Chapter 9 Waste management

What are the different sources of wastewater?

1. Domestic wastes
   These comprises of wastes from sinks, toilets, washing machines etc. They contains solids, organic matter, ammonia, some metals and large numbers of faecal bacteria.
2. Industrial wastes
   These comprises of metals, toxic organic compounds and acids. They are produced from washing, processing and cooling. The wastes may be present as suspension or solution form.
3. Surface drainage
   These comprises of metals, bacteria, organic solids. It comes from runoff from impermeable areas like pavements, roads, car parking etc. The flow is a reflection of the precipitation.
4. Agricultural waste water
   These comprises of animal waste, bacteria, nutrients, organic matter, fertilisers, pesticides. It happens where there is intensive farming.
5. Leachates
   These comprises of effluents that contains organic matter, metal, pesticide etc. It originates from solid waste of domestic, industrial or agriculture use.

What is sewerage system?

It is waste water collection system usually constructed to collect domestic wastewater, industrial wastewater and surface drainage.

What are the important hydraulic properties that should be considered before construction of sewerage system?

1. Adequate scouring so that solids do not accumulate in sewer
2. Short retention time, especially in hot climates, to avoid formation of septic conditions
3. Adequate capacity to avoid the system discharging during the peak flows

What are the operating facets to be considered for operating sewerage system?

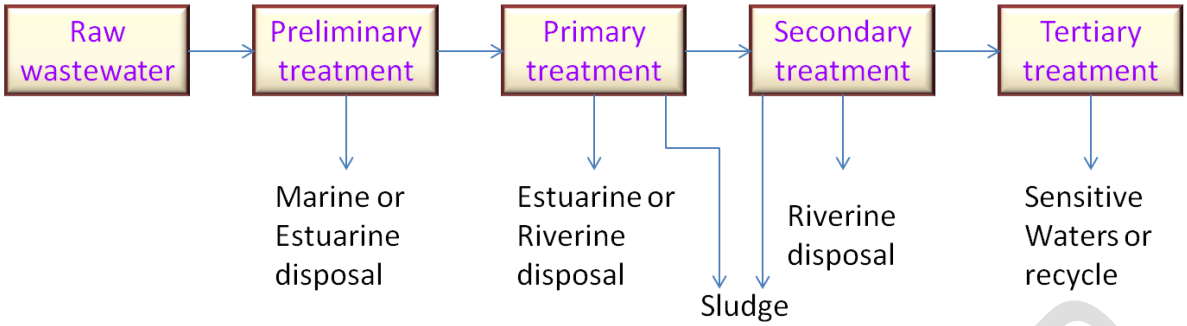
1. Health of the worker
   Poisonous gases (H_2S, HCN) may be generated in the sewer, organic solvents and petroleum products may produce toxic or explosive vapours.
2. Damage to the fabric of the sewer
   Strong acid or alkalis may corrode the sewer, solids may be deposited or some substance may react with the mortar. These may lead to sewer collapse.
3. Damage to treatment plant
   Toxic substance discharged into a sewer may interfere with the operation of a wastewater treatment plant.
4. Damage to receiving water
   Toxic substances that pass unchanged through a treatment plant or directly to a receiving water may cause damage to flora and fauna.

Treatment

Wastewater treatment rarely produces any by products of any value. CH_4 is exception. The design of the system is primarily concerned with lower cost.

