NPTEL ONLINE CERTIFICATION COURSES

Course Name: Introduction to Environmental Engineering and Science – Fundamentals and Sustainability Concepts

Faculty Name: Dr. Brajesh Kumar Dubey

Department : Civil engineering

Topic Basics of Wastewater Collection, Treatment & Resource Recovery

Lecture 41: Wastewater collection and characterization

CONCEPTS COVERED

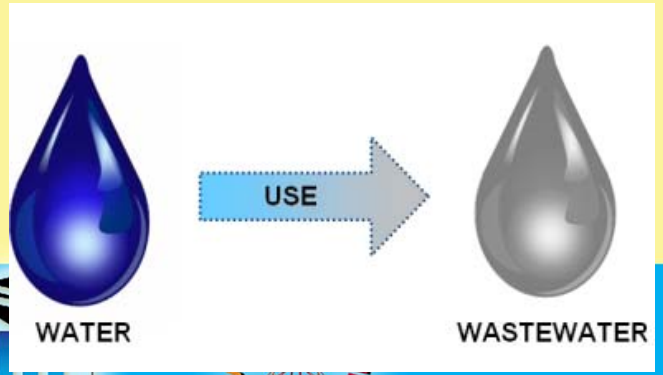
Concepts to be Covered

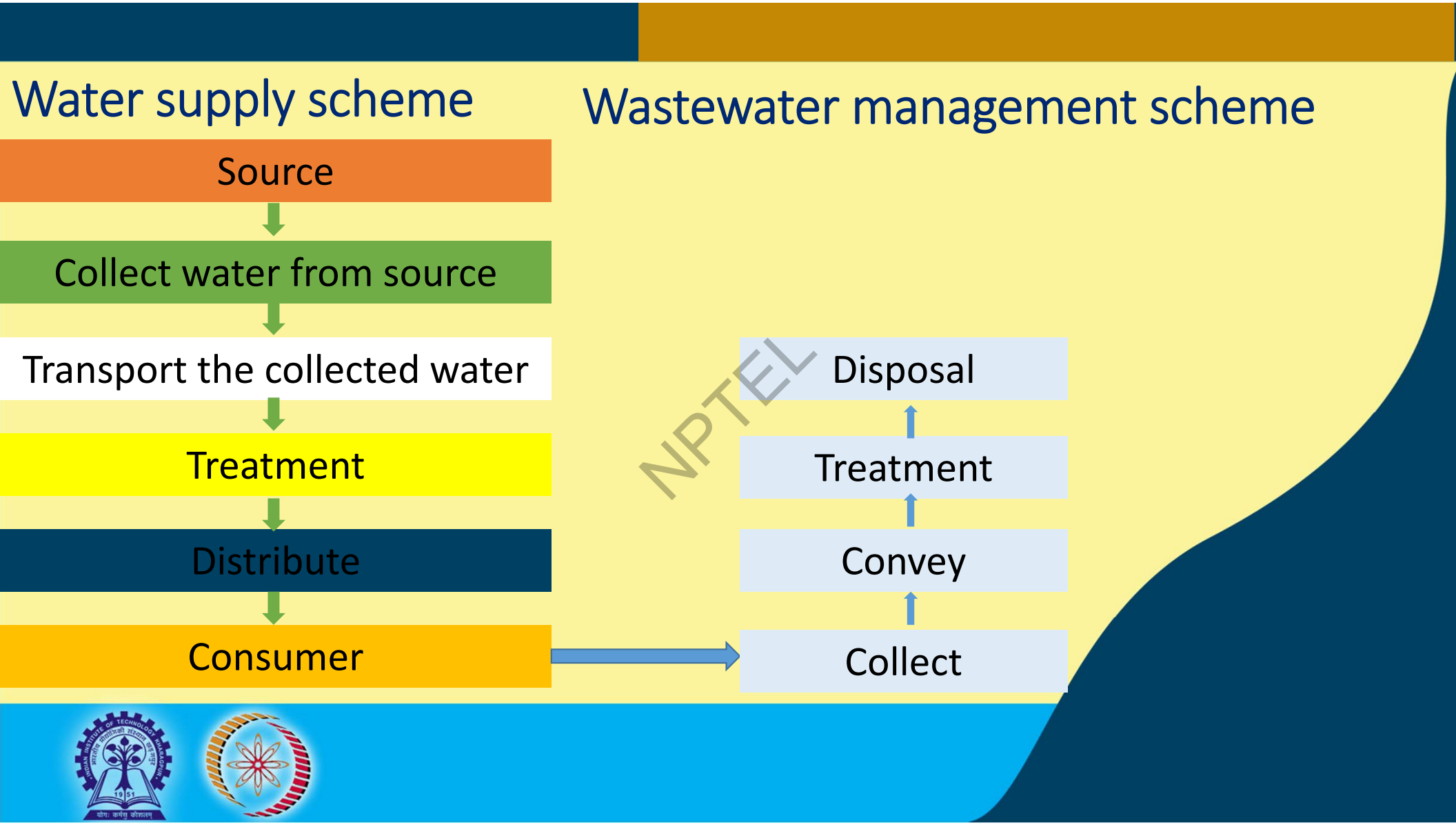
- ❑ Wastewater collection and characterization
- ❑ Preliminary treatment
- ❑ Primary treatment
- ❑ Secondary treatment
- ❑ Disposal

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***.




Water supply scheme
Source
Collect water from source
Transport the collected water
Treatment
Distribute
Consumer
Wastewater management scheme
Disposal
Treatment
Convey
Collect
NPTEL

As it was discussed in last week

Source: http://www.govisitcostarica.com/images/photos/full-cano-negro-brown-river.jpg

Source: http://headlinenewsstories.com/wp-content/uploads/2010/06/india.jpg

Source: http://sinkhouse1.com/wp-content/uploads/2011/07/Old-Sink.jpg

Pre-Treatment

Coagulation-Flocculation

Rapid Sand Filtration

Post-Treatment

Chlorination

This week

Source: http://sinkholes1.com/wp-content/uploads/2011/07/Old-Sink.jpg

Source: http://www.govisitgalarica.com/images/photos/full-cano-negro-brown-river.jpg

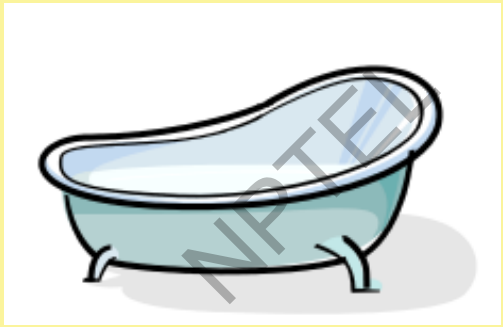
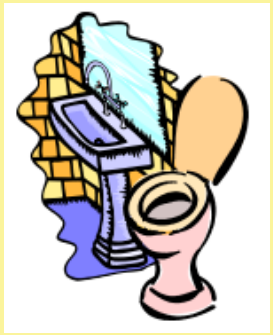
Source: http://sinkholes1.com/wp-content/uploads/2011/07/Old-Sink.jpg

Tertiary treatment ← **Secondary treatment** ← **Primary treatment**

Domestic Wastewater

Domestic wastewater (from homes) includes toilet waste and water used for laundry, bathing, and dishwashing.



Source:
http://www.neoakruthi.com/blog/domestic-sewage-treatment-plant.html

Industrial, Commercial, Institutional (ICI) Wastewater

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




Source:
http://www.neoakruthi.com/blog/domestic-sewage-treatment-plant.html

Fundamental definitions

Refuse

Garbage

Sewage

Sullage

Wet weather water

Dry weather flow

Sewerage

Sewer

Fundamental definitions

Wet weather water

Source: https://rainharvesting.co.uk

Dry weather flow

Source: https://wokejournal.com/2019/07/11/indias-population-will-surpass-chinas-by-2027-says-united-nations-report/

Systems of Sewerage

Separate system

Storm water

Dry weather flow

Combined system

Storm water and
Dry weather flow

Partially combined or
partially separate system

Systems of Sewerage

SEPARATE SYSTEM OF SEWERAGE

In this system two sets of sewers are laid. The sanitary sewage is carried through sanitary sewers while the storm sewage is carried through storm sewers. The sewage is carried to the treatment plant and storm water is disposed of to the river.

Advantages:

1) Size of the sewers are small
2) Sewage load on treatment unit is less
3) Rivers are not polluted
4) Storm water can be discharged to rivers without treatment.

Systems of Sewerage

SEPARATE SYSTEM OF SEWERAGE

Disadvantage

1) Sewerage being small, difficulty in cleaning them
2) Frequent choking problem will be their
3) System proves costly as it involves two sets of sewers

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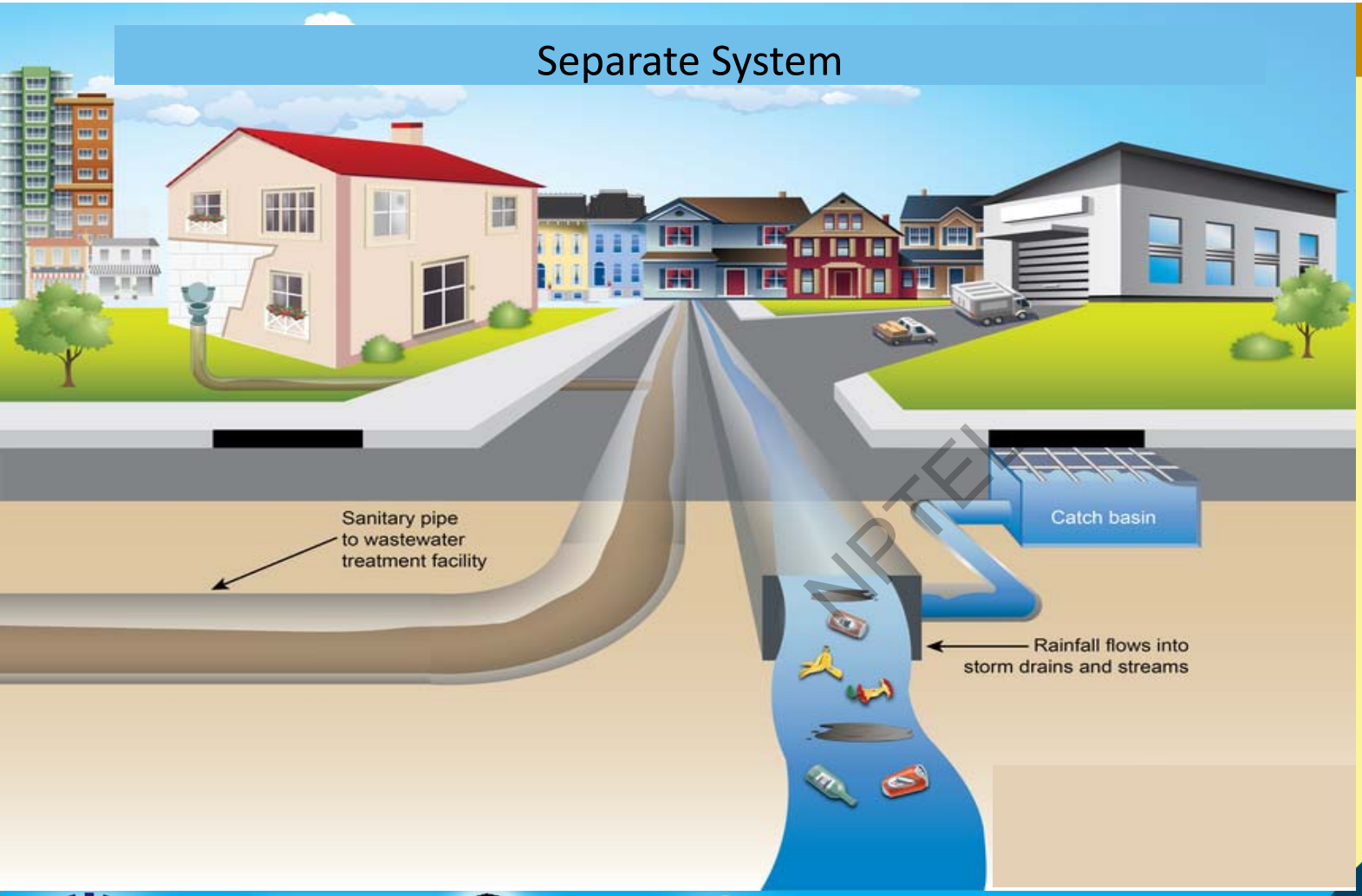
Separate System



Source: https://www.alexandriava.gov/tes/stormwater/info/default.aspx?id=100183

Systems of Sewerage

COMBINED SYSTEM OF SEWERAGE

When only one set of sewers are used to carry both sanitary sewage and surface water. This system is called combined system. Sewage and storm water both are carried to the treatment plant through combined sewers.

