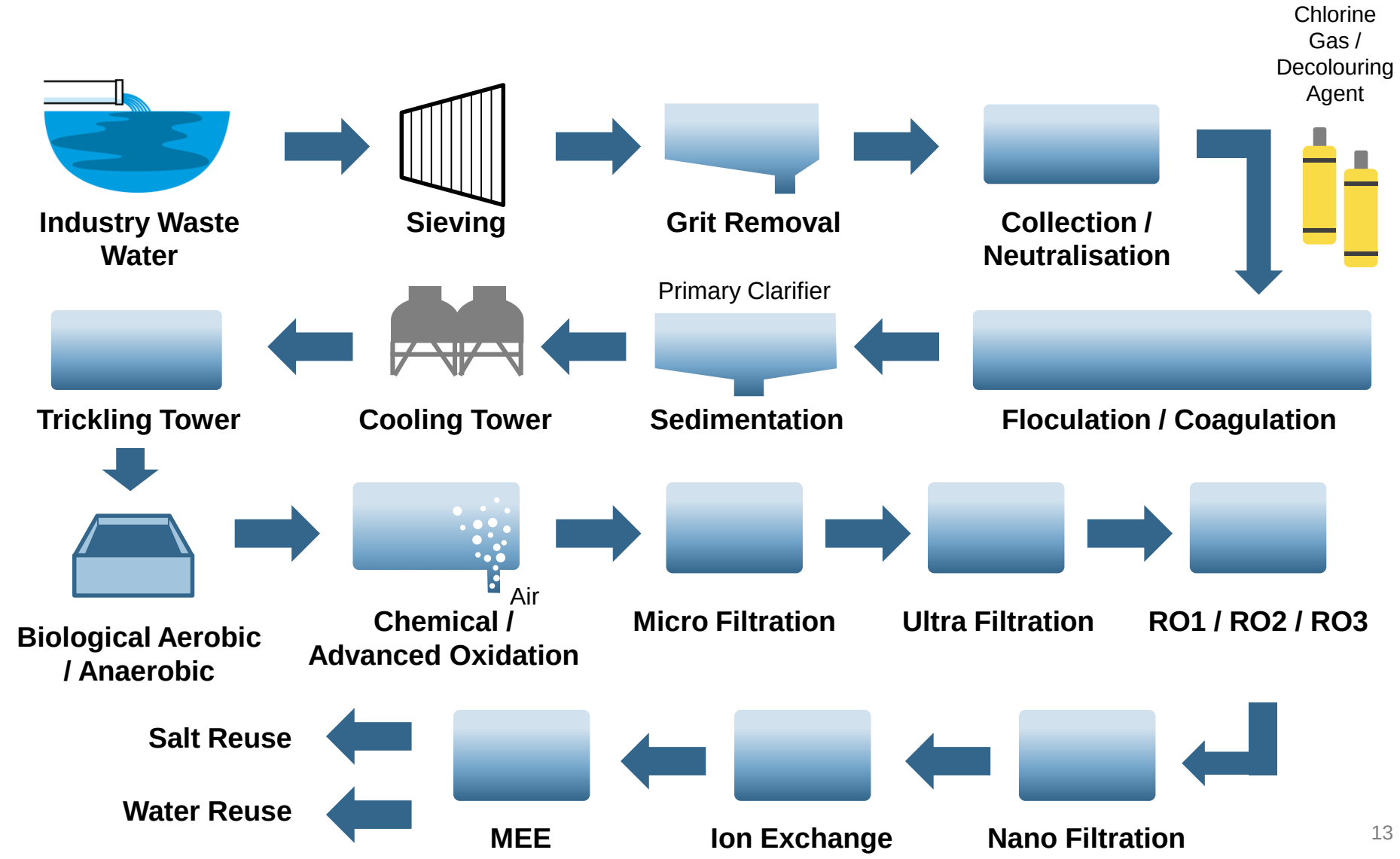
Biological Treatment

Discharge

WASTEWATER TREATMENT PLANT – TYPE 4



WASTEWATER TREATMENT PLANT – TYPE 5
ZERO LIQUID DISCHARGE (ZLD) SYSTEM



WWTP – CHINA

LINK BETWEEN WASTEWATER TREATMENT AND SUBSTITUTION OF HAZARDOUS CHEMICALS

Depending on the wastewater treatment technologies employed by the facilities, the hazardous chemical residues appear in the discharge water stream or in sludge.

It is important to understand and identify the type of chemicals and the concentration levels of the chemicals which can be broken down to

- CO_2.
- H_2O.
- Other safer residues.

The hazardous chemicals which cannot be treated by the WWTP technologies employed should be

- Restricted.
- Substituted.
- Controlled.

METHODS FOR WASTEWATER TREATMENT PLANT PERFORMANCE TESTING

- Standard Methods ASTM 5210D Biochemical Oxygen Demand.
- Respirometric Method (Respirometric Oxygen Uptake).
- Standard Methods ASTM 2710B Oxygen-Consumption Rate.
- (Specific Oxygen Uptake Rate; Dissolved Oxygen Probe Method).
- OECD 209 Activated Sludge, Respiration Inhibition Test.
- ASTM D5120 Standard test Method for Inhibition of Respiration in the Activated Sludge Process.
- Short-Term BOD Test (EZ-BOD instrument test for influent or effluent BOD-5 estimation).
- Suspended Solids (Photometric Method).
- CONTRAL Biodegradation Kinetics.
- Microscopic Evaluation of Biomass (Higher Forms and Filaments).