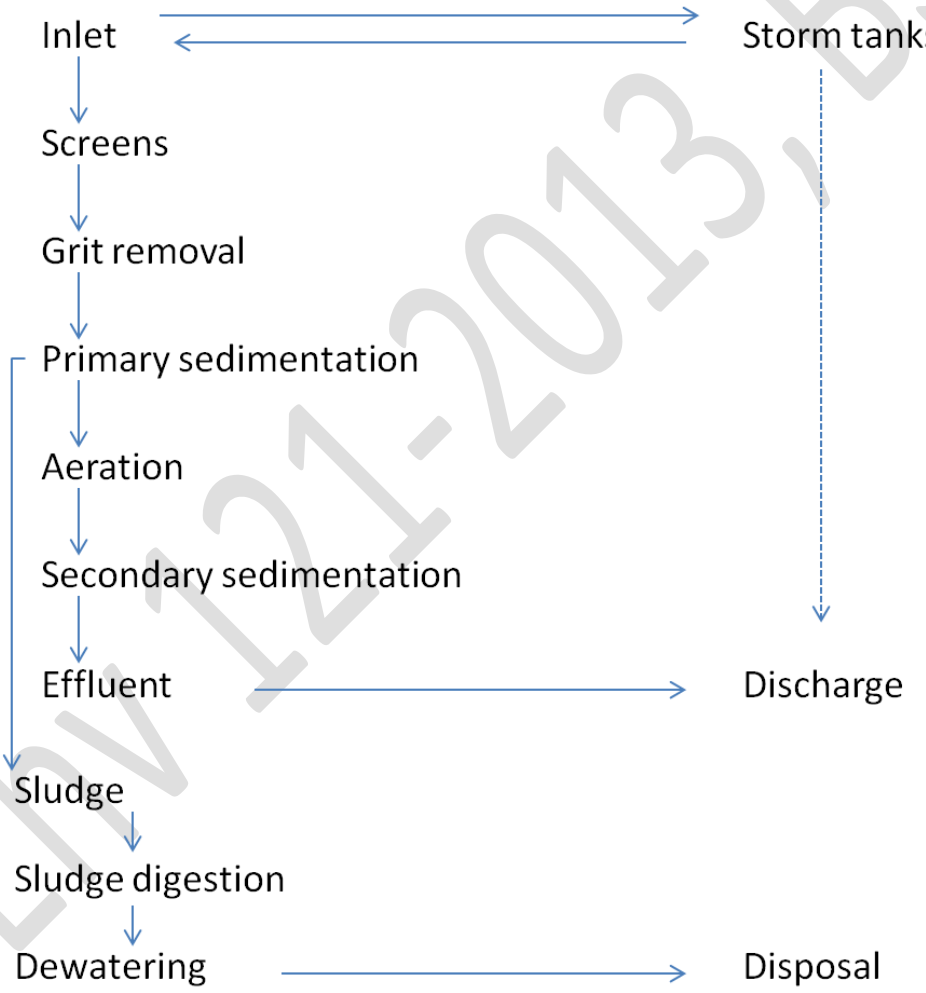
Segregation rather than destruction is another aspect.

Wastewater treatment is carried out usually in series of processes.



Treatment and disposal of wastewater

An **estuary** is a partly enclosed coastal body of brackish water with one or more rivers or streams flowing into it, and with a free connection to the open sea.



Wastewater treatment flow diagram

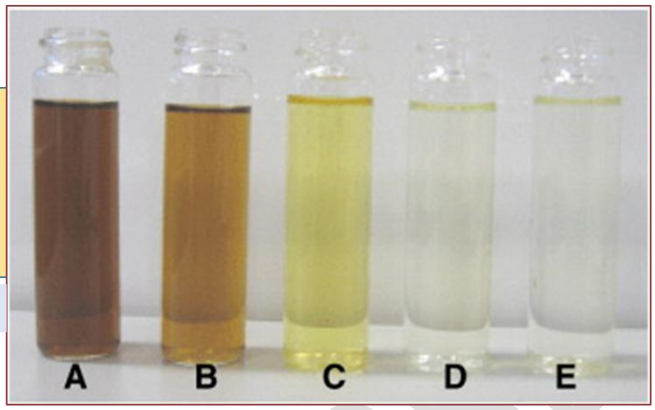
Pretreatment

It is necessary to pre-treat toxic wastes from industries, if there are more toxic material or where there is no discharge for the sewer system or where the waste waster is used for irrigation.

Many physical methods of pre-treating industrial wastes are carried out before they are discharged into sewers.

A. Raw landfill leachate
B. After chemical coagulation pretreatment
C. After electrocoagulation pretreatment
D. After EC-NF using the SR2 membrane
E. After EC-NF using the NF-270 membrane

EC- electro coagulation **NF**- nanofiltration



Landfill leachate treatment using hybrid coagulation-nanofiltration processes, Timo Mariama, Long Duc Nghiema, *Desalination*, Volume 250, Issue 2, **2010**, 677–681.

Process	Aim	Example
Screening	Removal of coarse solids	Vegetable canneries, paper mills
Centrifuging	Concentration of solids	Sludge dewatering in chemical industry
Filtration	Concentration of fine solids	Final polishing and sludge dewatering in chemical processing
Sedimentation	Removal of insoluble solids that settles down	Separation of inorganic solids in ore extraction, coal clay production
Floatation	Removal of solids and liquids having low specific gravity	Separation of oils, grease solids in chemical and food industry
Freezing	Concentration of liquids and sludge	Recovery of pickle liquor and non-ferrous metals
Solvent extraction*	Recovery of valuable material	Coal carbonizing and plastic manufacture
Ion exchange*	Separation and concentration	Metal processing
Reverse osmosis*	Separation of dissolved solids	Desalination of process and fresh water
Adsorption *	Concentration and removal of trace impurities	Pesticide manufacture, removal of dye stuff

* Methods used for removing metals where chemical precipitation is involved

What are the new technologies used for metal removal?

- New technologies make use of metal-binding capacities of micro-organism (yeast, algae, bacteria and aquatic flora)
- In US, *Sphagnum* moss (mosses are a botanical division (phylum) of small, soft plants) is used to remove Al, Cd, Zn, Ca, Mn and Mg.
- In Canary island, volcanic tuffs, rich in mineral phillipsite removes heavy metals, NH_4^+, soluble organic matter and bacteria from waste water.