Advantages:

1) Size of the sewers being large, chocking problems are less and easy to clean.
2) It proves economical as 1 set of sewers are laid.
3) Because of dilution of sanitary sewage with storm water nuisance potential is reduced

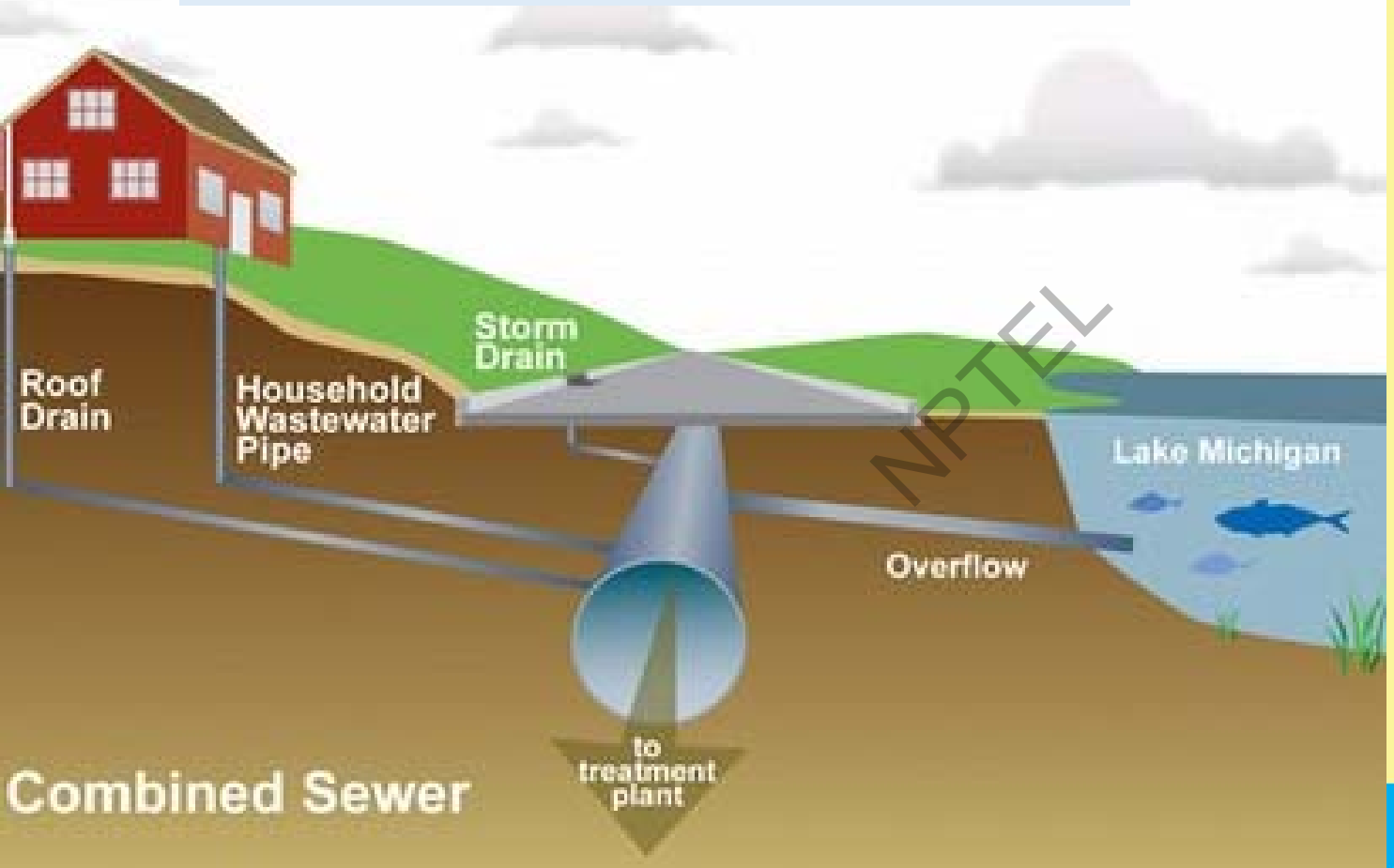
Systems of Sewerage

COMBINED SYSTEM OF SEWERAGE

Disadvantages:

1) Size of the sewers being large, difficulty in handling and transportation.
2) Load on treatment plant is unnecessarily increased
3) It is uneconomical if pumping is needed because of large amount of combined flow.
4) Unnecessarily storm water get polluted

Combined system



Source: https://www.alexandriava.gov/tes/stormwater/info/default.aspx?id=100183

Partially combined or partially separate system

A portion of storm water during rain is allowed to enter sanitary sewer to treatment plants while the remaining storm water is carried through open drains to the point of disposal.

Advantages:-

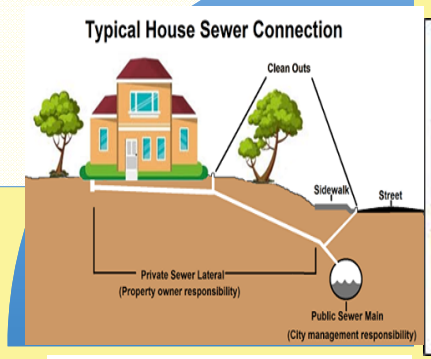
The sizes of sewers are not very large as some portion of storm water is carried through open drains. Combines the advantages of both the previous systems. Silting problem is completely eliminated.

Disadvantages:-

1. During dry weather, the velocity of flow may be low.
2. The storm water is unnecessary put load on to the treatment plants to extend.
3. Pumping of storm water in unnecessary over-load on the pumps.

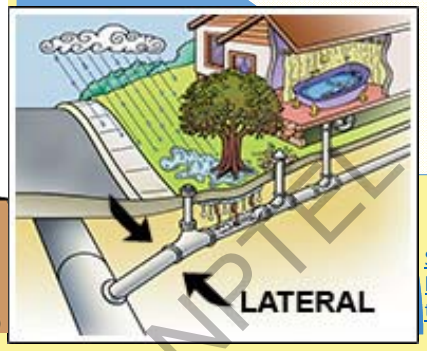
Classification of sewers

- House sewer



Source:
https://www.redwoodcity.org/departments/public-works/sewer

- Lateral sewer

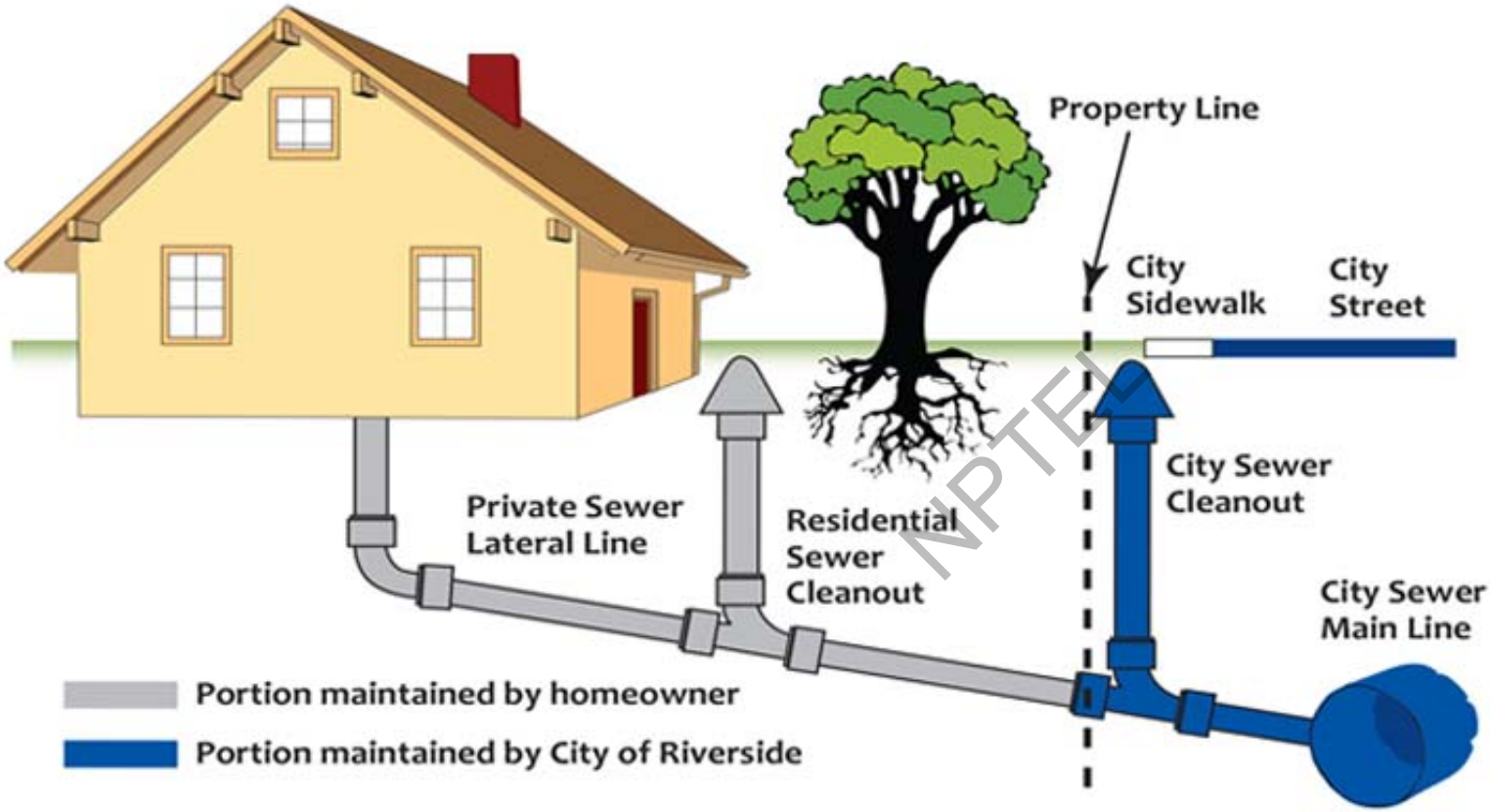


Source:
https://www.alexandriava.gov/tes/stormwater/info/default.aspx?id=100183

- Trunk or main sewer

Source:
https://www.shutterstock.com/es/search/sewer+outfall

- Out fall sewer



Source:
https://www.redwoodcity.org/departments/public-works/sewer

Characteristics of Sewage

Wastewater Characteristics

- Physical
- Chemical
- Biological

Physical characteristics:

1. Turbidity
2. Colour
3. Odour
4. Temperature

Chemical characteristics:

Total solids
- Suspended → size upto 1µm
- Colloidal → 1 µm to 10^{-3} µm
- Dissolved → < 10^{-3} µm

Organic matter
- Inorganic
  Example: Minerals, salts, gravel, debris, sand
- Organic
  Example: Cellulose, starch, sugar etc.

