Industrial Wastewater treatment

Module 4

Sl No	Domestic Wastewater	Industrial Wastewater
1	Spent water originating from all aspects of human sanitary water usage	Industrial wastewater emanates from the myriad of industrial process that utilizes water for a variety of purposes.
2	As the name implies principally originates in residences & is also reffered to as sanitary sewage	altered considerably in the process & the contain contaminants that degrades water quality such as nutrients, suspended sediments, bacteria, DO deficiency & toxic substances.
3	Odors - decomposition of organic matter or by substances added to w/w	may contain either odorous compounds or compounds that produce odors during the process of w/w treatment.
4	Fresh sewage is typically grey in color. As the travel time in the collection system increases - anaerobic condition color changes from grey to dark grey & ultimately black	Color depends on the type of industry & raw material usage

EFFECT ON STREAMS

- Inorganic salts
- Acids and/or alkalis
- Organic matter
- Suspended solids
- Floating solids and liquids
- Foam producing matter

g. Heated water
h. Color
i. Toxic chemicals
j. Micro organisms
k. Radioactive materials

- Inorganic salts
  - Cause water hard; - stream unsuitable for industrial, municipal and agricultural usage.
  - Salt laden - scale on distribution pipeline- increases resistance to flow & lowering overall capacity of the lines
  - N & P induce (microscopic plant life) algal growth in surface waters.

Acid & Alkalis

- stream unsuitable for recreational use
- eye irritations in swimmers, rapid corrosion of ship hulls
- Alkalinity - caustic embrtittlement of pipes

Organic matter

- unpleasant tastes, odors and general septic conditions, decreases DO.

- Suspended solids
  - Settle to the bottom – decompose- DO depletion
- Floating solids & liquid
  - passage of light through the water
  - Interferes with natural reaeration, toxic to fish and aquatic life
  - fire hazards
- Hated water
  - develop stratification
  - DO depletion,

Color

transmission of sunlight into stream & therefore lessens photosynthetic action oxygen absorption from the atmosphere

toxic chemicals

low concentrations - poisonous to fresh water fish & microorganisms

Insecticides - killed fish in farm ponds and streams

Microorganisms

may be beneficial or pathogenic

Radioactive materials

cumulative damaging effecting on living cells.

methods of industrial waste water treatment;

- **Volume Reduction**
- **Strength Reduction**
- **Neutralization**
- **Equalization**
- **Proportioning**

VOLUME REDUCTION

- Classification of wastes
- Conservation of waste water
- Changing production to decrease
- Reusing both industrial & municipal raw water supplies; or
- Elimination of batch or slug discharge of process waste

Classification Of Waste

volume of water requiring intensive treatment may be reduced considerably

- Wastes from manufacturing process
- Waters used as cooling agent in industrial process
- Wastes from sanitary uses

Conservation Of Waste Water

- Water conserved is waste saved.
- industry changes from an "open" to a "closed" system
- Eg: a paper mill when recycles white water
- Concentrated recycled waste water are often treated at the end of their period of usefulness
- saving is two fold.

Changing Production To Decrease Waste

- effective method
- Waste treatment at the source should be considered an integral part of production.

Reusing Industrial & Municipal Effluents For Raw Water Supplies

- Practiced mainly in areas where water is scarce
- Sewage plant effluent is most reliable at all season of the year

Elimination Of Batch Or Slug Discharge Of Process Waste

- Slug waste are retained in holding basin - continuously and uniformly over an 24-hours
- manufacture firm alters its practice so as to increase the frequency and lessen the magnitude of batch discharge;

STRENGTH REDUCTION

- Process changes
- Equipment modification
- Segregation of wastes
- Equalization of wastes
- By-product recovery
- Proportioning wastes, and
- Monitoring waste streams

STRENGTH REDUCTION

Process Changes

- that are most troublesome from a pollution stand point
- metal plating industries
- Change from copper-cyanide plating - acid-copper solution
- Replace the CuCN2 strike before the copper-plating bath with a nickel strike

Equipment Modification

- Changes in equipment can affect a reduction in the strength of the waste
- screens placed over seeds - strength and density of the waste.
- Traps- poultry -feather and pieces of fat.

Segregation Of Wastes

- result in two waste one strong and small in volume as the original unsegregated waste.
- dye waste - more economical and effectively treated in concentrated solution.

Equalization of Waste

- prefer to equalize their waste
- holding waste for a certain period of time
- consistent in its characteristic than separate influent
- Stabilization of pH and BOD and settling of solids

By-Product Recovery

- paper mill, with the aid of multiple-effect evaporator, recover caustic soda from cooking liquors

Proportioning of the waste

- by proportioning the discharge of concentrated wastes into the main sewer a plant

Monitoring waste stream

- sophistication in plant control
- sensing devices that enables the operator to stop, reduce or redirect the flow from any process when its concentrations of waste stream exceeds certain limits

NEUTRALIZATION

- Mixing wastewater so that the net effect is a neutral pH.
- ~~Passing acid wastes through the beds of limestone.~~
- Mixing acid wastes with lime slurries or dolomitic lime slurries.
- Adding the proper proportions of concentrated solutions of caustic soda (NaOH) or soda ash (Na CO_3) to acid wastes.
- Blowing waste boiler-flue gas through alkaline wastes.
- Adding compressed CO2 to alkaline wastes.
- Producing CO_2 in alkaline wastes.
- Adding sulphuric acid to alkaline wastes.

Mixing Wastes:

- within a single plant operation or b/w neighboring industrial plants.

Lime-Slurry Treatment For Acid Wastes

- similar to that obtained with limestone beds.