What are the chemical methods used for the treatment of toxic wastes?

- Adjustment of pH and precipitation of metals are accompanied by the use of $Ca(OH)_2$, NaOH and Na_2CO_3.
- Cl_2 is used for oxidation
- $Al_2(SO_4)_3$ and $FeSO_4$ are used for solid separation
- Lime (CaO or $Ca(OH)_2$) removes Fe, Cu, Cr, Pb, Hg, Ni, Zn effectively

Generally physical methods of pretreatment of wastewater is less expensive and less polluting than the chemical methods. In chemical methods use of lime is effective as well as cheap.

Why is it preferable to treat wastewater in a mixture with domestic sewerage?

1. Mixing reduces any toxic side effects
2. Domestic wastewater has an excess of N and P which can be used to reduce the nutrient deficiency in industrial wastewater
3. Balancing of lows and loads
4. Skilled operation

Preliminary treatment

Preliminary treatment is done to remove large floating solids and to remove grit

What is grit?

- Grit is a wide assortment of inorganic and heavier organic solids in municipal wastewater.
- The inorganic solids are pebbles, sand, silt, egg shell, glass and metal fragments while the organic materials are bone chips, seeds, coffee and tea grounds.

How are the large floating solids removed in preliminary treatment?

1. It is done by screening.
2. The raked bar removes solids having diameter > 6 mm.
3. They are then washed to remove organic matter and finally burnt/buried
4. Screens remove coarse materials like plastic.

How is grit removed in preliminary treatment?

- Grit is mainly removed by differential settlement. Since grit is more denser than organic particles their separation takes place in grit chambers or constant velocity channels.

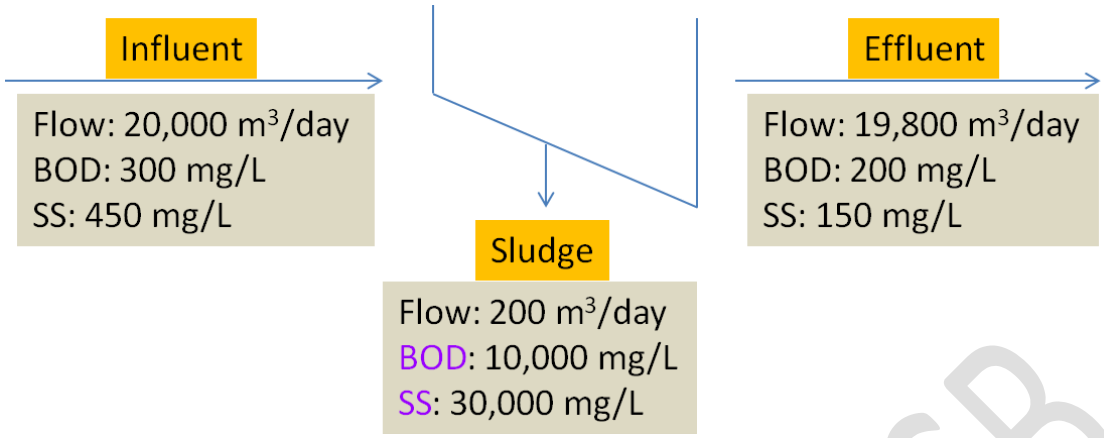
What is DWF?

- Dry weather flow (DWF) is the unit for flow of domestic wastewater
- It is the flow after 7 days without any rainfall
- Preliminary treatment can cope with 6 DWF
- Primary and secondary treatment can cope with only 3 DWF

Primary treatment

Primary treatment consists of **gravity settlement**

1. The effluent which contains the remaining organic matter in solution or colloidal suspension. This flows over the well and onto the next stage
2. The sludge which contains most of the organic solids that have settled down at the bottom of the tank and are to be withdrawn for subsequent treatment
3. The degree of segregation depends on wastes, tank design. Generally 66 % of suspended solids and 33 % of BOD goes into sludge.
4. Many of the organic materials tend to adsorb to these solids and will go into sludge. For bacteria the partition between effluent and sludge is roughly equal.



Secondary treatment

Why is Secondary treatment required?

1. To oxidize some of the organic matter into inorganic compounds like CO_2 etc.
2. To convert the remaining organic matter to solids which can settle down

Secondary treatment consists of two stages

- In the first stage reactor, bacterial growth converts the organic matter
- In the second stage bacteria are separated from the liquid

What are the different types of secondary treatment methods?

	Aerobic	Anaerobic
Fixed film	Percolating/trickling filter High rate filter/Bio towers	Anaerobic filter
Dispersed growth	Activated sludge Oxidation ditches	Up-flow activated Sludge Blanket Reactor (UASB)

- Secondary treatment is mainly carried out aerobically to oxidise organic matter
- The alternative is to carry out oxidation anaerobically
- Here part get oxidised to CO_2 part get reduced to CH_4
- This also reduces the cost of aeration
- Difficulty is to grow the bacteria. Below 15 °C they grow less

BOD of the waste is used to decide between aerobic or anaerobic methods

- If BOD > 1000 mg/L anaerobic is preferred
- If BOD < 300 mg/L aerobic is preferred
- Between 300-1000 mg/L local factors like skilled operators etc. are considered

Fixed film reactors

- Here the bacteria grow as a slime layer on an inert support which may be rock or plastic

What are the disadvantages of fixed film reactors ?