ACTIVITY

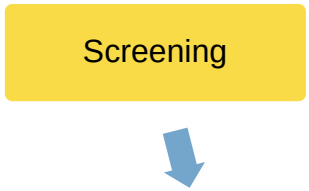
ROLE PLAY

Take notes.
Workbook,
Exercise (22-2).

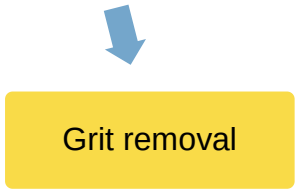
You are the Wastewater Treatment Plant Manager. Explain the benefits of effective wastewater treatment to your colleague in HR, who wants to understand how wastewater treatment links to the protection of the environment and substitution of hazardous chemicals.

Pre-Treatment

PROCESS FLOW PRE-TREATMENT

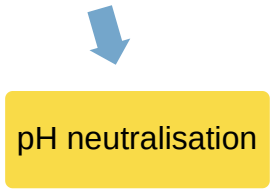


The screen size to be selected on the basis of the lower particle size can be sieved and removed.

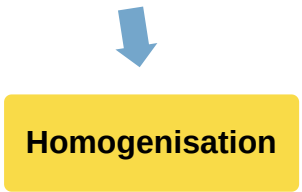


Removal of sand and gravel, cotton fluff, other heavy solid materials, higher specific gravity items other than organic biodegradable solids, food waste.

Removal of oils, greases from machine and non miscible compounds.



Average effluent load and effluent characteristics need to be considered before further processes. The primary treatment is the deciding factor to maintain the pH.

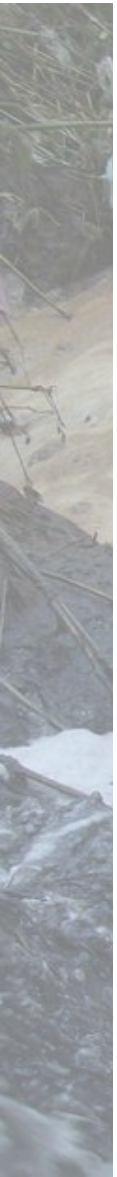


Average effluent load and effluent characteristics need to be considered before further processes. Consideration for the average pH based on the process house variable to be made

OVERVIEW TREATMENT POSSIBILITES
PRE-TREATMENT

Type of treatment	Description	Used in order to…
Screening	Screen filters	To remove the insoluble particles from effluent
Grit Removal	Particle separator	Separates heavier inorganic particles - specific gravity about 2.65
Grease removal	To separate the oils and grease	Removal of oils, greases from machine and non miscible compounds
pH Neutralisation	To correct the pH for further treatments	The primary treatment is the deciding factor to maintain the pH
Homogenisation	Collection and effluent standardisation	To make the effluent pH uniform, keep the variables of average effluent load and effluent characteristics at low

SCREENING



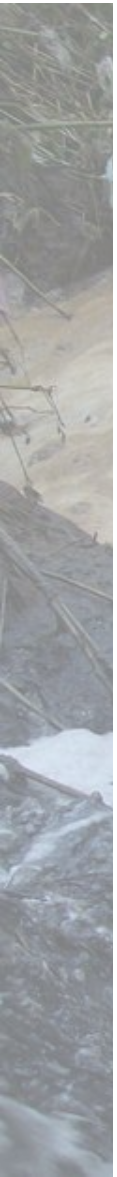
The first unit operation generally encountered in wastewater treatment plants is screening.

Screening removes larger materials and coarse solids from raw wastewater metals to prevent damage and clogging of downstream equipment, piping, and appurtenances.

Two types of screening processes:

- Manual.
- Automated.

GRIT REMOVAL AND SEDIMENTATION



Grit removal, hydro-mechanical process:

- Various techniques.
- This activity follows the screening.
- Techniques may vary based on plant conditions.

Sedimentation, physio/chemical activity:

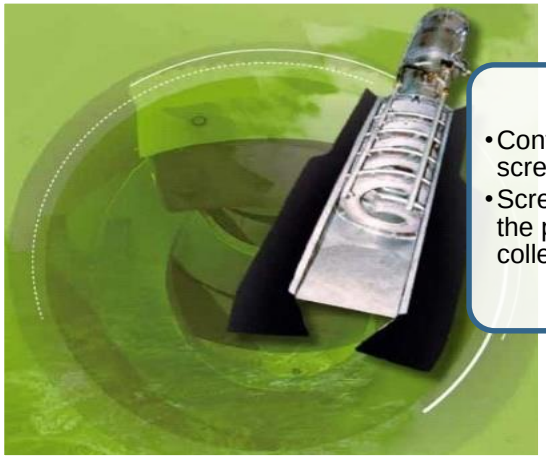
- Natural.
- Chemical based coagulation.
- This activity is follow the grit removal.
- Removal of total suspended solids.