Determination of solids

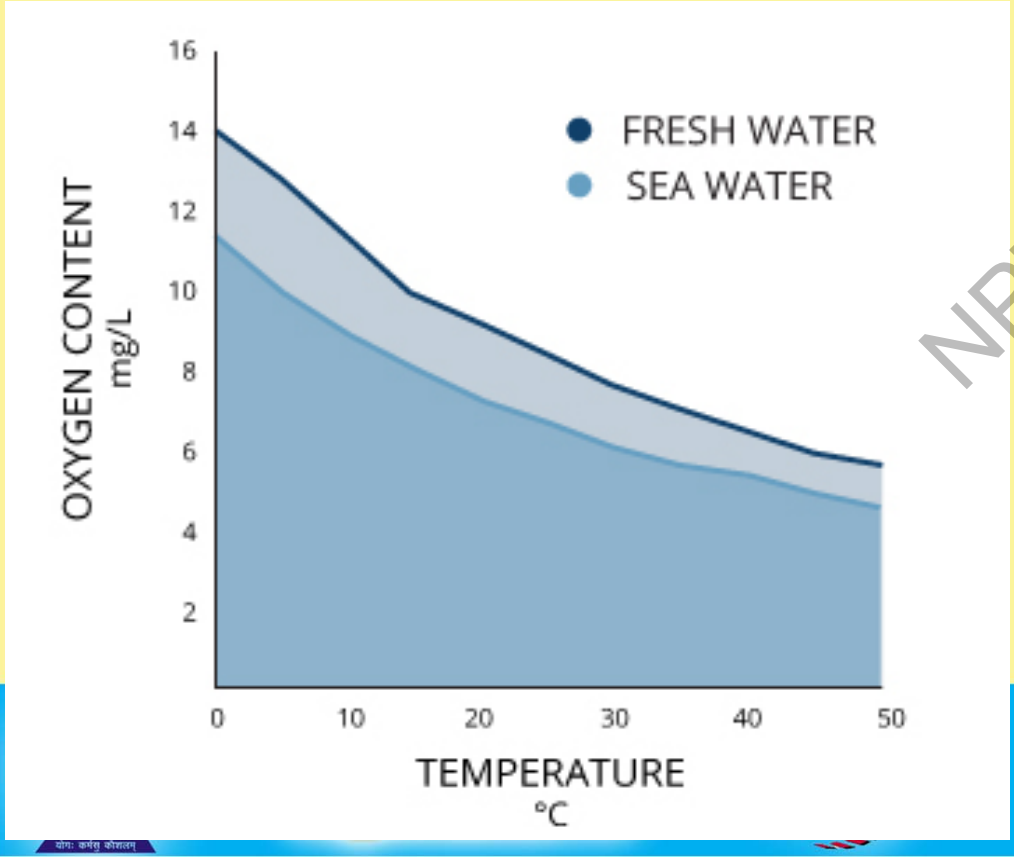
(i) Total solids
(ii) Suspended solids
(iii) Dissolved and colloidal solids
(iv) Volatile and fixed solids
(v) Settleable solids

Volume of settleable solids

Source:
https://www.fishersci.ca/shop/products/whe
aton-plastic-imhoff-cone/02927011

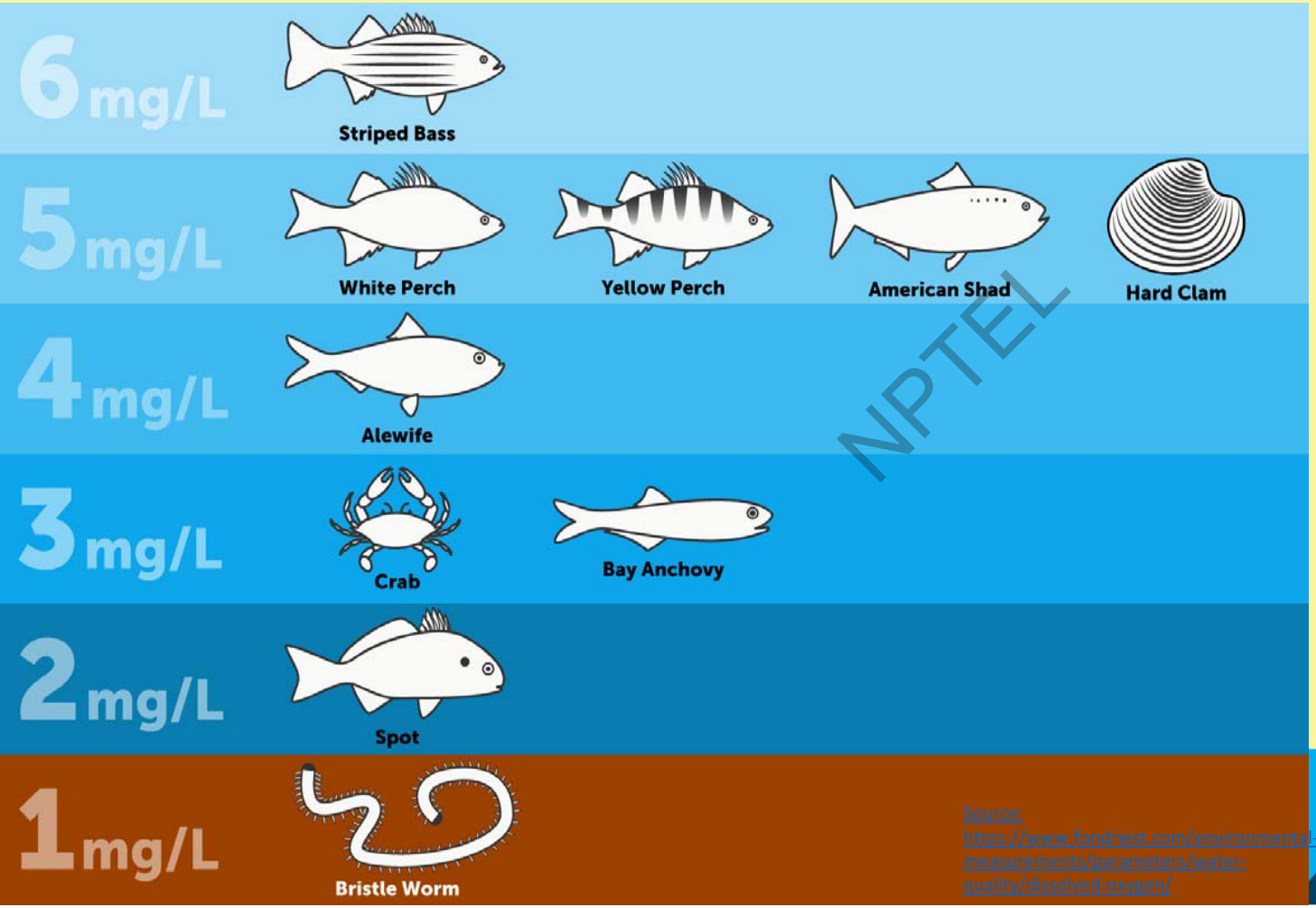
Dissolved oxygen (DO)

To know the extent of pollution of sewage.



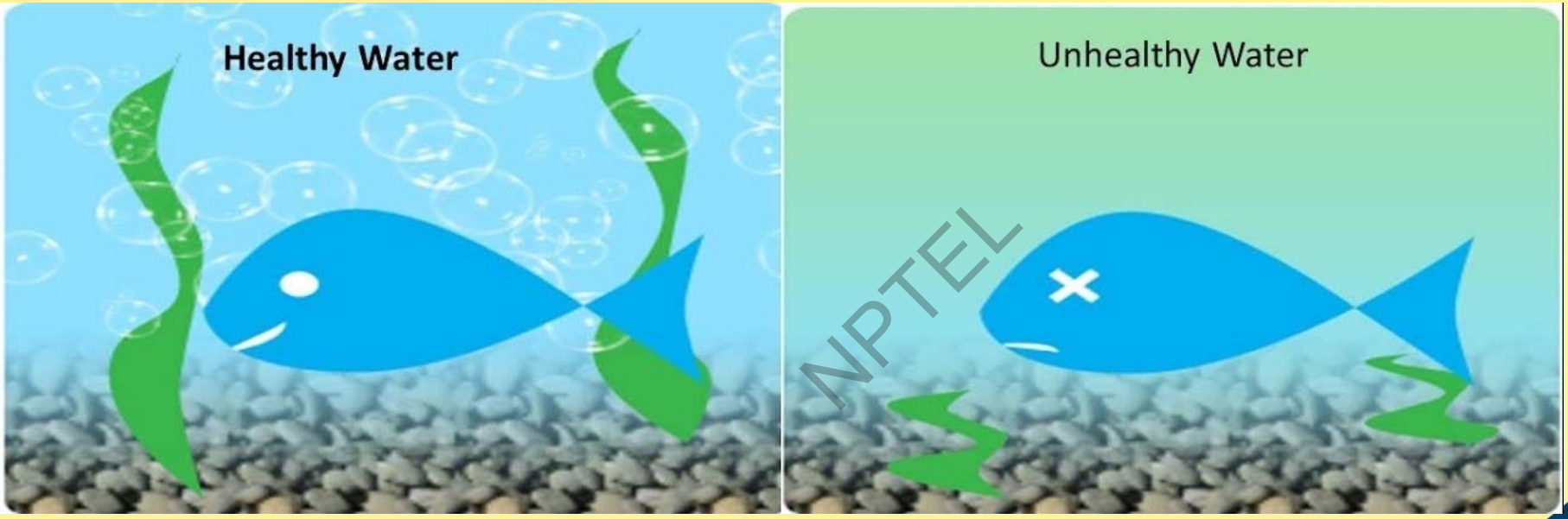
Source: https://www.fondriest.com/environmental-measurements/parameters/water-quality/dissolved-oxygen/

Dissolved oxygen (DO)



Source: https://www.fondriest.com/environmental-measurements/parameters/water-quality/dissolved-oxygen/

Dissolved oxygen (DO)



Source: https://activeanglingnz.com/2017/02/23/the-importance-of-dissolved-oxygen/

Types of organic matter:

1. Biologically active (means bacteria can stabilize this organic matter)
2. Biologically inactive (bacteria can not act on this organic matter)

Chemical Oxygen Demand (COD): It is chemical oxidation with potassium permanganate or potassium dichromate in an acid solution.