1. Wetting the entire surface of the support to avoid short-circuits
2. Controlling the thickness of film as thin films are more efficient

- The advantages are that the excess film which comes out can be easily separated from the effluent in the secondary sedimentation tank. Due to the larger surface area required this is best suited for rural areas.

Dispersed growth reactor

- This process uses *activated sludge process*
- Here the bacteria are intimately mixed with the organic matter
- In the secondary sedimentation tank, the bacteria are separated from the effluent
- Some bacteria are returned to the reactor, other constitute secondary sludge

What are the limitations of the activated sludge process?

- The separation of the bacteria
- Oxidation of all NH_3 in the waste to nitrate (nitrification)
- It required skilled supervision

Either fixed film reactor or activated sludge process can remove 90 - 98 % of BOD and 90 - 95 % suspended solids

- Remaining metals and chlorinated organic compounds are also removed
- Bacterial removal is around 80 - 90 %

Up-flow anaerobic sludge blanket reactor

What is USAB?

- Here anaerobic filters are used for treating industrial wastewater
- Here the bacteria grow as large flocks called granules and forms a blanket of granular sludge which suspends in the tank
- Wastewater flows upwards through the blanket and is processed (degraded) by the anaerobic microorganisms
- The upward flow combined with the settling action of gravity suspends the blanket with the aid of flocculants
- Small sludge granules begin to form whose surface area is covered in aggregations of bacteria
- Eventually the aggregates form into dense compact bio-films (granules)

The effluent from anaerobic treatment generally required some form of aerobic treatment before it is suitable for discharge

Secondary treatment produces BOD <20, SS < 30, NH_3 < 5 mg/L

Tertiary treatment

Why is tertiary treatment required?

- Tertiary treatment is done when the effluent that is discharged into the receiving water that is usually sensitive or where the effluent is being used for irrigation or recycling
- This treatment can produce treated waster of drinking quality

What are the different methods employed in tertiary treatment of wastewater?

- Depending on the type of pollution the methods vary
- If they were organic solids, they are removed by filtration through slow sand filter
- If it is bacteria, then disinfection or ultra-filtration is used
- For eutrophic water when it is required to reduce N and P, tertiary treatment can be done
- Combination of filtration and disinfection may be used as elaborate form of treatment for water meant for irrigation

Sludge treatment

Why is sludge treatment required?

- Many of the toxic materials entering a waste water treatment plant end up in sludge during treatment.
- They are highly polluting hence it needs to be treated and disposed of carefully

What are the different types of sludge treatment?

- Dewatering: primary sludge contains 97 % moisture and secondary sludge contains 99 %. By reducing the moisture content it is possible to reduce the volume to be treated and disposed
- Dewatering the organic content: the organic content of sludge solids is around 50 – 60 %. It is highly putrescible and inclined to emit odours.

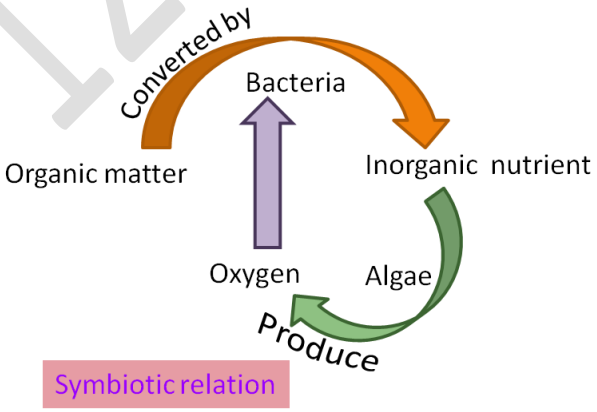
What are the methods employed for treatment of sludge in wastewater?

To reduce organics	Digestion Heat treatment Incineration	To reduce water	Thickening Filtration Drying beds
Disposal Dispersion	Land disposal Marine disposal	Containment	Land fill Sacrificial sites

Waste stabilization ponds

What are waste stabilisation ponds?

- Any pond, natural or artificial, receiving raw or partially treated sewage or waste, in which stabilization occurs through sunlight, air and microorganisms.
- They consists of a series of ponds in which bacterial and algal growth can occur in symbiotic manner
- The bacteria uses organic matter to produce inorganic nutrients which are used by algae, which in turn produce oxygen for bacteria.



What are waste stabilisation ponds?