Lime Stone Treatment for Acid Waste:

- Passing acid wastes through beds of limestone.
- 3. Neutralization proceeds chemically according to the following reaction
- $CaCO_3 + H_2SO_4 \longrightarrow CaSO_4 + H_2CO_3$

Caustic Soda Treatment For Acid Wastes

- caustic soda or sodium carbonate to acid wastes in proper proportions
- but more costly
- products are soluble and do not increase the hardness of receiving waters.

Using Waste Boiler-Flue Gas

- Well burned stack gases contain approximately 14 per cent carbon dioxide.
- Blowing waste boiler-flue gas through alkaline wastes
- relatively new and economical method for neutralizing them.

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

$$H_2CO_3 + 2\,NaOH \longrightarrow Na_2CO_3 + 2H_2O$$

$$H_2CO_3 + Na_2CO_3 \longrightarrow 2NaHCO_3 + H_2O$$

Producing Carbon Di Oxide In Alkaline Wastes:

- called submerged combustion
- used in the disposal of nylon wastes to neutralize the waste prior to biological treatment.

Sulfuric Acid Treatment For Alkaline Wastes

- fairly common but rather expensive means of neutralization.

$$NaOH + H_2SO_4 \longrightarrow Na_2\,SO + 2H_2O$$

Acid Waste Utilization In Industrial Process:

- may be possible to use acid wastes to affect a desired result in industrial processing – to wash, cool, or neutralize products.
- acid mine drainage water for cleaning raw coal.

EQUALIZATION

- method of retaining wastes in a basin -cycle of operation
- fairly uniformly in its sanitary characteristics (pH, color, turbidity, alkalinity, BOD, and so forth).

- significantly effect – BOD concentration reduction
- ironing out the slug of high concentration & physical, chemical, and biological reaction
- Air is sometimes injected into these basin to provide;
  - Better mixing
  - Chemical oxidation
  - biological oxidation,
  - Agitation to prevent suspended solids from settling.

- Most basin are rectangular or square
- mere holding waste, however, is not sufficient to equalize it. Each unit volume of waste be adequately mixed with other unit volumes of waste discharged many hours previously.
- mixing may me brought about in following ways;
  - Proper distribution and baffling –
    - perforated pipe across the entire width
    - most economical though usually the least efficient

- Mechanical agitation –
  - Agitators operated at a speed of 15 rpm by a 3-hp motor
- when:
  - Limited space is available
  - Removal of suspended solid is not desired
  - There are rapid fluctuations in the characteristics of the waste
  - Facility of subsequent treatment is a goal
- Aeration
  - most efficient way to mix wastes, but also the most expensive
  - facilitates mixing and equalization of waste, prevents or accumulation of settled materials in tank
- Combination of all three

PROPORTIONING

- Discharge of industrial waste in proportion to municipal sewer or to the stream
- it is possible to combine equalization and proportioning
- effluent from the equalization basin is metered into the sewer or stream objective is to keep constant % of industrial to domestic-sewage flow
- a holding tank with a variable-speed pump to control the effluent discharge

purpose:

- To protect municipal sewage treatment from chemical
- To protect biological-treatment devices from shock loads may inactivate the bacteria.
- To minimize fluctuation of sanitary standard in the treated effluent.

two general method of discharging

- manual control-
  - lower in initial cost but less accurate
  - Manual determination of the flow pattern of domestic sewage for each day in the week, over a period of month.
- automatic control by electronics
  - control of waste discharge according to sewage flow
  - involves placing a metering device, when register the amount of flow, at the most convenient main sewer connection.

REMOVAL OF INORGANIC SOLIDS

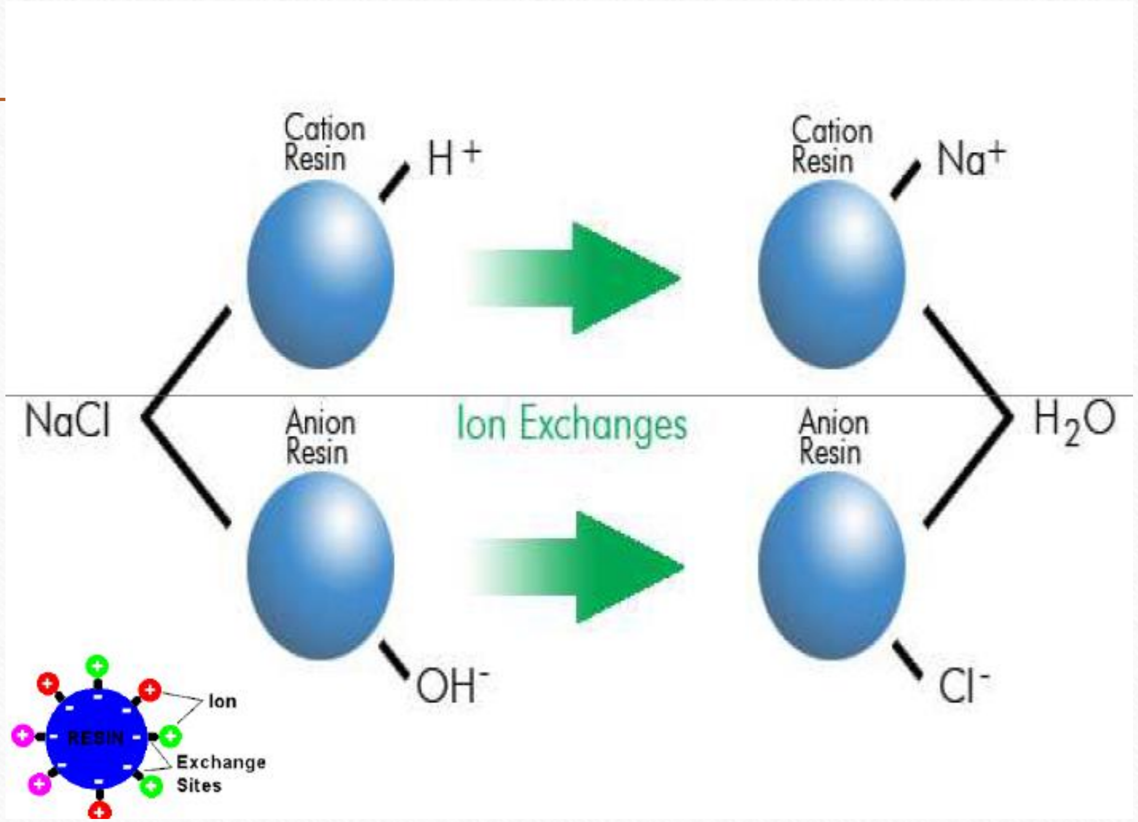
- i) Evaporation
- ii) Dialysis
- iii) Ion exchange
- iv) Algae
- v) Reverse osmosis
- vi) Miscellaneous Evaporation