EQUIPMENT – DIFFERENT SCREENS

Flat Screen

- Simple bar screen – manual cleaning.
- Appropriate for low particle loaded effluent.

Filter Screw



- Continuous screening.
- Screw removes the particles to collection zone.

Filter Spiral

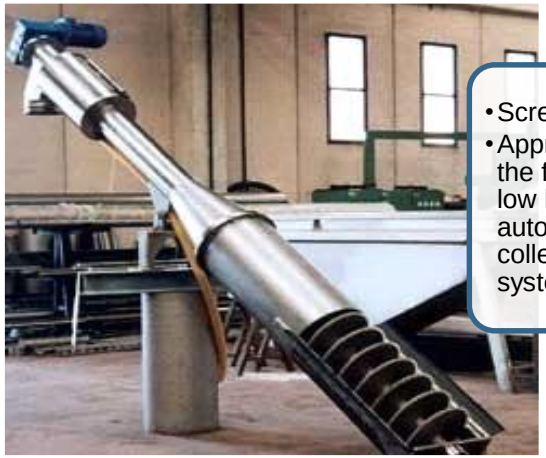
- Continuous screening.
- Scratch filter type particles are collected.
- Used in sticky and accumulative particle.

Rotary Screen

- Continuous screening.
- Particles are collected with a screen in rotation.
- Used for the continuous particle load in effluent.

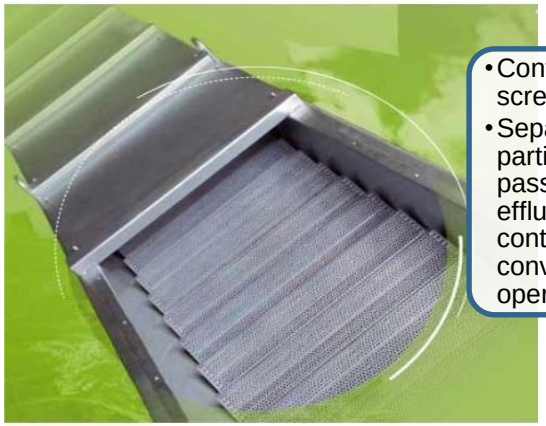
EQUIPMENT – DIFFERENT SCREENS

Inclined screw screen



- Screw screen.
- Appropriate for the flow involving low level and automated collection systems.

Belt fine screen



- Continuous screening.
- Separates the particles by passing the effluent through continues conveyor type operation screen.

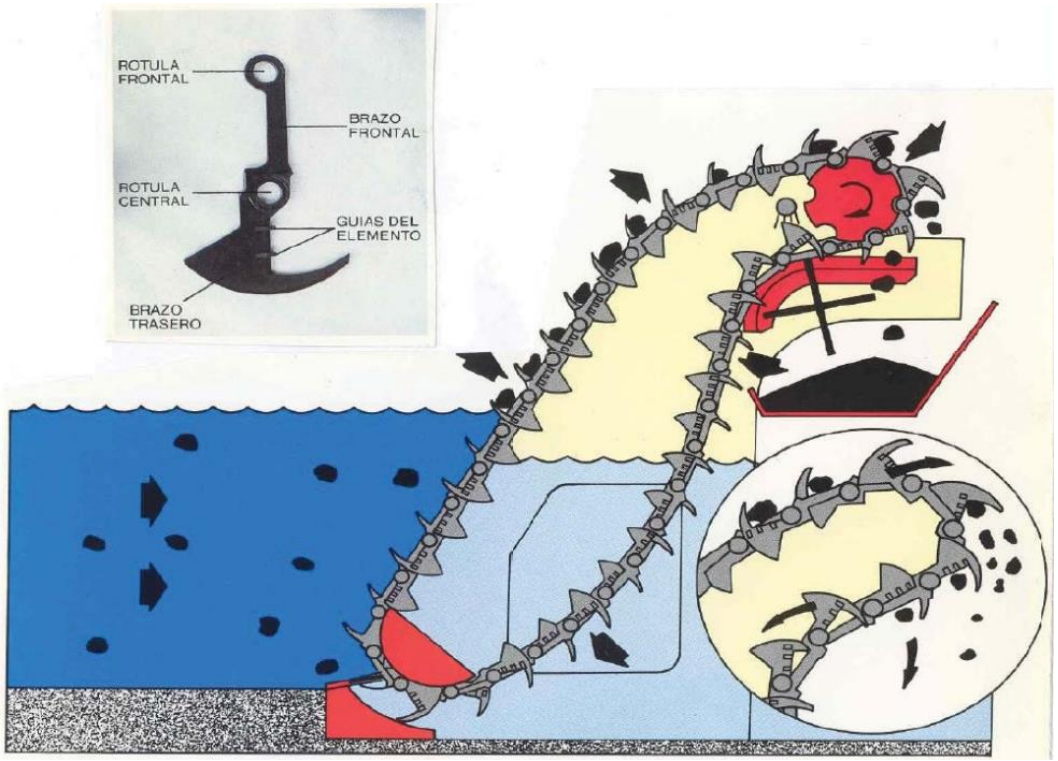
Overflow spill way

- Continuous screening.
- Appropriate for heavy particles collection.