- The first pond in the series acts like primary sedimentation tank
- One third of this pond occupied by sludge
- This is usually anaerobic, has little algal growth
- The effluent from this tank passes to 2-3 tanks
- Those ponds are aerobic; organic matter is broken down here

What are advantages and disadvantages of waste stabilisation ponds?

Advantage

1. Low capital cost (ponds are operated unlined)
2. Low operation cost (low power, maintenance and no skilled supervision)
3. Low technology (no parts)
4. Low bacterial effluent (up to 99.99 % removal)
5. May produce significant amount of fish in maturation ponds

Disadvantages

1. They have long retention time (20-30 days)
2. Require large surface area
3. Can be used only in lower altitudes (since it required sunlight and temperature)
4. Effluent contains lot of algae which affect oxygen demand

Non-sewered treatment and disposal

What are the methods employed for non-sewered treatment and disposal?

1. **Chemical closets, cesspool and cesspits**: these are temporary storage containers for domestic waste. They need to be emptied on regular basis. Regular use generates night soil which causes collection and disposal problems.
2. **Pit latrines**: these are medium term devices (1-2 yr). It provides some degree of treatment with a built-in soak away. They contaminate groundwater.
3. **Septic tanks**: these are underground treatment facilities for individual hose, hotel etc. It works based on primary sedimentation with sludge digestion. The liquid spends 12-24 hr in the tank, then it is disposed below ground through a soak away or field drain. The accumulated sludge is removed every 2-3 yrs.

Bio-medical waste management

What are bio-medical wastes?

- The waste generated in the process of diagnosis, treatment, prevention or research or human and animal diseases from hospitals, nursing homes, clinics, dispensaries, animal houses, veterinary institutions, pathological labs, blood banks etc is called bio-medical waste.

Biomedical waste (management and handling) rules, 1998

- State government will nominate any one or all the following agencies as the authority to enforce rules.
    - Directorate of health services
    - Directorate of animal husbandry/veterinary sciences and
    - State pollution control board
- All clinical waste generators or processors will obtain authorization for disposal form the prescribed authority.
- An advisory committee shall be constituted by the government or every state/union territory about matters related to implementation of the rules.
- Every occupier/operator shall submit an annual report to the prescribed by 31 January every year.
- Bio-medical waste shall not be mixed with other wastes and all Bio-medical waste shall be segregated, securely contained, labeled and transported.

- Proper treatment and controlled disposal of biomedical waste, using prescribed techniques shall be used.
- No untreated bio-medical waste shall be kept stored beyond a period of 48 hours.
- Every authorized person of the occupier/operator shall maintain records related to these rules and guidelines.
- When any accident occurs where the biomedical waste is handled or during transportation, the authorized person shall report to the prescribed authority immediately.
- All clinical wastes shall be classified into ten categories as (i) Human Anatomical Waste, (ii) Animal Waste, (iii) Microbiology & Biotechnology waste, (iv) Waste Sharps, (v) Discarded Medicines and Cytotoxic drugs, (vi) Solid Waste (related to blood and body fluids), (vii) Solid Waste (related to disposable items), (viii) Liquid Waste, (ix) Incineration Ash, (x) Chemical Waste.

Category	Waste Category	Treatment & Disposal
1	Human Anatomical Waste	Incineration/deep burial
2	Animal Waste	Incineration/deep burial
3	Microbiology & Biotechnology waste	Local autoclaving/ micro waving/ incineration
4	Waste Sharps	Disinfections (chemical treatment/autoclaving/micro waving and mutilation shredding
5	Discarded Medicines and Cytotoxic drugs	Incineration/ destruction & drugs disposal in secured landfills
6	Solid Waste (related to blood and body fluids)	Incineration, autoclaving/micro waving
7	Solid Waste (related to disposable items)	Disinfections by chemical treatment autoclaving/micro waving& mutilation shredding.
8	Liquid Waste	Disinfections by chemical treatment and discharge into drain
9	Incineration Ash	Disposal in municipal landfill
10	Chemical Waste	Chemical treatment & discharge into drain for liquid & secured landfill for solids

Air pollution control

- The most effective solution of air pollution is optimal combination of *Source correction method* and *End-of- the-pipe treatment/tail gas treatment*

Source correction method

1. Raw material changes
2. Process changes or modifications
3. Modification/replacement of process equipment
4. More effective operation of existing equipments

End-of-the-pipe treatment/Tail gas treatment

Air pollution control technology for particulate matter removal

i. Gravitational settling

ii. Centrifugal impactation
iii. Inertial impactation
iv. Direct interception
v. Diffusion
vi. Electrostatic precipitation

Primary treatment

i. Gravitational settling chamber
ii. Centrifugal collectors

They remove coarse particles of waste gas. Fine particles not removed. Can not give more than 80 % efficiency

Secondary treatment

i. Wet collectors/ wet scrubbers
ii. Fabric filter/bag filter
iii. Electrostatic precipitator

They remove fine particles also. Gives more than 99 % efficiency. Costly.

What is controlled technology?