Evaporation

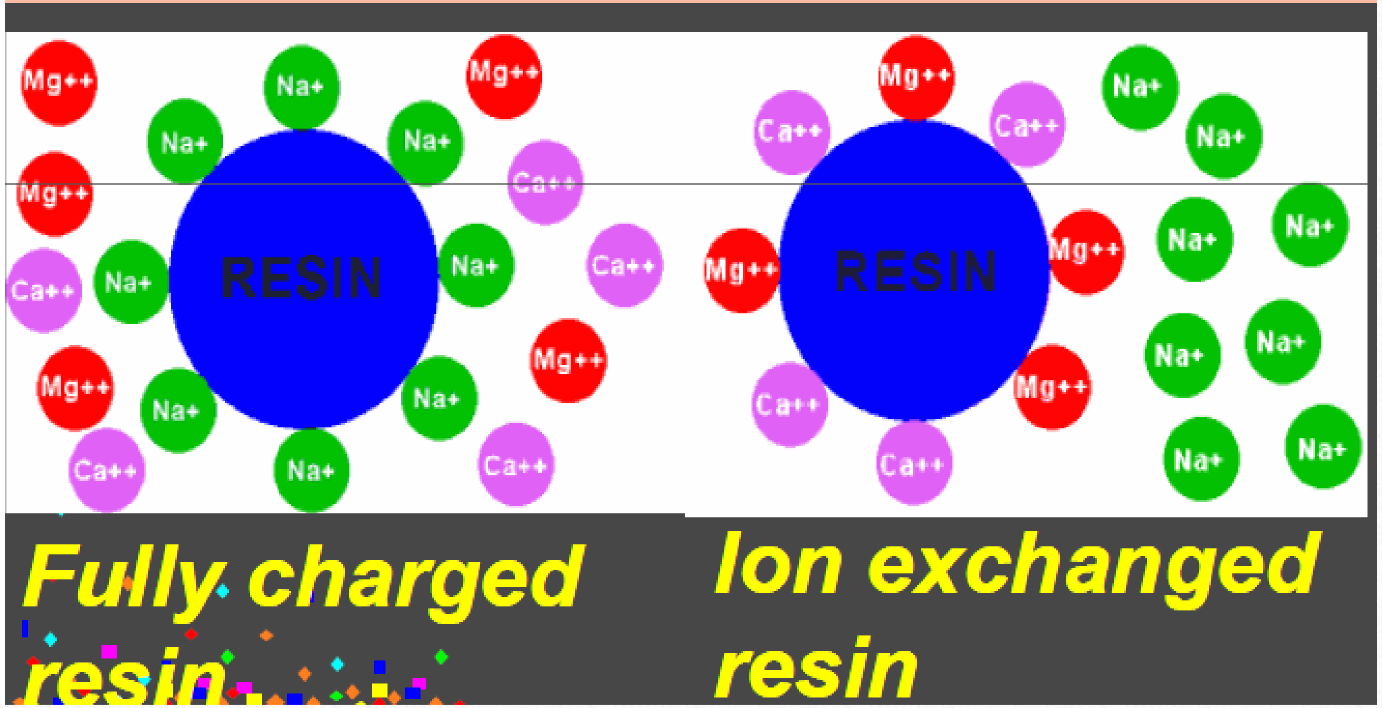
- "Evaporation" is a process of bringing wastewater to its boiling point and vaporizing pure water.
- The vapor is either used for power production, condensed and used for heating, or simply wasted to the surrounding atmosphere.
- The mineral solids concentrate in the residue may be sufficiently concentrated for the solids either to be reusable in the production cycle or to be disposed easily.
- • This method of disposal is used for radioactive wastes, and paper mills have for a long time been evaporating their sulfate cooking liquors to a degree where they may be returned to the cookers for reuse

Ion exchange

- *This technique has been* ***used extensively to remove hardness, and iron and manganese salts in drinking water supplies.***
- *It has also been used selectively* ***to remove specific impurities and to recover valuable trace metals like chromium, nickel, copper, lead and cadmium from industrial waste discharges.***