Theoretical oxygen Demand: It is the oxygen demand that can be worked out theoretically.

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Department : Civil engineering

Topic Basics of Wastewater Collection, Treatment & Resource Recovery

Lecture 43: BOD Concepts &
Preliminary treatment of wastewater

What is Biochemical Oxygen Demand (BOD)?

Definition

The quantity of oxygen utilised by a mixed population of micro-organisms to biologically degrade the organic matter in the wastewater under aerobic condition

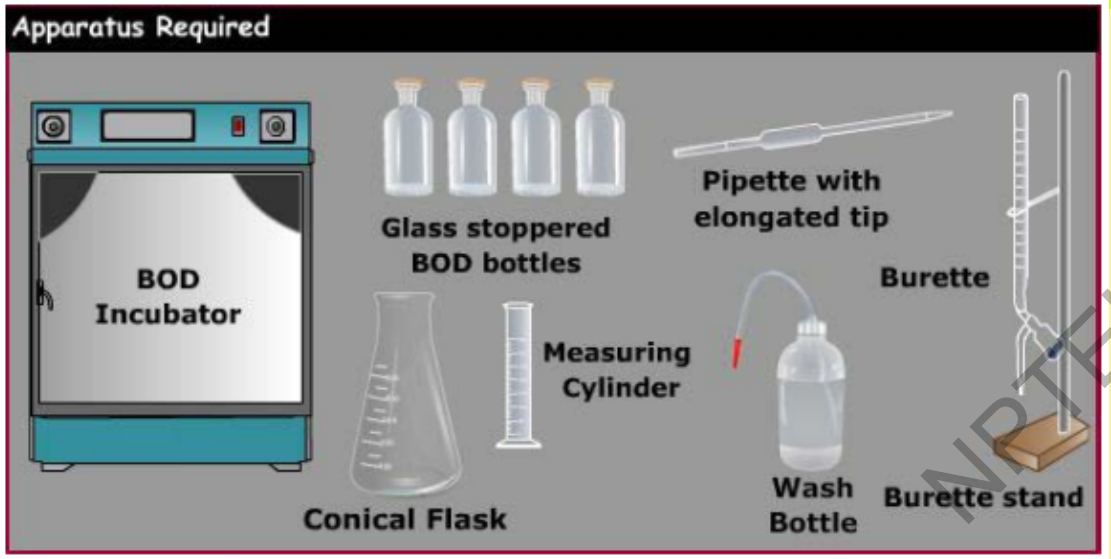
BOD is the most important parameter in water pollution control

It is used as a measure of organic pollution as a basis for estimating the oxygen needed for biological processes, and as an indicator of process performance.

$$\text{Organic matter} + O_2 \xrightarrow{\text{microorganism}} CO_2 + H_2O + \text{new cells}$$

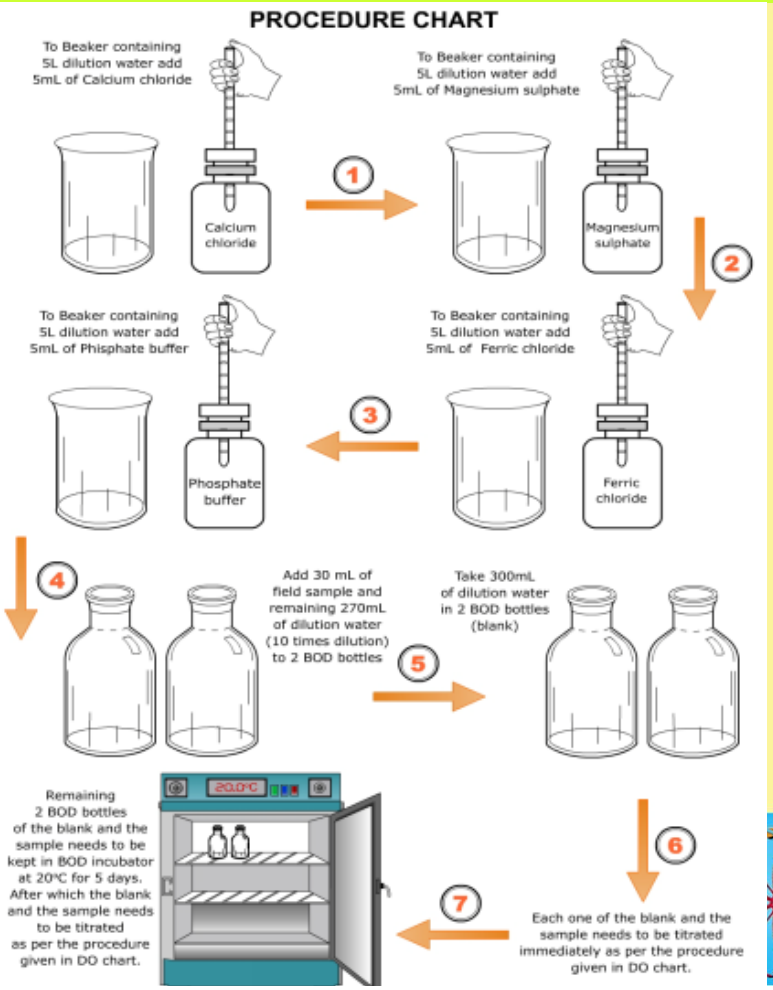
- BOD test, 5-day at 20°C
  3-day at 30°C

BOD measurement



Source: http://mitpolytechnic.ac.in/downlaods/09_knowledge-bank/05_civil/SEM-5/PHE/exp13f.pdf

BOD measurement



Source: http://mitpolytechnic.ac.in/downlaods/09_knowledge-bank/05_civil/SEM-5/PHE/exp13f.pdf

Calculation of BOD,

$$BOD_5^{20^\circ C} = \left(DO_{initial} - DO_{final}\right) \times Dilution\ factor$$

Where

$BOD_5^{20^\circ C}$= biochemical oxygen demand, mg/L

$DO_{initial}$= initial DO of the diluted wastewater sample about 15 min. after preparation, mg/L

DO_{final}= final DO of the diluted wastewater sample after incubation for five days, mg/L

Why dilution is needed?

- For a valid BOD test, the final DO should not be less than 1 mg/L BOD test is invalid if DO_t value near zero.
- Dilution can decrease organic strength of the sample.
- By using dilution factor, the actual value can be obtained.
- Dilution of wastes:
    - By direct pipetting into 300 mL BOD bottle

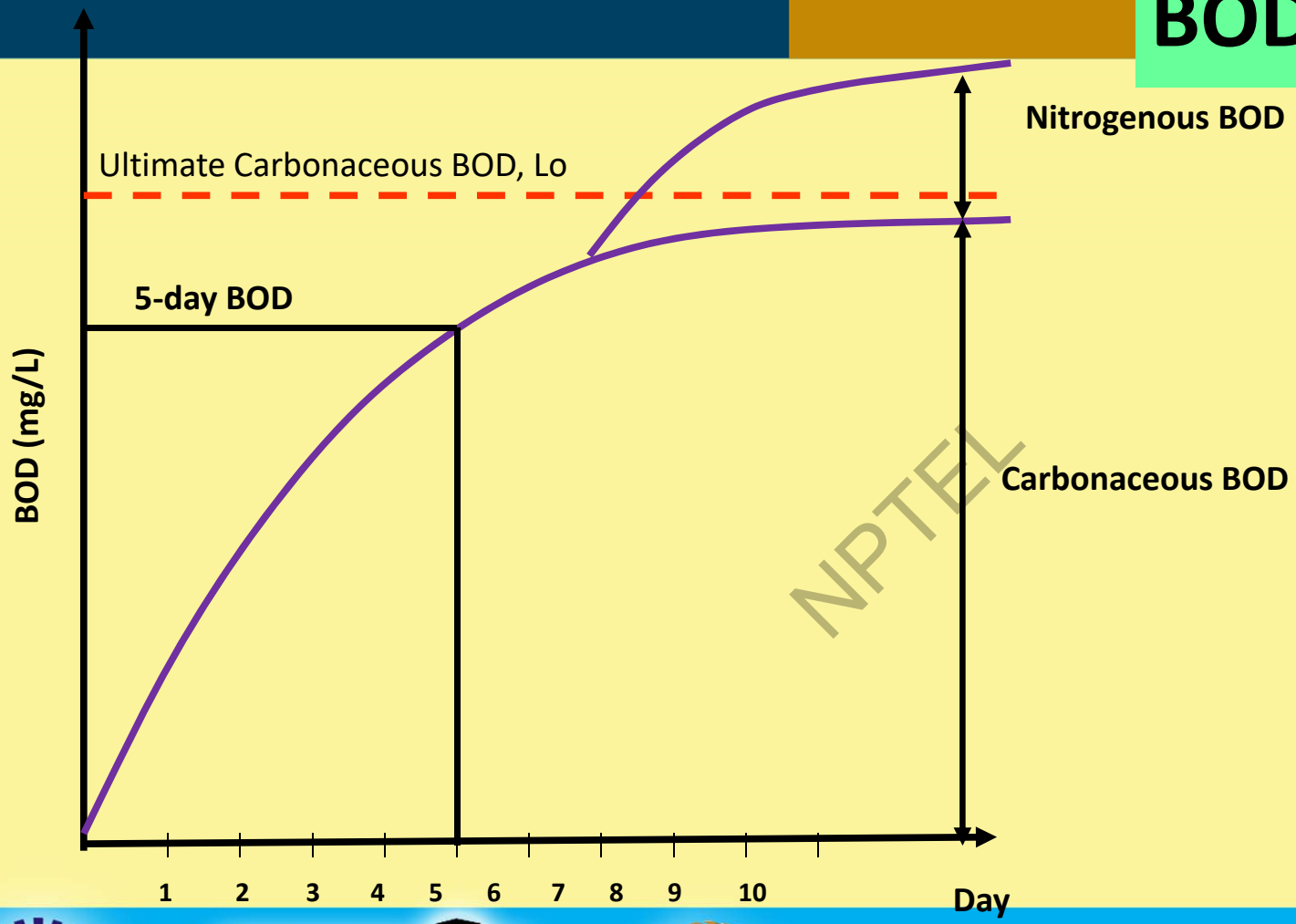
BOD Analysis

In aerobic processes (O_2 is present), heterotrophic bacteria oxidise about 1/3 of the colloidal and dissolved organic matter to stable end products ($CO_2 + H_2O$) and convert the remaining 2/3 into new microbial cells that can be removed from the wastewater by settling.

The overall biological conversion proceeds sequentially, with oxidation of carbonaceous material as the first step (known as carbonaceous oxygen demand):

Organic matter + O_2 → **$CO_2 + H_2O$ + new cells**

BOD curve



- The ultimate BOD (Lo) is defined as the maximum BOD exerted by the waste.
- The carbonaceous oxygen demand curve can be expressed mathematically as

$$BOD_t = Lo\ (1\text{-}10^{-Kt})$$

Where BOD_t = biochemical oxygen demand at time t, mg/L

Lo = ultimate BOD, mg/L

t = time, days

K = reaction rate constant, day^{-1}

In a BOD test the initial do of the 2% diluted sample is 6 mg/l and its find after 5 day incubation at 20^0C is 2 mg/l. The find 5-day BOD of sewage sample

Solution: $y_5^{20^0C}$ = $\{[DO]_{initial} - [DO]_{find}\}$ X Dilution factor

= $[6 - 2] \times \frac{100}{2}$ = 200 mg/l

Dilution factor : Number of times sewage is diluted with distilled water.