First step is to reduce the dust load by primary treatment. Then secondary treatment removes fine particles. Combination of the two gives controlled technology. It is cost effective.

Gravitational settling chamber

What do you understand by a particle (fractional) size analysis?

Analysis depends on type and function of the source

i. If particle size < 10 mm, particles are inhalable. It is called finer fraction
ii. If particle size > 10 mm, it is called coarse fraction
iii. If finer fraction > coarse fraction, secondary treatment done
iv. If coarse fraction > fine fraction, primary treatment done, then secondary

Describe the working principle of the gravitational settling chamber

- This device removes coarse particles
- Dirty gas stream is forced to enter this chamber
- Expansion takes place
- Velocity drops; heavier particles gets separated from the main stream
- These particles settles down on the hopper
- The clean gas is sent to the next settling chamber
- The particles settled in the hopper are collected and unloaded regularly

They operate at a velocity between 0.5-2.5 m/s

Some have enlarged conduits; some have horizontal shelves and baffles

Horizontal shelves reduce settling path distance, increase removal efficiency

Advantages

1. This is simple device. Easy design and maintain
2. Low pressure drop; no mechanical design to pass the gas through narrow gap
3. Low cost, removes coarse particulate matter

Disadvantages

1. Space problem. i.e. requires large area
2. Collection efficiency is low (< 50 %). Particle with < 50 mm can not be removed

Centrifugal collector

This reduces the coarse particle of dust load

What is the working principle of centrifugal collector?

- It works based on the centrifugal force.
- The centrifugal collector is known as cyclone collector/separator.
- The gas is forced inside the cyclone to pass through its tangential inlet duct
- Due to this a spinning vortex is formed
- Now the centrifugal force come into effect
- The coarse particle of the dirty gas make the chamber warm. They are thrown against the wall of the chamber
- The particles slide down the walls of the cone and ultimately settle down at the bottom
- The clean air from the inner vortex is discharged through the top
- Centrifugal force depends on particle mass, gas velocity within the cyclone, cyclone diameter

Advantages

1. Low cost
2. Simple to design and maintain
3. Space requirement is comparatively less
4. Low to moderate pressure drop
5. Can handle large volume of gas
6. Is able to operate at higher temperature
7. Dry removal of particulate matter takes place

Disadvantages

1. It is not efficient for the removal of finer particle with size 5- 25 mm.
2. It is highly sensitive to dust loading and flow rate

Wet scrubber/collector

Working principle

Wet scrubber can function as either or both particulate and gas control devices

- This uses liquid (H_2O) to assist in removal of PM from carrier gas
- The PM are agglomerated with H_2O and then separated into clean gas and contaminated liquid stream

There are four major steps involved

Transportation, collision, adhesion, precipitation

1. The particles are moved to the vicinity of the water droplets and collide with each other
2. The particles are adhered to the liquid media and precipitated to the bottom
3. Scrubber can remove particle size of 0.1-200 mm efficiently

1. **Impingement (to collide or strike)**

- When gas containing the dust is swept through an area containing liquid droplets, dust particles will collide upon the droplets and adhere to them. If the droplet is 100-300 times the size of the particle, collection is effective due to inelastic collision.

2. **Interception**

- Particle that move with gas stream may not collide on the droplet but can be captured because they brush against the droplet and adhere. This is effective in removing particle diameter > 0.3 mm.

3. **Diffusion**

- When the particles are dispersed onto the liquid medium it helps removal of particles. This is effective in removing particle diameter > 0.3 mm.

4. **Condensation**

- When condensation of liquid medium happens on the particles, its size increases. It helps in easy removal of the particles.

Advantages

1. Low initial cost
2. It can remove particulate and gaseous pollutants
3. Moderately high collection efficiency for small particles
4. Applicable for high temperature
5. There is no particle re-entrainment.

Disadvantage

1. High power consumption for higher efficiency
2. Moderate to high maintenance costs owing to corrosion and abrasion
3. Wet disposal of the collected material

Fabric filter/Bag house

- A filter is generally a porous structure composed of granular or fibrous material which tends to retain the particulate and allows the gas to pass through the voids of the filter
- The material may be (i) fabric or cloth filters (ii) fibrous or deep bed filters
- Fibrous and deep bed filter have large void of 97 to 99 % total volume
- Fabric filter are made in the form of tubular bags or cloth envelop
- The dust loading of 1 g/m^3 ideal for cloth envelop
- They remove dust of 0.5 mm
- A bag house consists of 2-6 m long bags
- Upper end is closed, lower ends are attached to inlet
- Hopper at the bond serves as the collector for dust