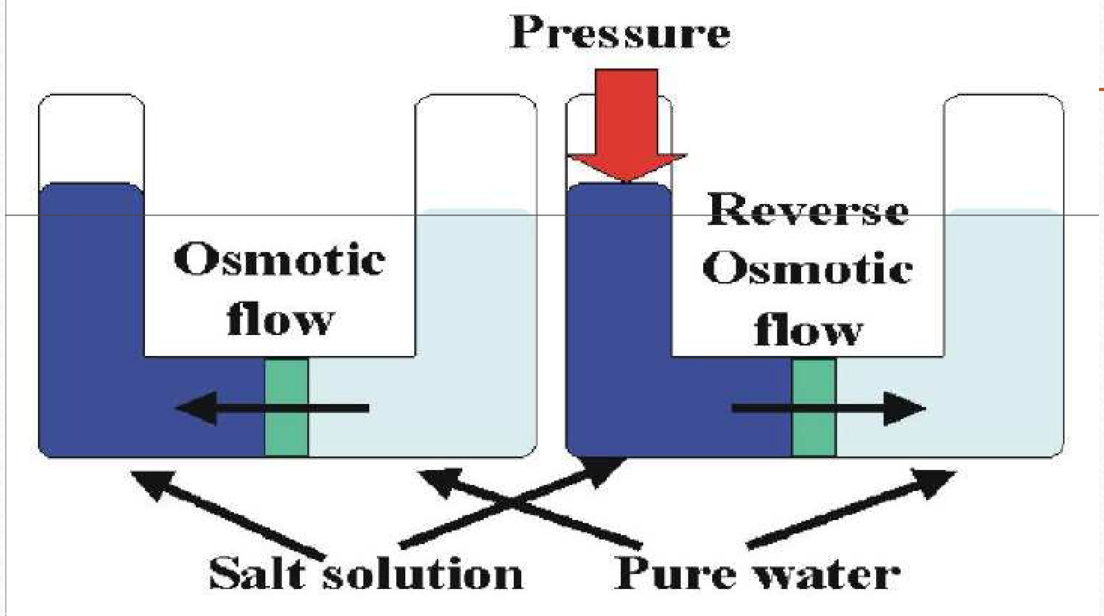


$2R\text{-}NA$	+	$Ca(HCO_3)_2$	->	R_2CA	+	$2NaHCO_3$
Sodium Ion Exchange Resin	+	Calcium Bicarbonate in Water	->	Calcium Ion Exchange Resin	+	Sodium Bicarbonate in Water

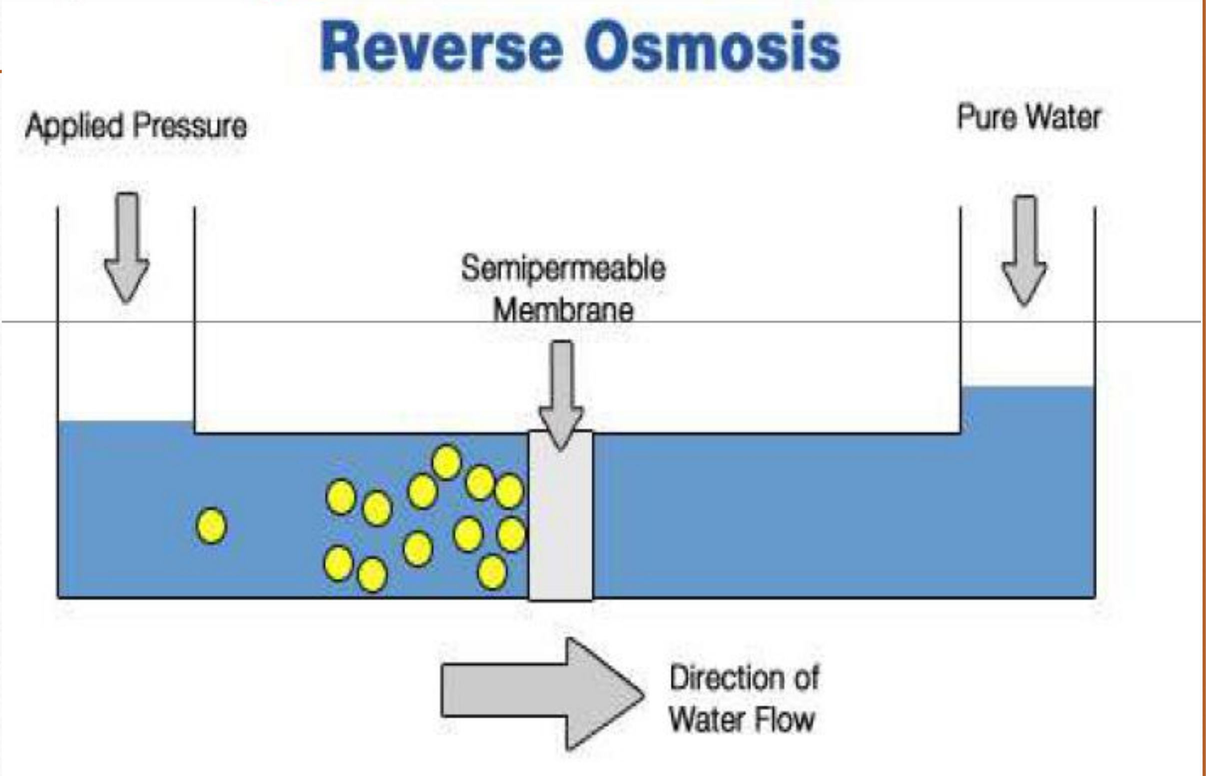


- *The process takes advantage of the ability of certain natural and synthetic materials*
- *to exchange one of their ions.*
- *A number of naturally occuring minerals have ion exchange properties.*
- *Among them the notable ones are aluminum silicate minerals, which are called zeolites.*
- *Synthetic zeolites have been prepared using solutions of sodium silicate and sodium aluminate.*