Eg: for 2% solution, Dilution

Factor = 100/2 = 50.

If 5 day BOD at 20^0C is 200 mg/l. Find 3 day BOD at 15^0C and 8 day BOD at 30^0C.

Take K_{20} = 0.23 d^{-1} (base e)

Solution : $K_T = K_{20}\,(1.047)^{T-20}$

$K_{15} = 0.23(1.047)^{15-20} = 0.182\ d^{-1}$

$K_{30} = 0.23\,(1.047)^{30-20} = 0.364\ d^{-1}$

$y_5^{20^0C} = L_0[1- e^{-K_{20}t}]$

$200 = L_0[1- e^{-0.23 \times 5}]$

L_0 = 292.67

3 day BOD at 15^0C, $y_3^{15^0}$ = $L_0[1 - e^{-K_{15}t}]$

= $292.67[1 - e^{-0.182 \times 3}]$

= 123.137 mg/l

8 day BOD at 30^0C, $y_8^{30^0C}$ = $L_0[1 - e^{-K_{30}t}]$

= $292.67[1 - e^{-0.364 \times 8}]$

= 276.758 mg/l

BOD/COD ratio:

1. If BOD_u / COD lies between 0.92 and 1, then the waste water can be considered to be fully biodegradable.
2. If BOD_5 / COD vary between 0.63 and 0.68 then the waste water can be considered to be fully biodegradable wastes.

Relative Stability:

Ratio of amount of oxygen available in the effluent (DO) to the total oxygen required to satisfy the first stage BOD demand.

Population Equivalent:

Population equivalent refers to the amount of oxygen-demanding substances (measured in BOD or BOD_5) in wastewaters whose oxygen consumption during biodegradation equals the average oxygen demand of the wastewater produced by one person during one day.

$$\text{Population equivalent} = \frac{Total\ Standard\ BOD_5\ of\ industrial\ sewage\ per\ day}{Standard\ BOD_5\ of\ domestic\ seweage\ per\ person\ per\ day}$$

Average standard BOD_5 of domestic sewage is about 0.08 kg/day/person.

What is wastewater treatment

- Usually refer to sewage treatment, or domestic wastewater treatment
- Process of removing contaminants from wastewater, both runoff and domestic

Why treat wastewater?

- Untreated wastewater harmful to health
- Breeding sites for insects, pests and micro organisms
- Can cause environmental pollution and affect ecosystem

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Topic Basics of Wastewater Collection, Treatment & Resource Recovery

Lecture 44: Wastewater Treatment -1

Treatment processes are classified as :

(i) Preliminary treatment

(ii) Primary treatment

(iii) Secondary or biological treatment

(iv) Tertiary treatment

(I) Preliminary Treatment:

Separating floating materials, heavy inorganic solids.

Processes used :

(a) Screening : Floating matter removal

(b) Grit chambers or detritus tanks : To remove grit or sand

(c) Skimming tanks : To remove oils or greases

Treatment processes are classified as :

(ii) Primary Treatment : Removal of large suspended organic solids.

Sedimentation tank : To remove suspended solids

(iii) Secondary Treatment : The effluent from sedimentation tank should be stabilized aerobically or anaerobically to get clearer effluents

Aerobic biological units

a) Filters : Trickling Filters
b) Aeration tanks : Activated sludge process
c) Oxidation ponds

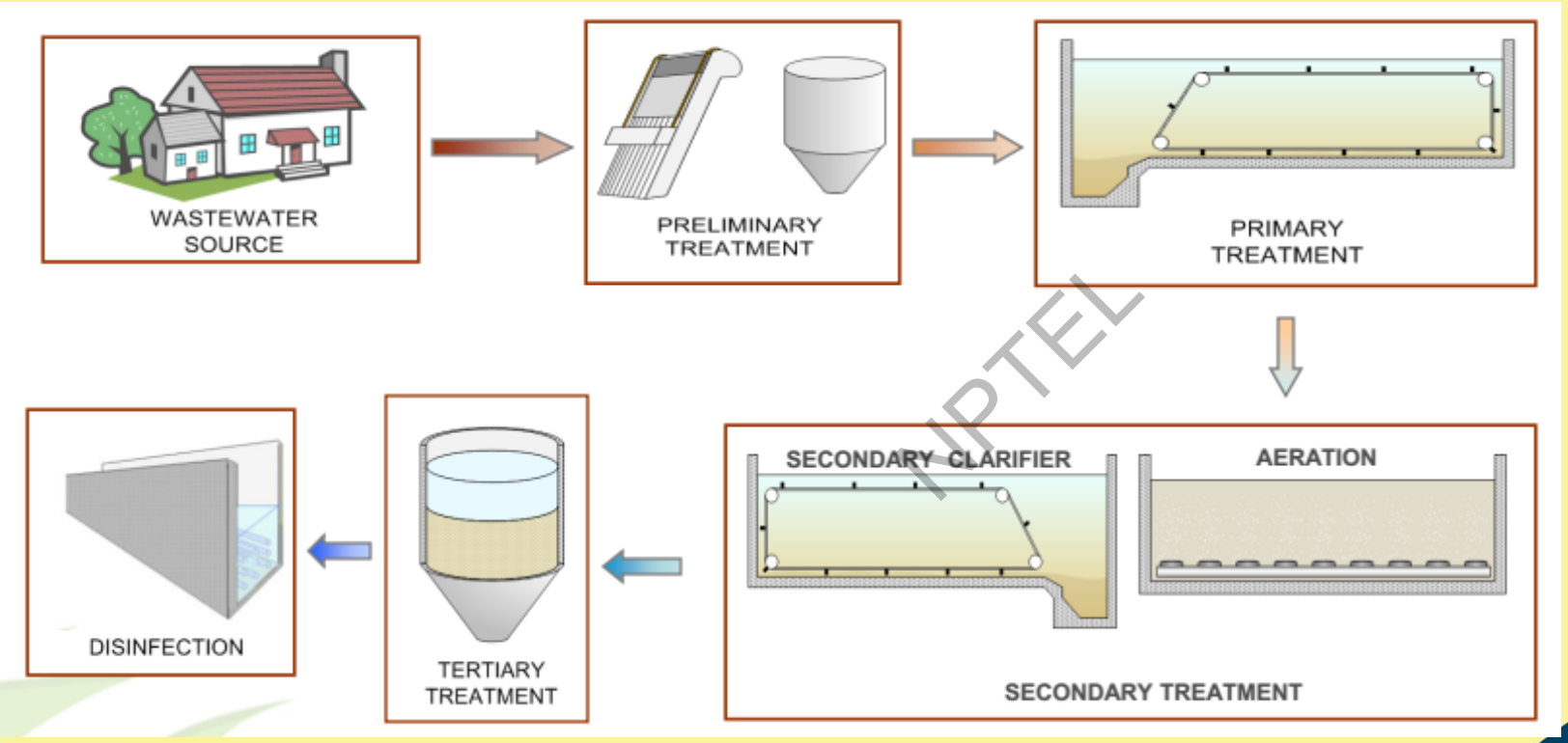
Anaerobic biological units

a) Septic tank
b) Imhoff tank
c) Sludge digestion tank

Treatment processes are classified as :

(iv) Final or Tertiary treatment: To kill pathogenic bacteria chlorination of sewage.

Wastewater Treatment



Source: https://www.denverwater.org/your-water/treatment-process

Preliminary treatment

- Remove large objects
- Ex: sticks, rags, toilet paper, cloth
- Raked screen
- Clog equipment in sewage treatment plant

Wastewater Screening

Wastewater Screening is the first unit operation in all wastewater treatment plants. Screen is the device used to retain solids found in the influent wastewater to the treatment plant. The main purpose of **screening** is to remove solid materials that could:

- Cause damage to other process equipment
- Cause reduction in efficiency of the whole system
- Contaminate waterways

Wastewater Screening

Screens are generally classified into three based on the size of their openings in the screening element and mechanism of removal.

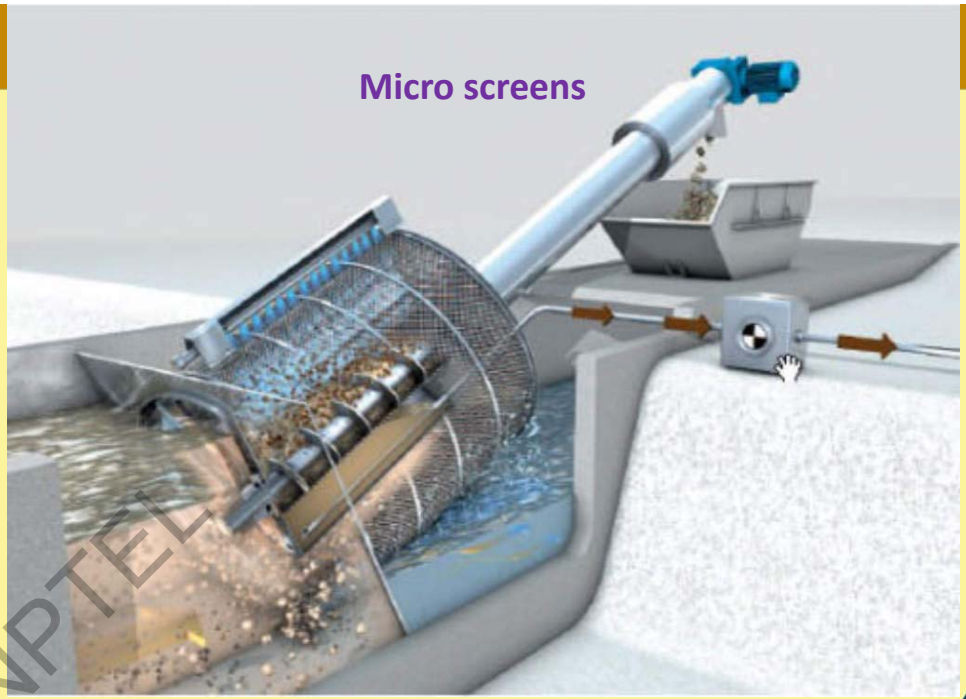
Coarse screens
Fine screens
Micro screens