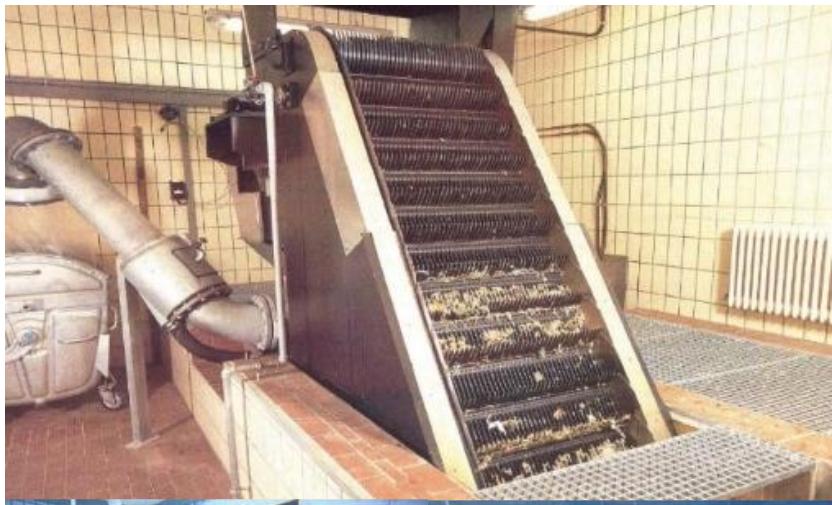
Step screen

- Stationary belt fine screen without conveyor.

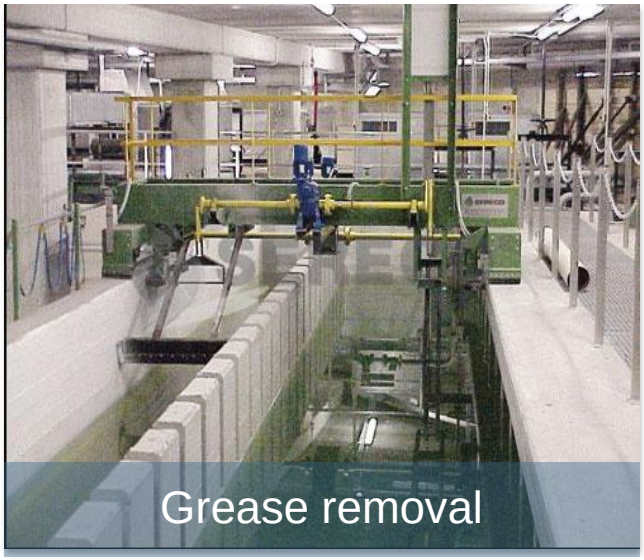
PRE-TREATMENT EQUIPMENT – SLIDING SCREEN SIEVES