Difference between Osmosis and RO

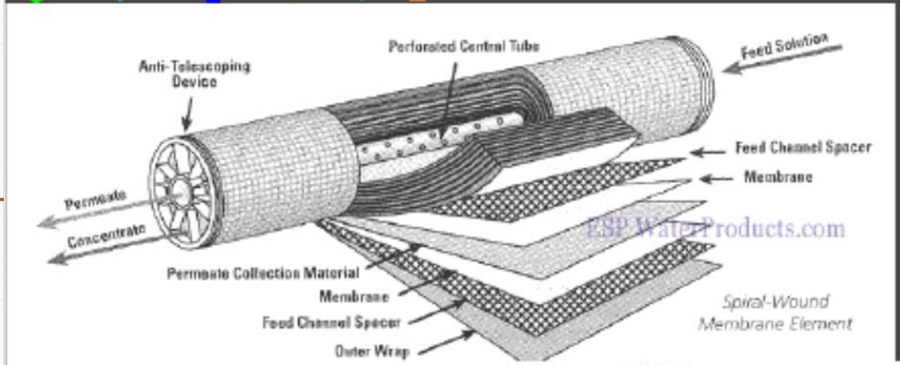


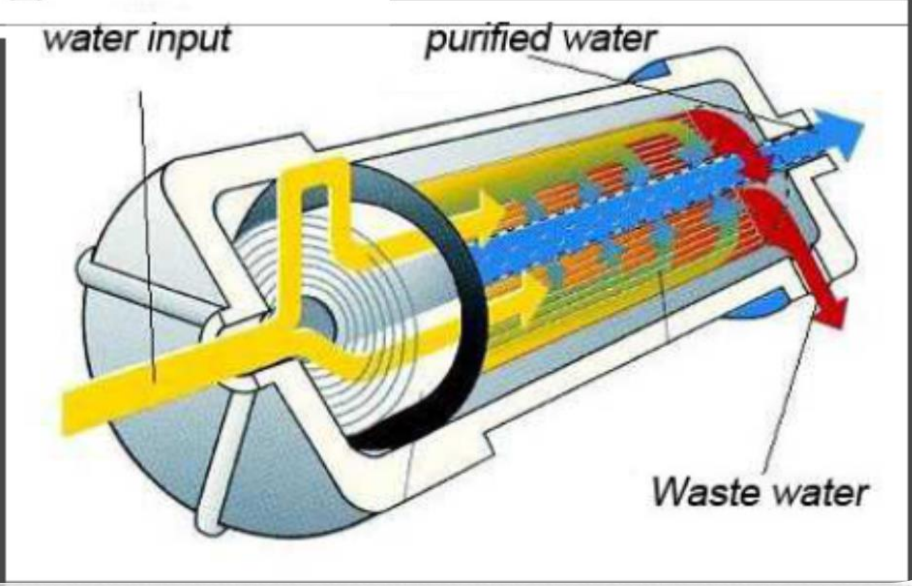
3. Reverse Osmosis



- **Reverse osmosis** (RO) is a membranetechnology filtration method that removes many types of large molecules and ions from solutions by applying pressure to the solution when it is on one side of a selective membrane.
- The result is that the solute is retained on the pressurized side of the membrane and the pure solvent is allowed to pass to the other side. To be "selective," this membrane should not allow large molecules or ions through the pores (holes), but should allow smaller components of the solution (such as the solvent) to pass freely
- Commonly used membrane is Cellulose Acetate
- Pre-treatment of wastewater is needed to avoid membrane fouling.
- High COD and BOD can also affect membrane.
- Flushes away impurities and does not collect them.
- It can remove almost everything. It allows only water (H2O) to pass
- Very efficient but Cost is high