Coarse screens

Source: https://www.indiamart.com/proddetail/bar-screen-9391107091.html

Fine screens

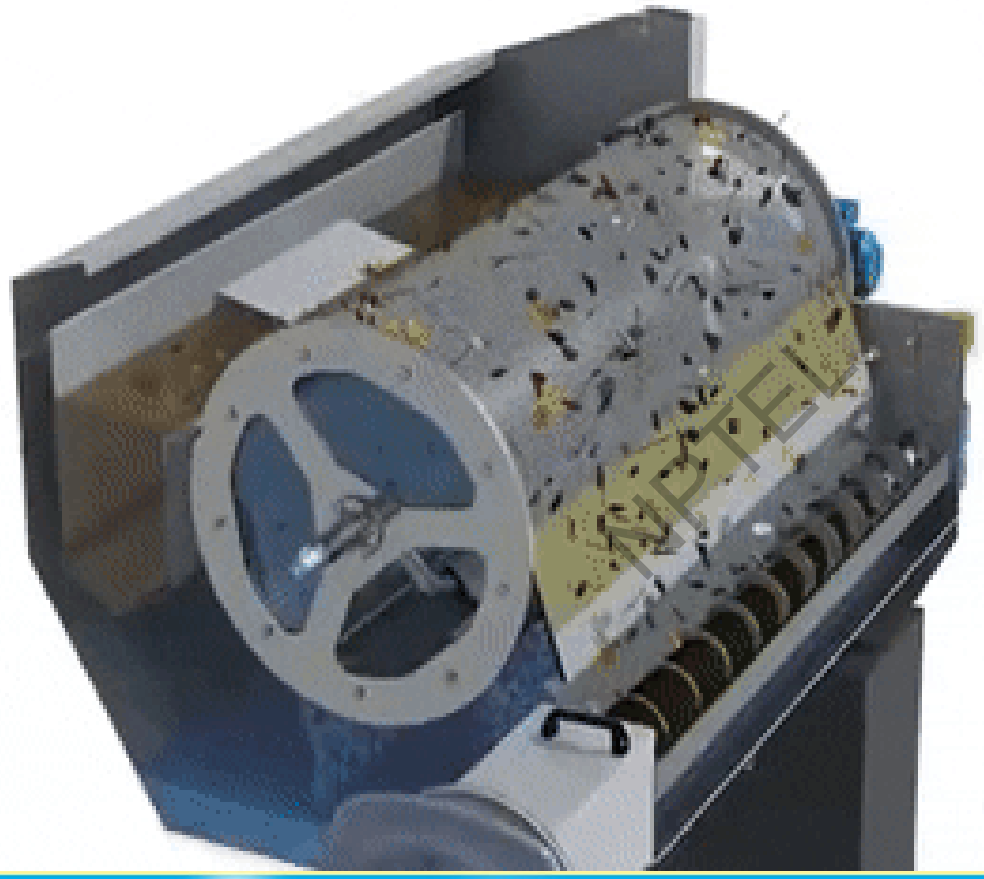
Micro screens



Source: https://www.huber-technology.com/products/micro-screening-filtration.html

Source: https://www.indiamart.com/proddetail/bar-screen-9391107091.html

Micro screens



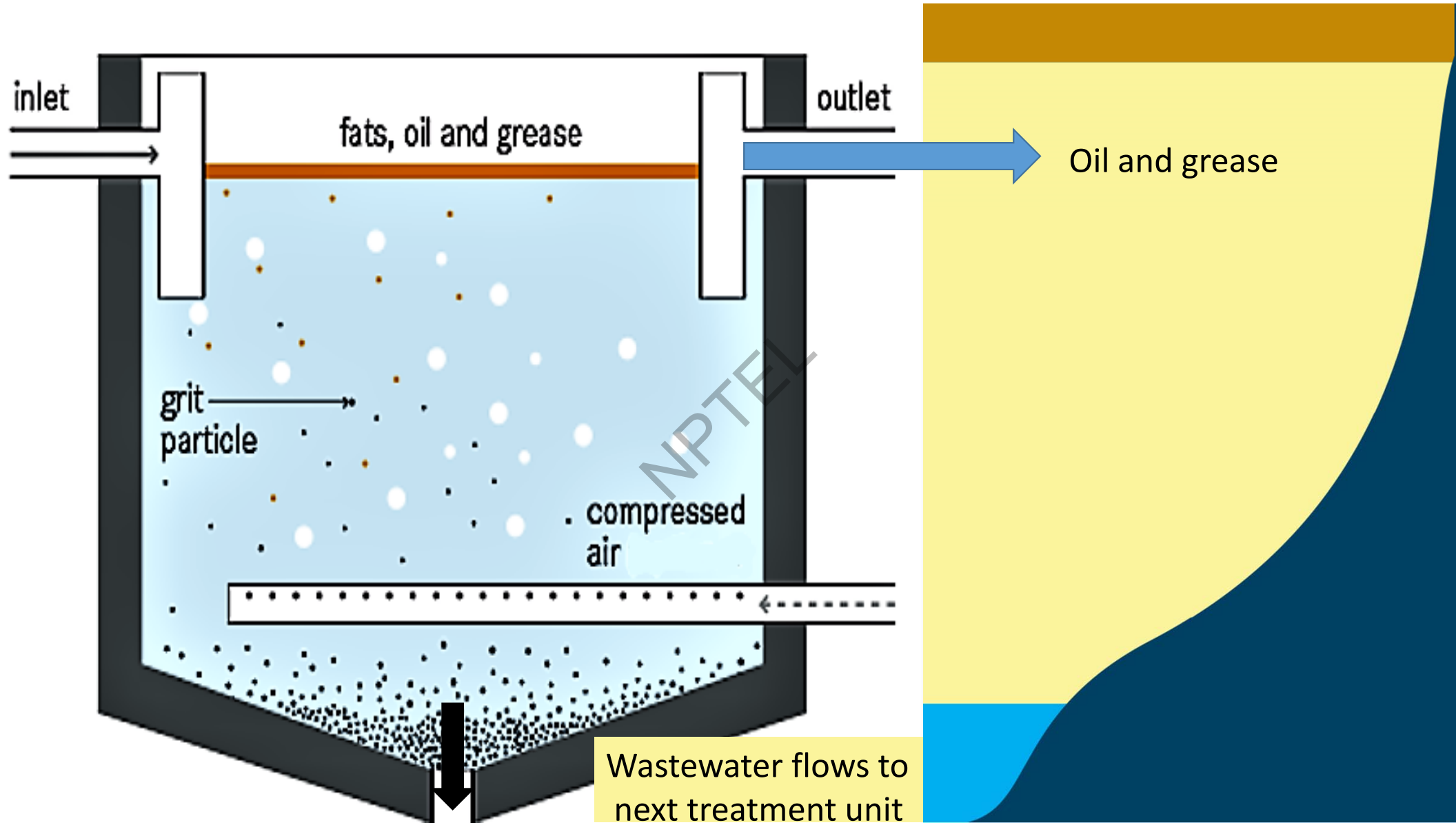
Source: https://gfycat.com/gifs/search/wastewater+treatment

Wastewater Skimming

- Mostly all types of sewage contains floating matters such as grease, oils, fats etc.
- The sources of these floating matters are kitchens, garages, soap-industries etc.
- These matters form scum over the surface of the sewage and interfere with various sewage treatment operations
- They clog the fine screens.
- They considerably reduce the efficiency of the activated sludge process.
- They decrease the biological growth due to which various bacteria and protozoa cann't perform their work.

Wastewater Skimming

Source:
https://www.youtube.com/watch?v=Kv7wBOGMU8Q


inlet
outlet
fats, oil and grease
Oil and grease
grit
particle
compressed
air
Wastewater flows to
next treatment unit

Wastewater Grit chamber

Grit chambers are used to remove grit particles present in the wastewater.

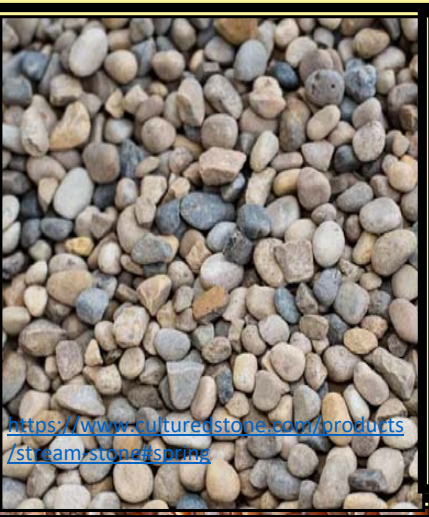
Their functions are:

- To protect the mechanical equipment used in the wastewater treatment plant from abrasion.
- To prevent heavy deposits in pipelines and channels
- To reduce the frequency of digester cleaning.
- To reduce maintenance cost in high speed centrifuges which needs almost all grit particles to be removed.

Wastewater Grit chamber

- Grit chambers are used to remove grit present in the wastewater.
- To separate out the grit, gravel, sand, egg, sells etc. of size 2 mm or larger. It is a settling tank with lesser detention time of 1 min and flow velocity : 0.2 to 0.3 m/sec.
- The flow velocity should neither be far low as not to cause settling of lighter organic matter nor should it be so high as not to cause the settlement of the entire silt and grit present.

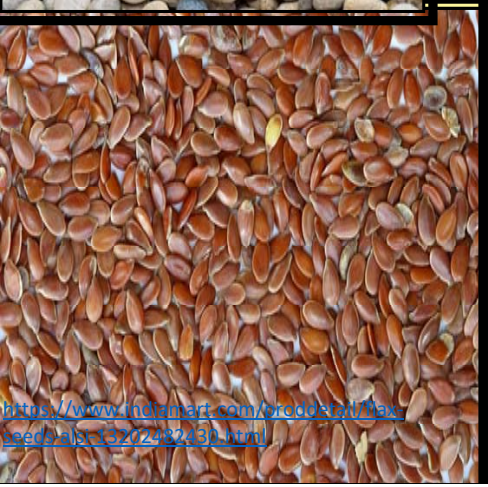
Grit particles



https://www.culturedstone.com/products/stream-stone#spring

Source: https://en.wikipedia.org/wiki/Sand

Source: https://geologycafe.com/rocks/basalt.html



https://www.indiamart.com/proddetail/flax-seed-3320248243D.html

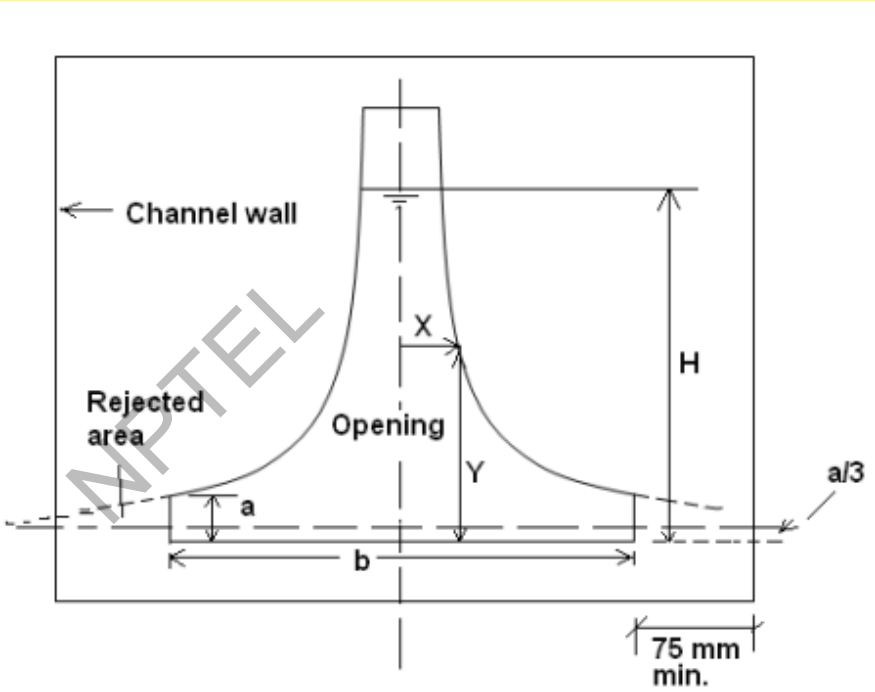
https://www.indiamart.com/proddetail/flax-seed-21513

Grit chamber: Proportional weir

With variation in sewage flow received at treatment plant it is important that velocity of the wastewater in the grit chamber should be maintained nearly constant.