Operation scheme for sliding screen

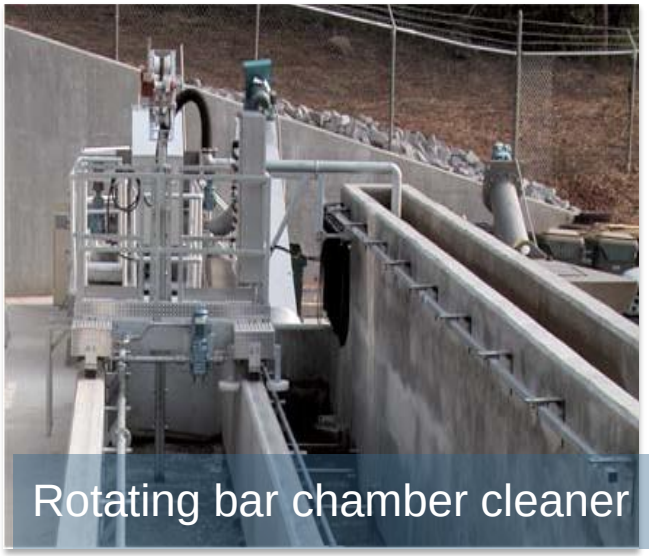


GRIT AND GREASE REMOVAL - EXAMPLES



Grease removal

Conveyor type grit removal



Rotating bar chamber cleaner

Grease and scum remover

GRIT AND GREASE REMOVAL PROCESS VIDEO

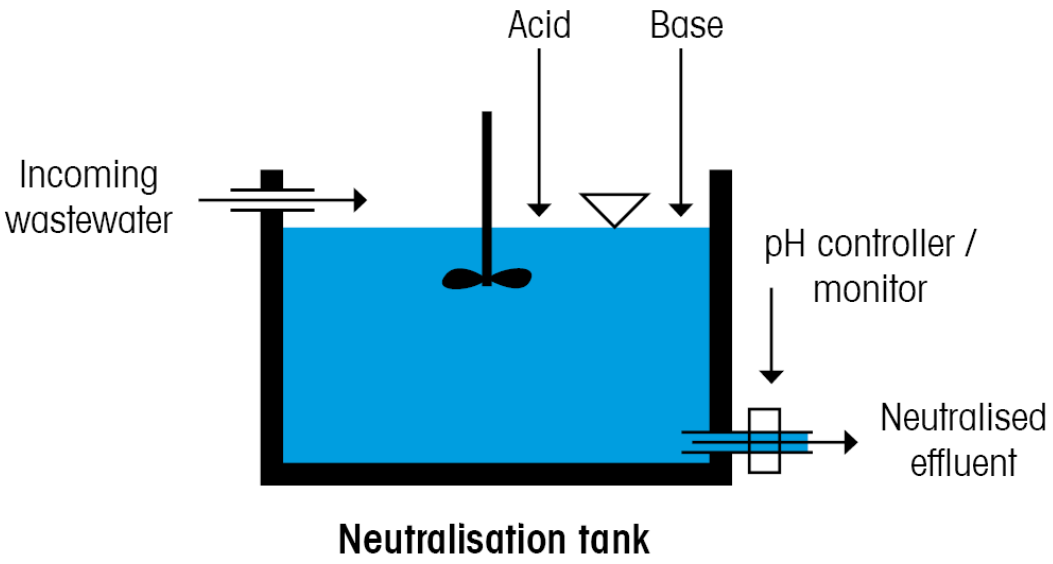
Reference: Work Videos - https://www.youtube.com/watch?v=rGVOKFqG9B0

PH NEUTRALISATION

All neutralisation processes, irrespective of type of waste, share several basic features and operate on the principle of acid-base reaction.

An adequate design of a neutralisation process should consider the following:

- Influent wastewater parameters.
- Type of neutralising agent used.
- Availability of land.
- Laboratory scale experimental results.



PH- NEUTRALISATION – EXAMPLES

Inline pH control system with pH electrode

Inline pH controlsystem dosing pumps with PLC contolled system

CONTROL MEASURES PRE-TREATMENT

Sedimentation — Velocity of the water is lowered below the suspension velocity. The suspended particles settle out of the water due to gravity.

Coagulation — Removal of TSS (Total suspended solids) from waste water. Destabilisation of colloids by addition of chemicals that neutralise the negative charges. Additions of coagulants and pH plays major role.

Flocculation — Agglomeration of destabilised particles into a large size particles known as flocs which can be effectively removed by sedimentation or flotation.

Clarifiers — Support TSS removal by sedimentation and as sludge.

Floatation and DAF — Support removal of the TSS by flocculation and as scum.

CONTROL MEASURES PRE- TREATMENT

Type of Control Measure	Description	Requirements
Sedimentation	Used in clarifier	Suspended particles settle out of the water due to gravity.
Coagulation	Removal of TSS by coagulation	Removal of TSS, (total suspended solids) from waste water. Destabilization of colloids by addition of chemicals.
Flocculation	Removal of TSS by flocculation	Agglomeration of destabilised particles to a large size particles known as flocs , can be effectively removed by sedimentation or flotation.
Clarifiers	Used for sedimentation	Removes solid particulates or suspended solids from liquid for clarification and (or) thickening.
Floatation and DAF	Used for Flocculation	Helps in removing the TSS by flocculation and as scum.

Primary Treatment

PRIMARY TREATMENT

Aim:

Primary treatment of waste water, (sewage) is the removal of settleable organic and inorganic solids by sedimentation, and the removal of materials that will float (scum) by skimming. Quiescent settling allows separation of floating material and heavy solids from liquid waste.

Expected outcome:

Eliminate all dispersed, suspended solids and chemicals which can be coagulated and flocculated to separate them as sludge from the waste water. Reduce the COD to a large extent and send out the residual water with approximately 1/3 BOD reduced by this process.

PRIMARY TREATMENT - TECHNIQUES

Primary treatment techniques:

- Coagulation
- Flocculation
- Sedimentation
- Clarification
- Filtration etc.

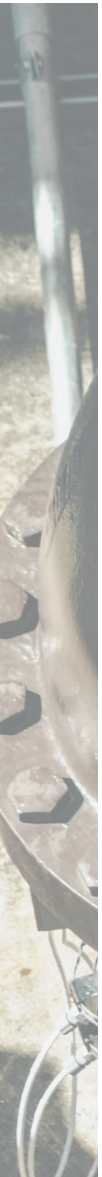
Clarifiers are employed to removed the TSS, TDS and for correction of pH.

CONTROL MEASURES PRIMARY TREATMENT

Type of Control Measure	Description	Requirements
Coagulation	Formation of coagulants in clarifiers, helps in removal of TSS	Destabilising the collloids by adding coagulants with hi valence chemicals Al3+, Fe3+.
Flocculation	Agglomeration of destabilised colloids to higher mass particles known as flocs	Gentle mixing of flocculation causes destabilised colloids to cluster by adding organic polymers
Sedimentation	Process of separating colloids and total suspended solids by settling using coagulation and flocculation	The size and density of the particles, physical properties of the solids decide the settling behaviour. Classified by four types of settling behaviours like, 1) free settling, 2) flocculations, 3)suspension and concentrate, 4) compression of sludge
Clarification	Process of settling solid particles and suspended solids	Deposited by the sedimentation process by clarification or thickening
Filtration	Filtration using decantation	The clarified water are decanted using various weirs

Secondary Treatment

SECONDARY TREATMENT



Aim:

To further treat the effluent from primary treatment to remove the residual organics and suspended solids. In most cases, secondary treatment follows primary treatment and involves the removal of biodegradable dissolved and colloidal organic matter using aerobic biological treatment processes.