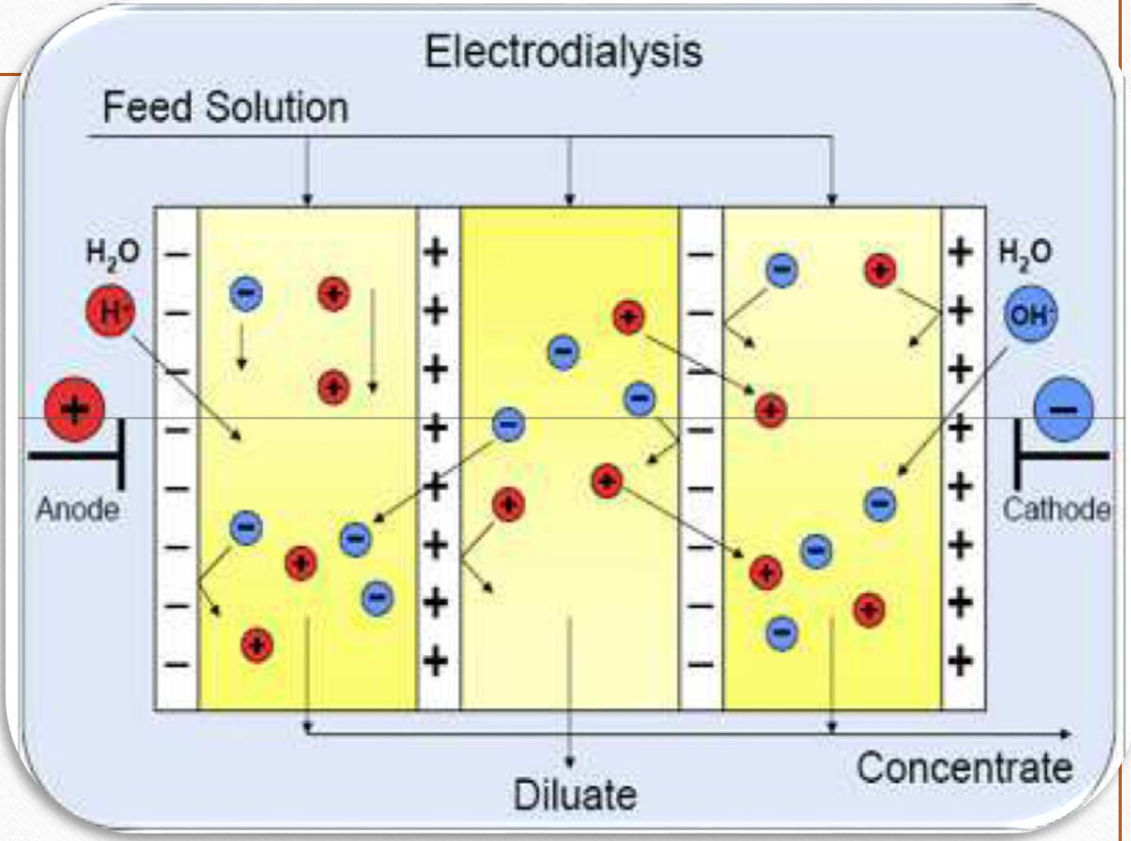
RO MEMBRANE


Perforated Central Tube
Anti-Telescoping Device
Feed Solution
Feed Channel Spacer
Membrane
Permeate
Concentrate
ESP WaterProducts.com
Permeate Collection Material
Membrane
Feed Channel Spacer
Outer Wrap
Spiral-Wound Membrane Element


water input
purified water
Waste water

4. Electrodialysis

- • Electrodialysis is an electrochemical process whereby electrically charged particles, ions, are transported from a raw solution (retentate, diluate) into a more concentrated solution permeate, concentrate) through ion-selective membranes by applying an electric field.
- • When a salt solution is under the influence of an electric field, as is the case in an electro dialysis module, the charge carriers in the solution come into motion.



- **This means that the negatively charged anions migrate towards the anode and the positively charged cations towards the cathode.**
- • In order to separate salts from a solution, ion-selective membranes, through which only one type of ion can permeate in an ideal case, are arranged in the solution perpendicular to the electric field.
- Thus negatively charged particles (anions) can pass through an anion exchange membrane on their way to the anode but are selectively retained by the upstream cation exchange membrane.
- • This separation stage results in a concentration of electrolytes in the socalled concentrate loop and a depletion of charge carriers in the so-called diluate loop.

REMOVAL ORGANIC DISSOLVED SOLIDS

Some of the methods used are:

- **lgooning in oxidation ponds;**
- **activated-sludge treatment;**
- **trickling filtration;**
- **anaerobic digestion**
- **Adsorption**
- **high-rate aerobic treatment (total oxidation);**
- **wet combustion;**
- **subsurface disposal; and**
- **the Bio-Disc system (RBC**).

Adsorption

- One of the most commonly used techniques for removing organics involves the process of adsorption, which is the physical adhesion of chemicals on to the surface of the solid
- The effectiveness of the adsorbent is directly related to the amount of surface area available to attract the particles of contaminant.
- The most commonly used adsorbent is a very porous matrix of granular activated carbon, which has an enormous surface area (~ 1000 m2/g).

Adsorption

- most economical and technically attractive method available for removing soluble organics such as phenols, chlorinated hydrocarbons, surfactants, and color and odor producing substances from waste water
- adsorbate: material being adsorbed
- Adsorbent: material doing the adsorbing. (examples are activated carbon or ion exchange resin).

Physical adsorption

- Van der Waals attraction between adsorbate and adsorbent.
- The attraction is not fixed to a specific site and the adsorbate is relatively site and the adsorbate is relatively free to move on the surface.
- This is relatively weak, reversible, adsorption capable of multilayer adsorption.

Chemical adsorption

- Some degree of chemical bonding between adsorbate and adsorbent characterized by strong attractiveness.
- Adsorbed molecules are not free to move on the surface on the surface.
- There is a high degree of specificity and typically a monolayer is formed.
- The process is seldom reversible.

REMOVAL COLLOIDAL SOLIDS

- Electro coagulation
- Sedimentation
- Floatation
- Coagulation
- Precipitation

Electrocoagulation:

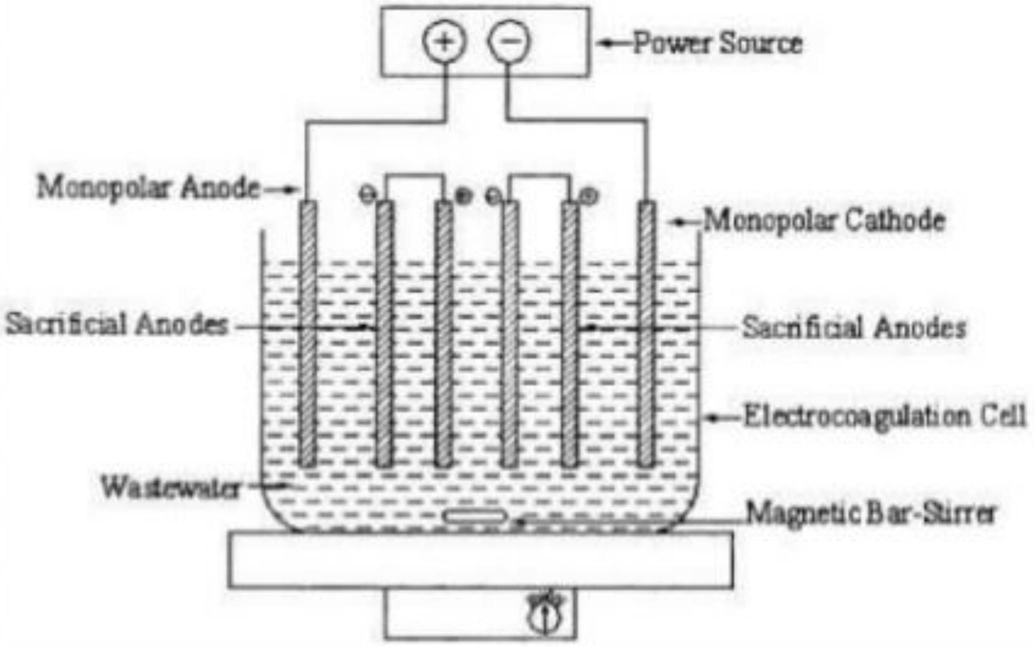
- Electrocoagulation is an advanced and economical water treatment technology. It effectively removes suspended solids to sub-micrometre levels
- Electrocoagulation is the process of destabilizing suspended, emulsified, or dissolved contaminants in an aqueous medium by introducing an electrical current into the medium.