Working principle

- Dirty gas pass through inlet pipe, strikes baffle plate
- Larger particle fall into hopper due to gravity
- Carrier gas flows upward into tubes then outward with 0.4-1 L/min speed
- Smaller particles retained on the fabric as a cake due to interception, inertial impactation, diffusion, electrostatic attraction and gravitational settling
- Filter efficiency during cake formation is low, but finally it increases to 99 %
- This cake also acts as a filter medium and further remove dust
- The bag act as matrix to support the dust cake
- Due to accumulation of dust air resistance increases
- Hence cleaning of the bag is required periodically
- Cleaning can be done by rapping, shaking vibration or by reverse air flow

Advantages

1. High collection efficiency
2. It can even remove sub-micron particles
3. It can operate on a wide variety of dust
4. It can operate over an extremely wide range of volumetric flow rate
5. Pressure drop is moderate
6. Simple construction and operation
7. Nominal power consumption
8. Dry disposal of collected material

Disadvantage

1. The high temperature of the gas needs to be cooled (100-450 C)
2. The flue gas must be dry otherwise condensation is possible (clogging)
3. The fabric is liable to chemical attack
4. While selecting the fabric, acidity, alkalinity should be checked
5. It requires large floor area
6. High maintenance of fabric and replacement cost

Electrostatic precipitator (ESP)

- One of the most widely used device (power plant, cement, paper mill, refinery)
- The particulates are by-products of combustion
- They may also be dust fibers or acid mist from process
- It uses electrical energy to remove particulate
- Removes all kinds of dust with high efficiency
- Even 0.1 mm can particle can also be removed

Working principle

- One of the main electrostatic precipitators the gas stream is passed between two electrodes, across which a high potential difference is maintained. One of the electrodes is a discharging electrode while the other is a collecting electrode
- Due to high potential difference, a powerful ionizing zone (corona zone)is created
- Gas ionization is the dissociation of gas molecules into free ions
- As the particles in the carrier gas pass through this zone, they get electrically charged and migrate to the oppositely charged collecting electrode
- The particle, once deposited on the collecting electrode, lost their charge and are removed mechanically by rapping, vibration and washing to a hopper

Advantages

1. Very High collection efficiency
2. It can even remove sub-micron particles
3. It can handle large volume of gas with low pressure drop (0.2-1.25 cm of H_2O)
4. It is used for either day collection of solid or wet collection of fume and mist
5. It can be designed for a wide range of gas temperature
6. Maintenance cost is nominal unless corrosive and abrasive material are present in flue gas.
7. Treatment time is negligible (0.1 – 10 sec)
8. Cleaning is easy by removing units of the precipitator from operation

Disadvantage

1. High initial capital cost
2. Sensitive to variable dust loading and flow rate
3. It uses high voltage hence, may pose risk to personal safety of staff
4. Collection efficiency reduces with time
5. It may not work on particulates of high electrical resistivity
6. Space requirement is more because of the large size of the equipment
7. Possible explosion hazards during collection of combustible gases or particulates. Well trained personel are necessary to operate
8. The poisonous gas, ozone is produced by negatively charged discharge electrodes during ionization
9. Gases cannot be removed

Air pollution control technology for gaseous pollutant removal

The major gaseous pollutant: SO_2, NOx, CO, HC

- **Absorption**
  - Effluent gases are passed through absorber
  - They remove SO_2, H_2S, HCl, Cl_2, NH_3, HCs, NOx
  - Potassium tetra chloro mercurate for SO_2
  - Absorbent should have good solubility, low freezing point, low toxicity
  - They should be non-volatile, non-flammable, chemical stable, inexpensive
  - Ex. Wet scrubber/ Spray tower, plate tower, packed tower, venturi collector
- **Adsorption**
  - It is a process by which any gas vapour or liquid will adhere to some degree to any solid surface due to the residual forces that are available on its surface
  - The residual forces are a part of the forces which hold atoms, molecules or ion together in the solid state and exist at its surface
  - Absorbing solid "adsorbent"; adsorbed material "adsorbate"
  - Physical adsorption
  - Chemisorption

Physical adsorption

- The gas molecule adhere to the surface of the solid adsorbent due to inter-molecular force (vander Waals force) between them
- The process is exothermic

Advantage

- It is reversible
- The adsorbed material can be easily removed by increasing the temperature or by reducing the pressure without effecting any change in the chemical composition
- The rate of adsorption is rapid

Chemisorption

- It results from chemical interaction between the adsorbate and adsorbing medium
- The bonding force in this process is much stronger, the heat liberated is much larger than physical adsorption
- It is an irreversible process

The amount that can be adsorbed by a given weight of adsorbent depends on

1. The concentration of the material in the space around the adsorbent
2. The total surface area of the adsorbent
3. The temperature
4. The presence of the molecule which may compete for a place on the adsorbent
5. The characteristic of the molecule to be adsorbed i.e. weight, electrical polarity, chemical activity, size and shape
6. The macro structure of the adsorbing surface i.e. size and shape of the pores
7. The chemical nature of the adsorbent surface including electrical polarity and chemical activity

Adsorption is used for removal of odour and the for the removal of small quantity of pollutant present in large volume of the gas