Expected Outcome:

Secondary treated sewage is expected to produce effluent with a monthly average of less than 30 mg/l BOD (biochemical oxygen demand) and less than 30 mg/l suspended solids.

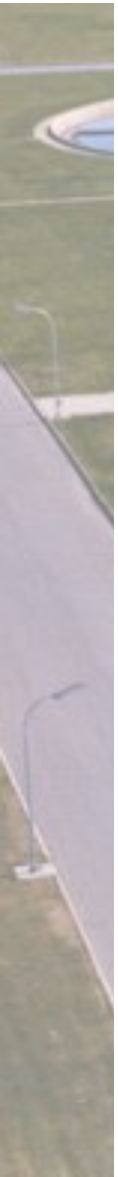
Source: http://www.fao.org/docrep/T0551E/t0551e05.htm#3.2.4%20tertiary%20andor%20advanced%20treatment

BIOLOGICAL WASTEWATER TREATMENT

- Micro-organisms consume organic matter from the wastewater, using oxygen for respiration.
- Millions of aerobic and facultative micro-organisms remove pollutants through their living and growing processes.

E.Coli

THREE STEPS IN BIOLOGICAL TREATMENT

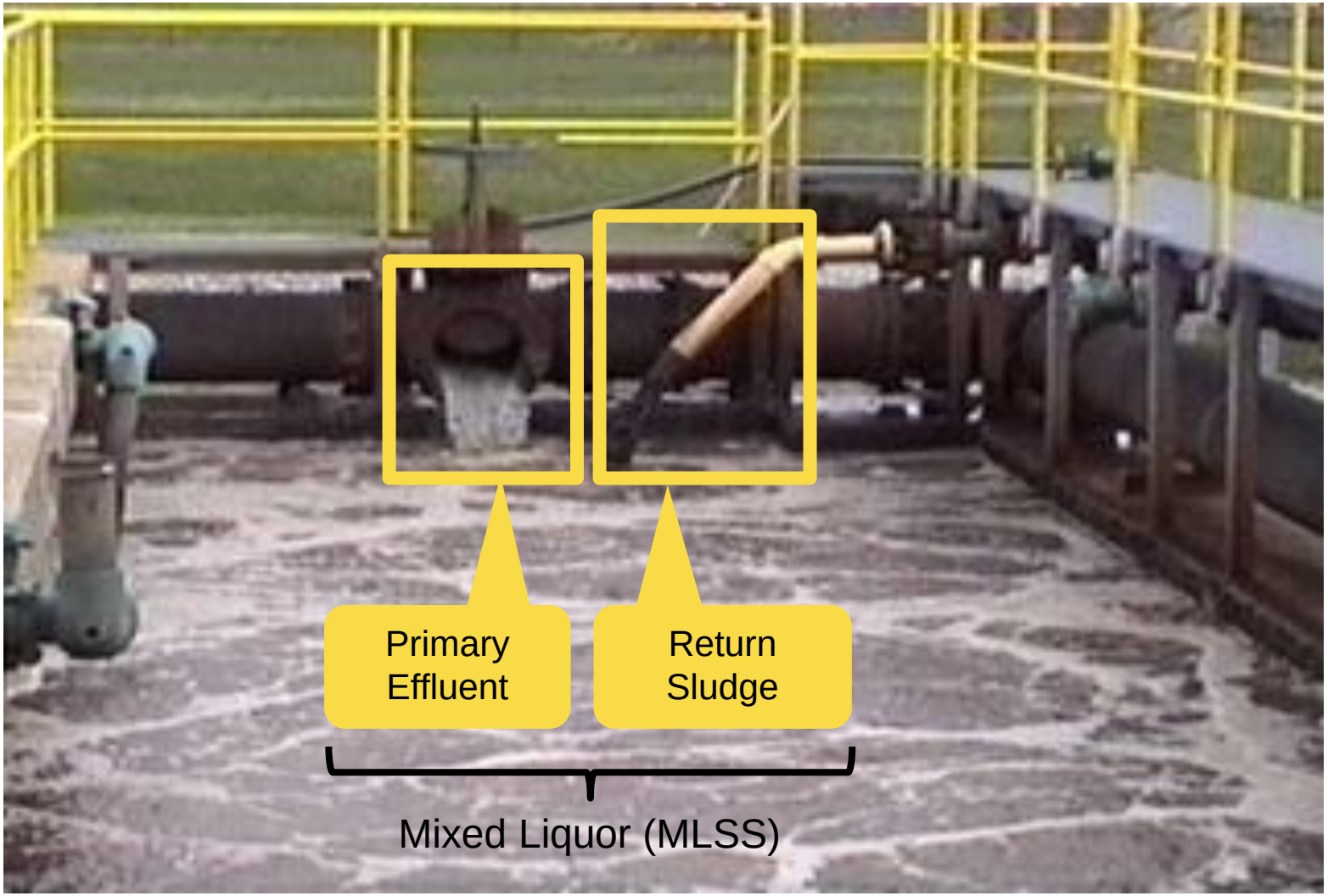


1) Transfer of food from wastewater into micro organism cell:
   a. Adequate mixing.
   b. Enough retention time.