Requirements of EC

- EC reactor is made up of an electrolytic cell with one anode and one cathode. EC system essentially consists of pairs of conductive metal plates in parallel, which act as monopolar electrodes. It also required sacrificial anodes. The requirements to operate EC are

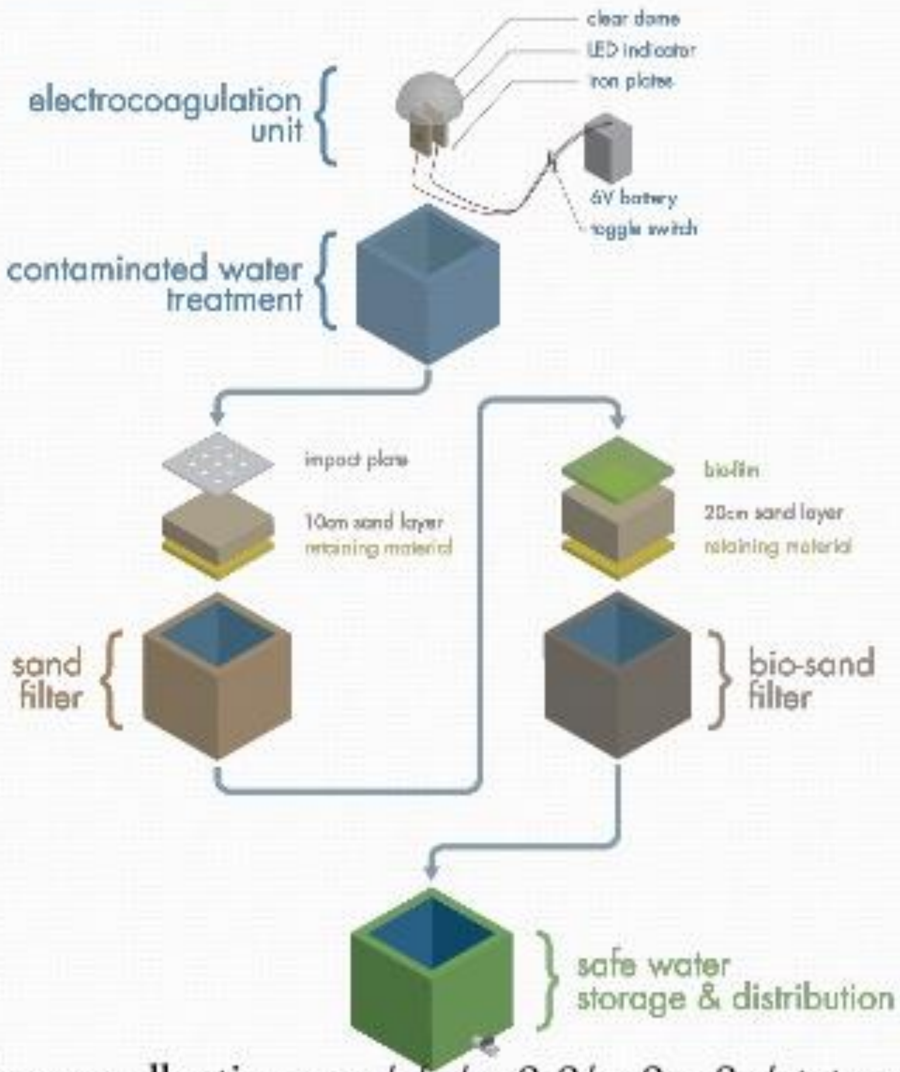
a. Direct current power source
b. Resistance Box
c. Multimeter

Schematic Diagram



http://www.worldofchemicals.com/article/18/EC-reactor-electrodes.jpg

Working



http://payload.cargocollective.com/1/0/20818/2289083/ststem-overview.png

Advantages

- Removes suspended and colloidal solids
- Breaks oil emulsions in water
- Removes fats, oil, and grease
- Removes complex organics
- Destroys and removes bacteria, viruses and cysts
- Color removal up to 95%
- BOD removal > 60%
- COD removal > 70%

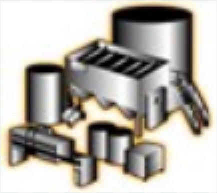
Disadvantages

- The 'sacrificial electrodes' are dissolved into wastewater streams as a result of oxidation, and need to be regularly replaced.
- The use of electricity may be expensive in many places.
- High conductivity of the wastewater suspension is required.

Methods for suspended solids removal

- ***Sedimentation*** is the more common technique in wastewater treatment because it involves little mechanical equipment and it is very stable to operate. However, there are some situations where flotation is a better choice.

- ***Flotation*** is a good technique for solids removal when the density difference between water and the solids is marginal, or the solids have a high fat or oil content.



Methods for suspended solids removal

- ***Coagulation*** is employed for removal of waste materials in suspended or colloidal form. Colloids are particles within the size range of 1 nm to 0.1 nm, do not settle out on standing and can not be removed by conventional physical treatment processes.