Otherwise, when flow is lower deposition of not only inorganic solids but also organic solids will occur in grit chamber due to lowering of velocity; whereas, with higher flow than average, when the velocity will exceed the critical velocity scoring of already deposited grit particle will occur leading to failure of performance. Hence for proper functioning, the velocity should not be allowed to change in spite of the change in flow in the grit chamber. This can be achieved by provision of proportional weir or Parshall flume.

Grit chamber: Proportional weir



Source: Peavy, H. S., Rowe, D. R., & Tchobanoglous, G. (1985). Environmental Engineering McGraw-Hill Book Co. *New York*.

Source: https://www.openchannelflow.com/blog/unusual-types-of-thin-plate-weirs

Grit chamber: Parshall flume

Source: https://di-box.com.pl/en/flow-rate-measurement-with-parshall-flumes.htm

Disposal of Grit

Grit collected can be disposed in the following manner:

- In large treatment plant, grit is incinerated with sludge
- In the past grits along with screening was dumped into sea.
- Generally, grit should be washed before disposal to remove organic matter.
- Land disposal after washing is most common.

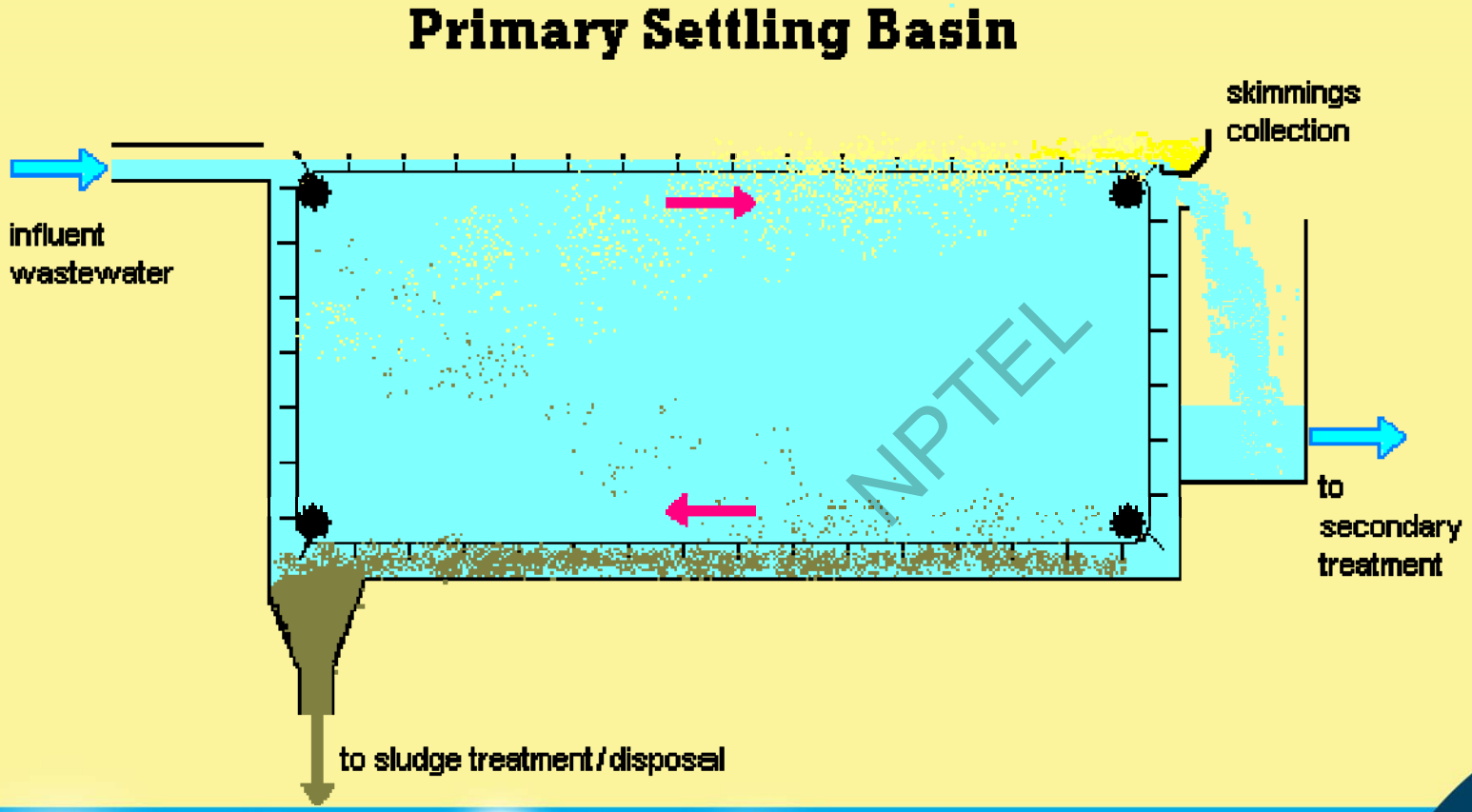
Primary treatment

Primary treatment is the second step in wastewater treatment.

It allows for the physical separation of solids and greases from the wastewater.

The screened wastewater flows into a primary settling tank where it is held for several hours allowing solid particles to settle to the bottom of the tank.

Primary treatment



Source: http://www.csun.edu/~vchsc006/356b/WW.html

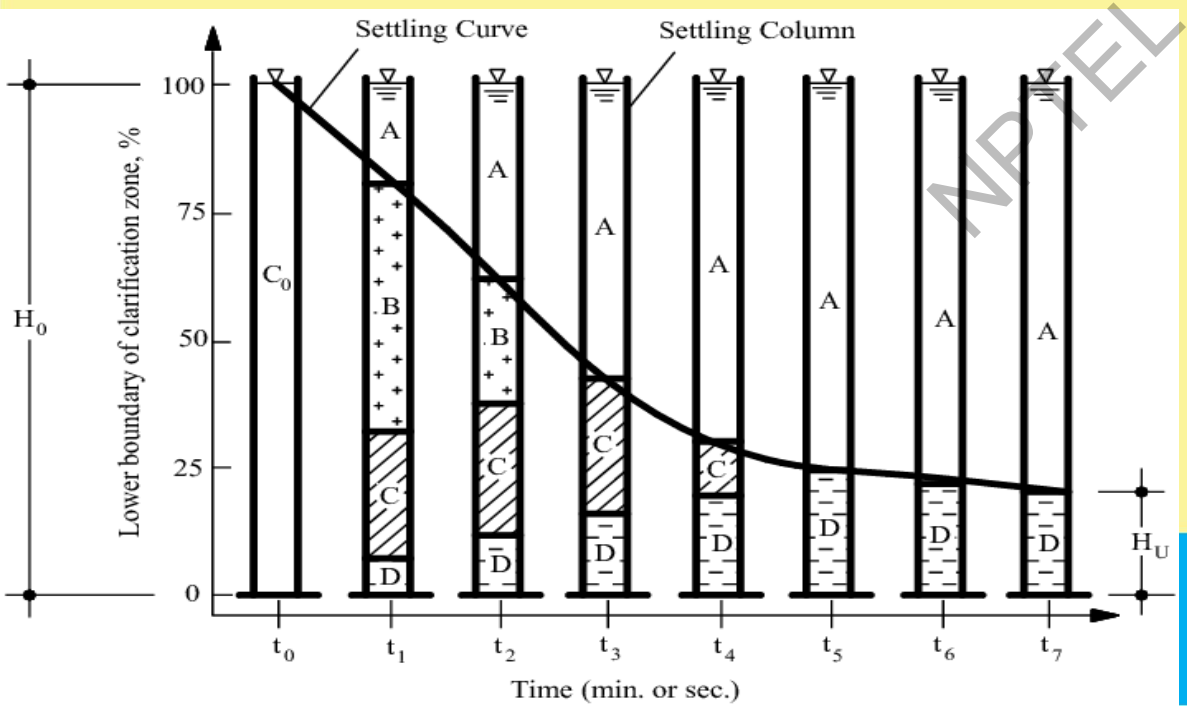
Types of Settling

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

Type II: Flocculent Particle settlement

Type III: Hindered or Zone settling

Type IV: Compression settling



Source: https://slideplayer.com/slide/9787113/

CE2 Type I and II are discussed in week 8

Civil Engg--11, 02-09-2019

Trickling filter

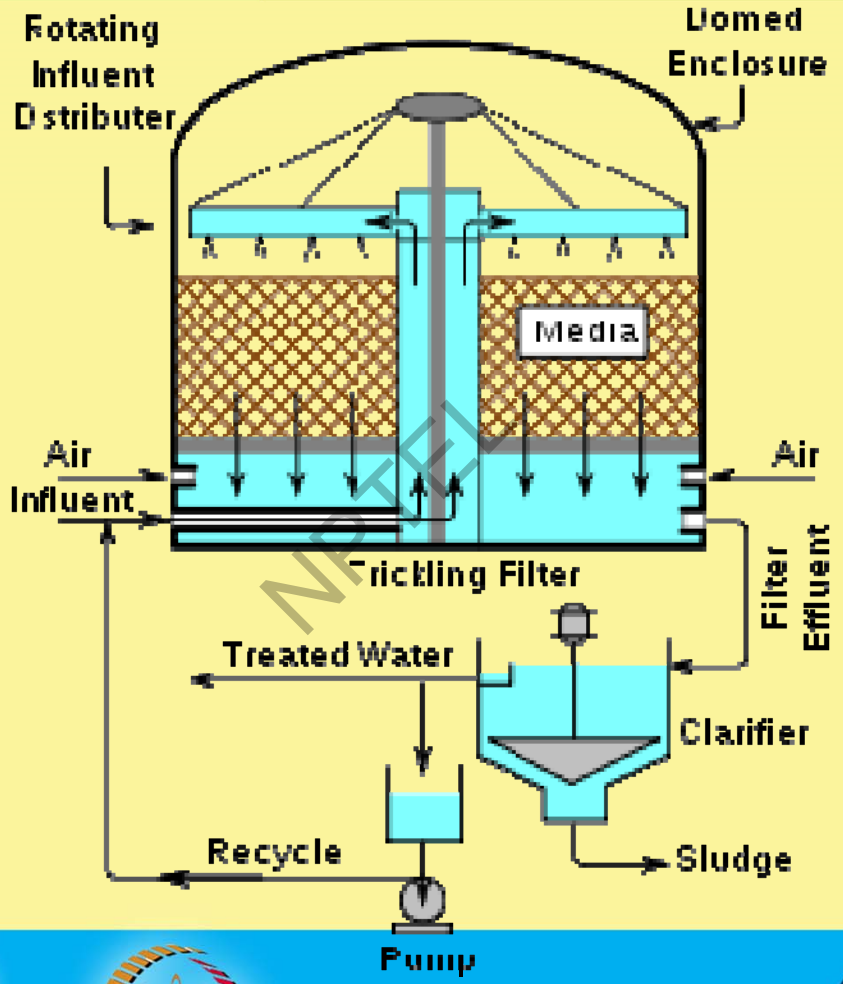
Trickling filter

- Trickling filters are used to remove organic matter from wastewater.
- The Trickling filter is an aerobic treatment system that utilizes microorganisms attached to a medium to remove organic matter from wastewater.
- This type of system is common to a number of technologies such as rotating biological contactors and packed bed reactors (biotowers).
- These systems are known as attached-growth processes.
- In contrast, systems in which microorganisms are sustained in a liquid are known as suspended-growth processes.