2) Conversion of food to new cells and by-product:
   a. Acclimated biomass.
   b. Useable food supply.
   c. Adequate D.O.
   d. Proper nutrient balance.100 : 5 : 1 (C : N : P)

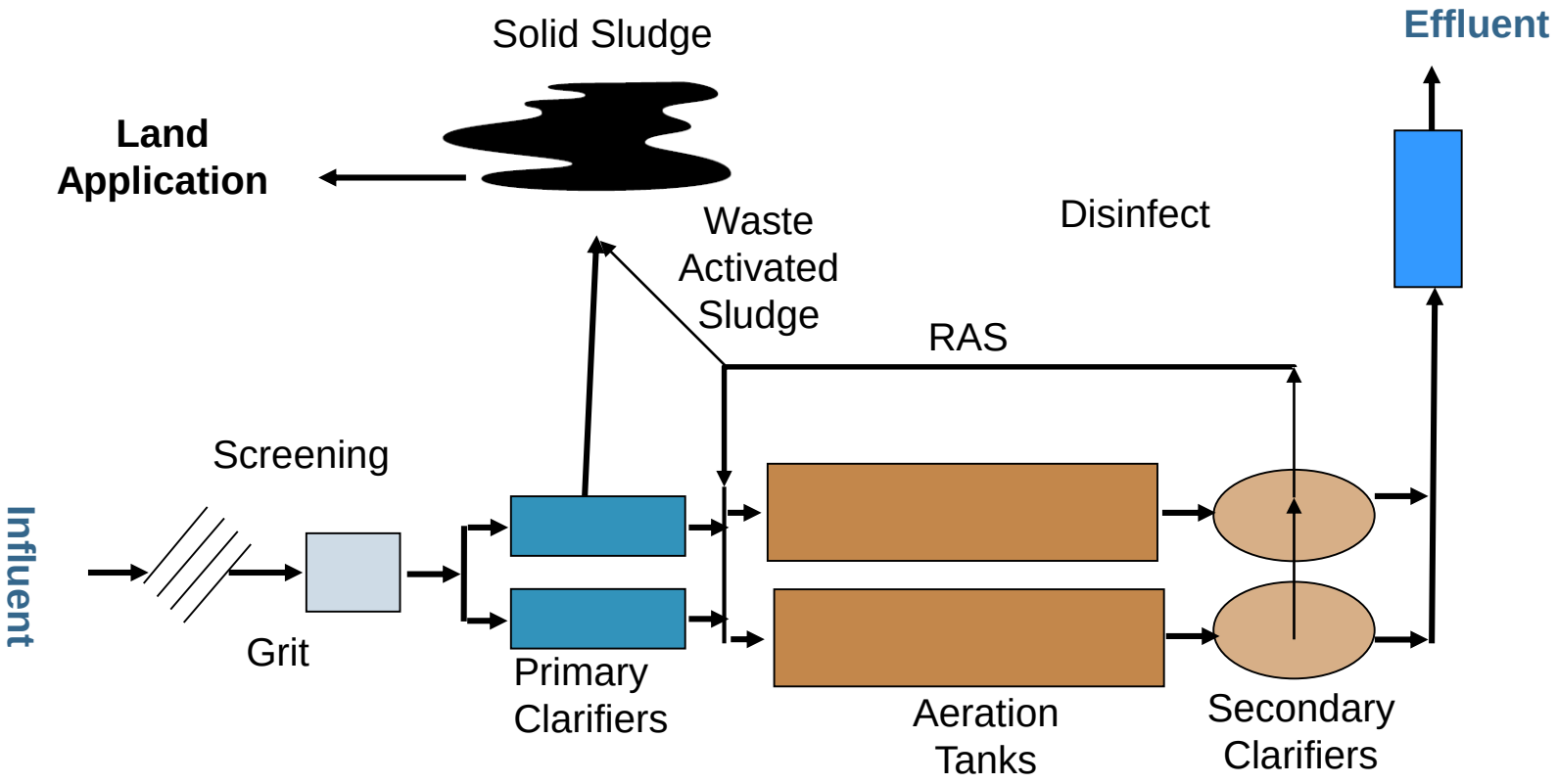
3) Flocculation and Solids Removal:
   a. Proper mixing.
   b. Proper growth environment.
   c. Secondary clarification.