This is also used to remove valuable organic substances

The commonly used adsorbents used for adsorption of gaseous pollutants are

- Activated carbon (eliminating odours, purifying gas, recovering solvents)
- Activated alumina (drying air, gases and liquids)
- Silica gel (drying and purifying gases)
- Molecular sieves (controlling and recovering Hg, SO_2 and NOx)

Widely used devices which work on the principle are

1. Fixed bed adsorber
2. Moving bed adsorber
3. Fluidized adsorber

Condensation

- It works only if the vapour-gas mixture is rich in vapour or saturated with it
- The efficiency of condensation can be increased by using refrigerated fluids such as chilled water
- When a spray of cooling medium (cold medium) comes in contact with the contaminated stream of air, cooled vapour which is condensed is separated from the cooling medium
- The cooling medium and condensate mixture are removed treated and disposed

The devices work on the principle of condensation are as follows

1. Surface condenser
2. Contact condenser

Surface condenser

- The coolants pass through the tubes whereas the vapour is on the shell side

The coolant used are

- Water refrigerant, chilled water or brine
- In surface condensers physical adsorption plays an important role because contaminants are adsorbed onto a surface as gaseous components condenses
- In a shell and tube condenser the cooling medium flows through the tubes in the vapour condenses on the surface of the tubes
- The condensed vapour collects as a film of liquid and the liquid drains off to storage

Contact condenser

- Here the vapour and cooling medium are brought into direct contact

- The cooled vapour condenses on to the wall and condensate mixture are removed treated and disposed

Advantages

- Low cost, greater efficiency in removing organic vapours
- The method of condensation is used as an air pollution control device in petroleum refining, petrochemical manufacturing, manufacturing of ammonia, chlorines solutions and miscellaneous processes involved in dry cleaning, degreasing and rat dipping

Combustion

- It is the chemical alteration of contaminants
- Here the organic compounds are converted into CO_2 and H_2O
- When the waste gas has certain combustible value and when the recovery of waste is not required, then this method is followed

It involves three Ts

Temperature

- Combustion zone temperature should be 375 – 825 °C depending on specific gas

Turbulence

- It governs the velocity of waste gas
- It is required for optimal mixing of contaminants
- It is measured in terms of gas velocity
- The range should be between 4.5 – 7.5 m/sec

Time

- Residence time (the time for which the contaminated gas remains in the combustion zone) ensured optimal combustion.
- It ranges from 0.2 -0.5 sec

The basic type of control technologies which work on the principle of combustion are

1. Direct combustion or flaring of the waste gas
2. Thermal incineration / flame combustion
3. Catalytic oxidation

Direct combustion

- In this method waste gas is burnt directly in a combustor with or without the aid of additional fuel such as natural gas
- In a well designed combustor the combustion can be carried out when the combined mixture has a heating value of 900 Kcal/m^3 or more
- In the heating value is low the gases should be preheated for the combustion process, This is relatively safe method of disposal of large quantities of highly combustible waste gases
- The process is economical only if the waste gas itself contributes more than 50 % of the total heating value required for incineration

Advantages

1. Simplicity and low cost
2. No danger of explosion
3. Suitable for both intermittent and continuous flow of low quality fuel mixture

Disadvantages

1. Large amount of heat energy and other valuable products, instead of being recovered are being wasted
2. Complete combustion of pollutants, especially hydrocarbons, may not take place and as a result, flares are often smoky and sooty and create nuisance with reference to public acceptance

Thermal combustion

- In this method waste gas stream is preheated in a heat exchanger and then passed through the combustion zone of a burner supplied with supplemental fuel
- As a result, the combustibles in the waste gas are brought above their ignition temperature and burn with oxygen present in the contaminated stream
- This method is applied when the heating value of the waste gas is in the range of 50-750 KJ/m^3

Catalytic combustion

It takes place through

i. Adsorption of the gas on the active surface (Pt, Pd catalyst)
ii. Chemical reaction of combustibles with O_2
iii. Desorption of the reaction products from the surface

This process is a surface reaction process and suitable methods for exposing the maximum surface area are prime design criteria

- Since the waste gases containing combustible pollutants from industrial processes are at a fairly low temperature, the preheating burner is provided with a catalytic combustion unit. The burner helps to bring the waste gas up to that temperature at which the catalyst will be most effective
- The effluent gases what come from a catalytic combustion unit are CO_2, H_2O vapour and N_2 only
- These are widely used for processes involving paint and enamel bake ovens, varnish kettles etc.
- The operating cost of a catalytic units are low with the exception of the cost of maintaining the catalyst
- The maintenance cost of the catalyst depends upon the nature of the fuel
- The waste gas must be cleaned of particulates before it enters incinerator
- Deposition of particulates on the surface of the catalyst reduces catalytic action
- This lowers the effectiveness of the bed as well as its life
- The normal operating life of a catalyst without particulate deposition problem may be from 3-5 years