Working Mechanism of Trickling Filter

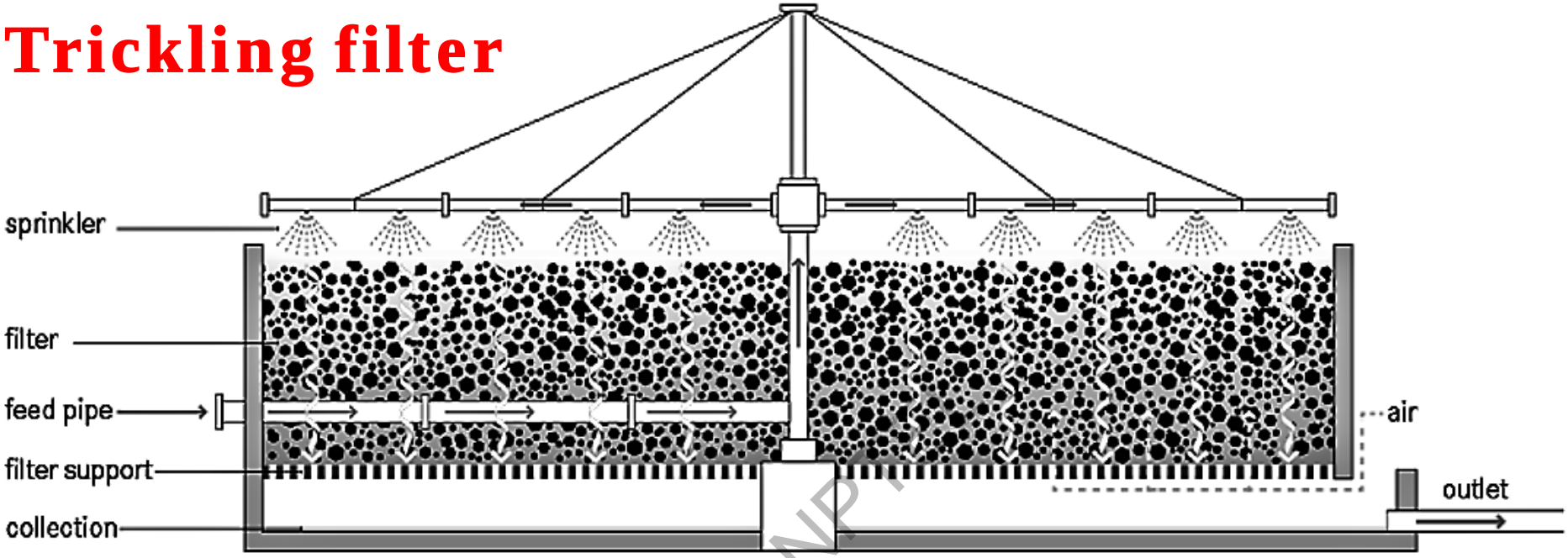
- The settled sewage from primary sedimentation tank is sprinkled intermittently over the filter bed when sewage trickles down, a microbial layer develops on the surface of rock which is called slime layer which is mostly consist of bacteria.
- Oxidation of the organic matter is carried out under aerobic conditions. A bacterial film is formed around the particles of the filtering media and for the existence of this film oxygen is supplied by the intermittent working of the filter and by the provision of the suitable ventilation facilities in the body of the filter.
- The sewage is oxidized by the bacteria producing effluent in the form of water, gases and new cells.

Trickling filter



Source: https://en.wikipedia.org/wiki/Trickling_filter

Trickling filter



Source: https://sswm.info/taxonomy/term/3806/trickling-filter

Advantages

- Simple, reliable, biological process.
- May qualify for equivalent secondary discharge standards.
- Effective in treating high concentrations of organics depending on the type of medium used.
- Appropriate for small- to medium-sized communities.
- Rapidly reduce soluble BOD_5 in applied wastewater.
- Efficient nitrification units.
- Durable process elements.
- Low power requirements.

Disadvantages

- Additional treatment may be needed to meet more stringent discharge standards.
- Requires regular operator attention.
- Incidence of clogging is relatively high.
- Requires low loadings depending on the medium.
- Flexibility and control are limited in comparison with activated-sludge processes.
- Psychoda and odor problems.
- Ponding on filter media

Source: https://www.youtube.com/watch?v=Z9eN3PTtIdY

Source: http://entnemdept.ufl.edu/creatures/URBAN/FLIES/drain_fly.html

Source: https://www.youtube.com/watch?v=Z9eN3PTtIdY

Disadvantages

- Ponding on filter media

Filters media gets clogged due to growth of algae and fungi and this is called ponding. Adding chlorine or Copper Sulphate to the sewage kills algae there by ponding can be avoided.

Source: https://www.youtube.com/watch?v=Z9eN3PTtIdY

EFFICIENCY

Efficiency (ŋ) = $\frac{BOD\ removed}{BOD\ applied} \times 100$

Efficiency (ŋ) = $\frac{100}{1+0.0044\sqrt{u}}$

ŋ = Efficiency of filter in terms of percentage of applied BOD removed.

u = Organic loading in kg/ha. m/day applied to the filter. (unit organic loading)

Find the diameter of standard trickling filter if influent BOD is 150 mg/l and desired effluent BOD is 20 mg/l, to handle 2 MLD of waste water flow. Assume depth = 2m.

Solution :

$$\eta = \frac{y_i - y_e}{y_i} \times 100 = \frac{100}{1+0.0044\sqrt{\frac{Qy_i}{V}}}$$

$$\eta = \frac{150-20}{150} \times 100 = \frac{100}{1+0.0044\sqrt{\frac{2\times150}{V\times1}}}$$

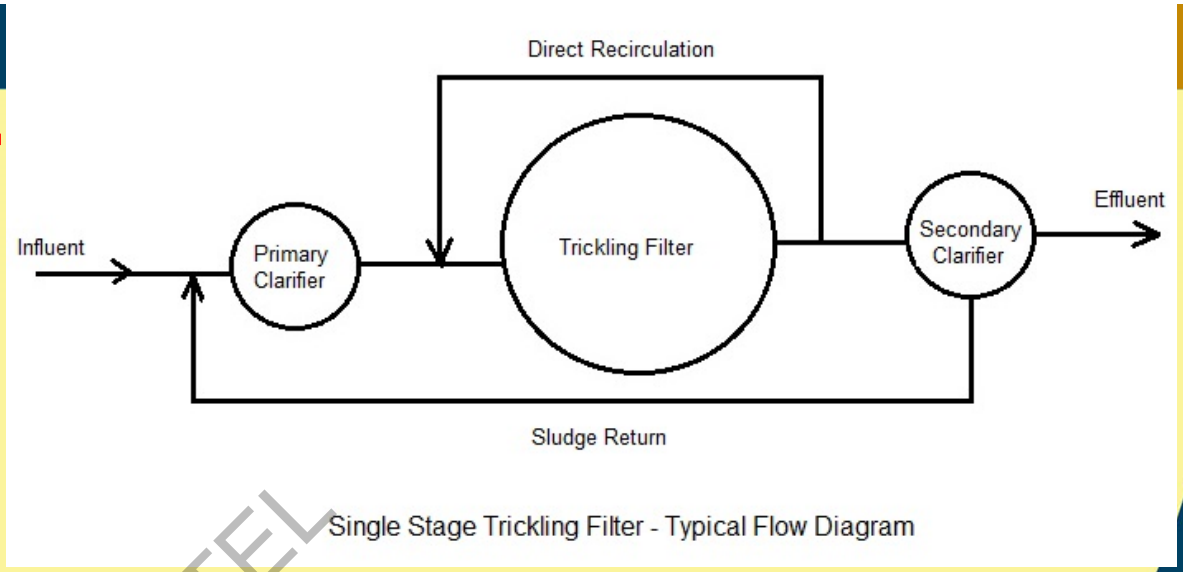
V = 0.245ha.m

V = 0.245 X 10^4 m^3

Surface area of TF = $\frac{\pi}{4}d^2 = \frac{Volume}{depth} = \frac{0.245\times10^4}{2}$

Diameter (d) = 39.5 m

Single stage trickling filter

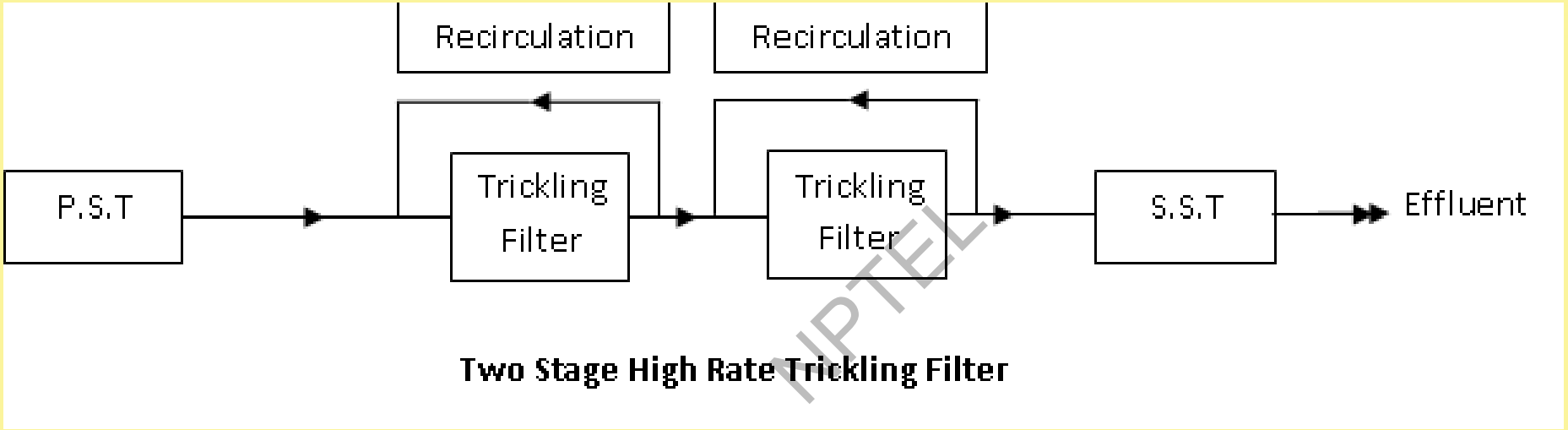


Single Stage Trickling Filter - Typical Flow Diagram

Source: https://www.engineeringexcelspreadsheets.com/2014/04/trickling-filter-design-calculations-spreadsheet/

Single Stage Re-circulation Process :
Recirculation helps in seeding the sewage with bacteria and accelerating biological oxidation process. Recirculation also helps in reducing odours, fly nuisance.

Single stage trickling filter



Two Stage High Rate Trickling Filter

Source: http://www.engineeringarticles.org/trickling-filter-classification-and-mechanism/

NPTEL ONLINE CERTIFICATION COURSES

Thank you