ACTIVATED SLUDGE PROCESS - EXAMPLE

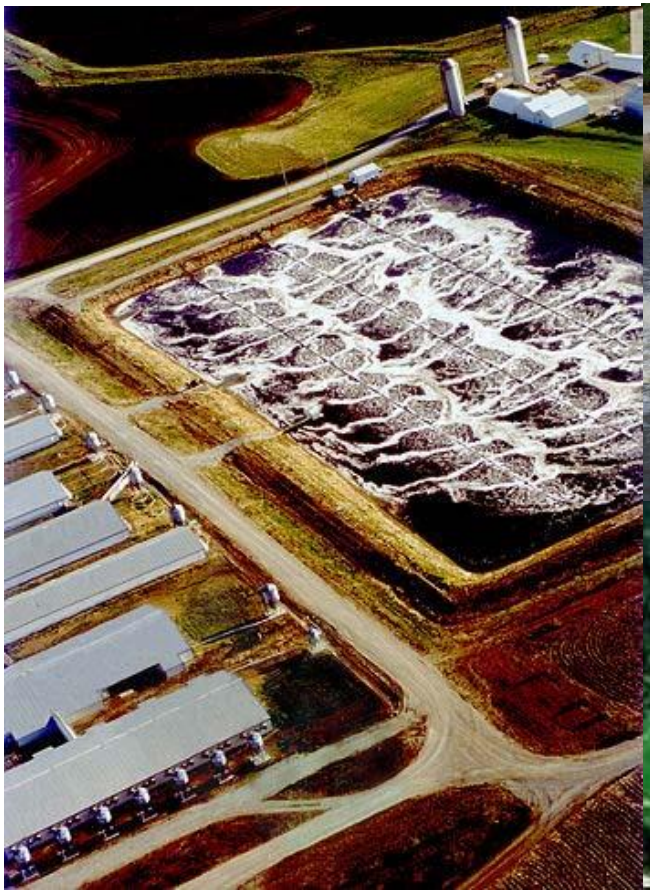


Aeration Tank

TYPICAL FLOW-THROUGH ACTIVATED SLUDGE PLANT



SECONDARY TREATMENT - AERATED LAGOON



CONTROL MEASURES SECONDARY TREATMENT

Type of Control Measure	Description	Requirements
Biological treatment	Treating the effluent using the biological microbes to remove the chemicals	Requirement of micro organisms to consume chemicals from wastewater
Aerobic biological treatment	Using the aeration conditions	Using oxygen to break the –N=N- bond in colours and other chemicals using aerobic (with air and oxygen conditions). Main requirements include the Dissolved oxygen(DO), microbes and nutrients for microbes(food- the organic load)
anaerobic biological treatment	Using the non aeration conditions	Using microorganisms to convert complex organic chemicals to methane and CO2 under anaerobic conditions

Tertiary Treatment

TERTIARY TREATMENT

Aim:

Tertiary treatment (also known as advanced treatment), refers to any treatment process or processes to remove some type of water contamination not removed by primary and secondary wastewater treatment. Advanced wastewater treatment may use biological or physical-chemical treatment processes to remove water contaminants not removed by primary and secondary treatment, such as nutrients, toxic materials or additional suspended solids and BOD removal.

Expected Outcome:

In various combinations, these processes can achieve any degree of pollution control that is desired.

Reference: http://www.brighthub.com/environment/science-environmental/articles/68537.aspx

CONTROL MEASURES SECONDARY TREATMENT

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Anaerobic biological treatment	Using the non aeration conditions	Using microorganisms to convert complex organic chemicals to methane and CO2 under anaerobic conditions

OVERVIEW TREATMENT POSSIBILITES
TERTIARY TREATMENT

Type of treatment	Description	Used in order to…
High rate filtration	Used to filter the residual suspended solids and particles which can be filtered using electrolytical charges	For the residual colour, suspended solids formed after secondary treatments
Advanced oxidation process	Removal of residual chemicals and bacteria by oxidation process	Using different oxidation processes, like ozone and fenton process
Ultra filtration	Using membrane filtration process	Used for bivalent salts and dissolved solids with weak electrolytical force
Nano filtration	Using membrane filtration process	Used for monovalent salts and dissolved solids with strong electrolytical force
Reverse osmosis	Using membrane filtration process	Used for removal of dissolved solids using reverse osmosis concept by high pressure pumps and membranes
Multiple effect evaporator	Concentration of salt using evaporation, by removal of excess water	Used multiple effect evaporation by evaporation and vacuum evaporation technologies

CONTROL MEASURES TERTIARY TREATMENT

Type of Control Measure	Description	Requirements
High rate filtration	Used to filter the residual suspended solids and particles which can be filtered using electrolytical charges	Multimedia filtration, using filter media and activated carbon filters
Advanced oxidation process	Removal of residual chemicals and bacteria by oxidation process	Use of different oxidation process by selective and suitable oxidation method considering the effluent characteristics
Ultra filtration	Using membrane filtration process	Use of selected salts suitable for separation by ultra filtration
Nano filtration	Using membrane filtration process	Use of selected salts suitable for separation by nano filtration
Reverse osmosis	Using membrane filtration process	Critical parameters include the minimal total suspended solids and different salts, complex salts which can’t be separated by ultrafiltration and nano filtration
Multiple effect evaporator	Concentration of salt using evaporation, by removal of excess water	Rejects from the filtration process and used for separation of solid waste from rejected liquid waste

ACTIVITY

REFLECTION

Take notes.
Workbook,
Exercise (22-3).

Discuss the technology available in your company or that you have come across.

Discuss your experiences with the group. What were the advantages and disadvantages of the technology you used.

Open To Questions

SUMMARY

Every participant to feedback with one key learning from the session.

Take notes in your workbook, Exercise (22-4).