- ***Precipitation.*** In the water treatment, the precipitation process is used for softening (removal of the hardness caused by calcium and magnesium) and removal of iron and manganese.

Sedimentation:

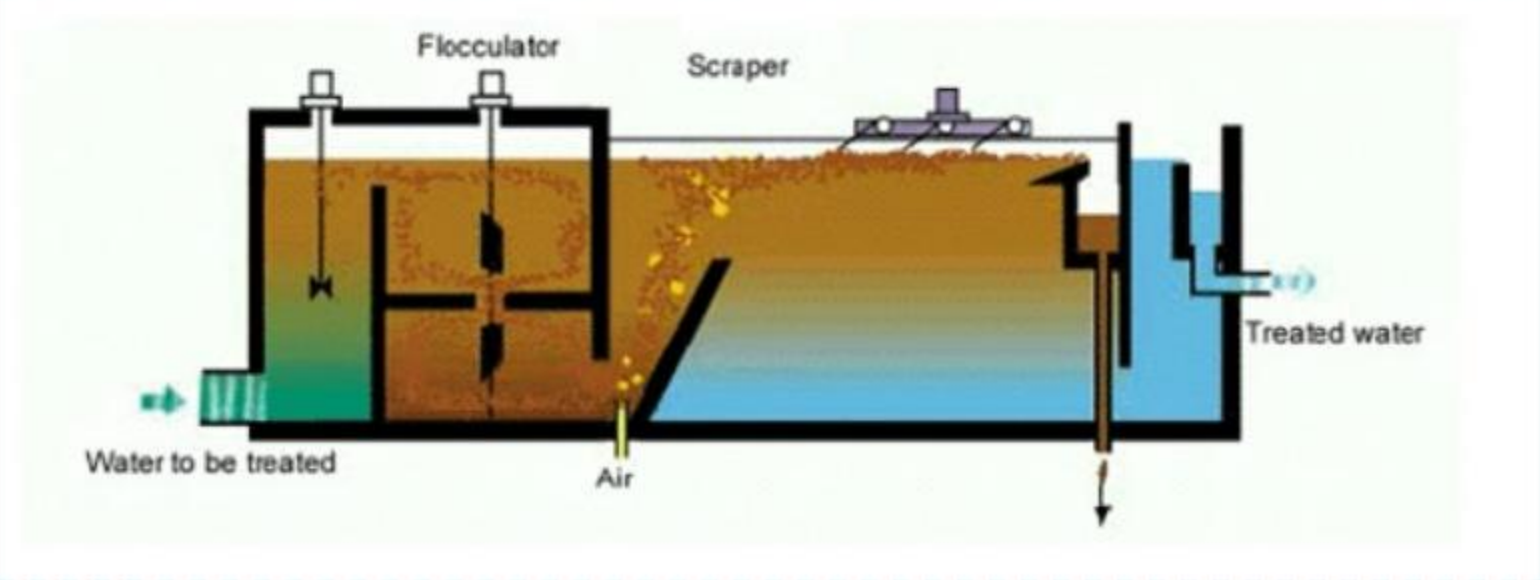
- *Reduce solids* by at least 50%, with proportional reduce of BOD.
- *Addition of chemicals* to assist settlement by coagulating particles or chemical precipitation can be essential.
- Can have acceptable discharge standards with regular desludging *without a secondary treatment* .
- Primary tanks are *desludged* at intervals of between *8 and 24 hours*.
- Secondary settlement follows any form of *biological aeration or filtration* to produce an effluent low in solids.
- Particularly demanding discharge consents may dictate a *tertiary treatment* to remove solids and BOD by a further 50%.

Flotation:

Dissolved air flotation, which is a common technique. This technique basically consists on injecting an aqueous stream containing dissolved air into the wastewater . The dissolved air forms bubbles when it comes out of solution and carries suspended particles, which tend to concentrate at the bubble wastewater interface, to the surface, where they form an emulsion.

Flotation:

General diagram for flotation methods:



Coagulation:

Paperboards wastes can be effectively coagulated with low dosages of alum. Silica or polyelectrolyte will aid in the formation of a rapid settling floc.

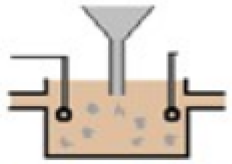
Wastes that contain emulsified oil can also be clarified by coagulation.

For effective coagulation, alkalinity should first be added, . After addition of alkali and coagulant, a rapid mixing is recommended.

Precipitation:

Chemical precipitation in wastewater treatment involves the addition of chemicals to alter the physical and chemical state of dissolved and suspended material and to facilitate their removal. It is usually combined with coagulation, flocculation, separation.

Principle: Dissolved compounds, for instance heavy metal ions, are brought into their insoluble hydroxides by pH increase through dosing of lime or NaOH. Using coagulation, flocculation techniques these small hydroxide nuclei become larger flocs for separation. With proper precipitants these flocs also serve as entrapment for other dissolved (organic) compounds; a form of co-precipitation.


precipitation

Tier 1

Joint Treatment of Industrial Waste and Domestic Sewage : Feasibility

- Industrial discharges often significantly alter the total flow and concentrations of various wastewater constituents, such as biochemical oxygen demand (BOD), suspended solids, and heavy metals, to be treated by municipal treatment facilities.
- These factors are important in determining the size and type of treatment processes required to meet the increasingly stringent standards being imposed on communities.
- Planning for the joint treatment of domestic and industrial wastewater is a crucial element in the design of cost-effective treatment systems.
- The impact of joint treatment on the various participants and their corresponding responses will be important in determining the type and size of facilities required.

Advantages

- The municipality is required to provide joint treatment when certain conditions are met, but it has considerable flexibility in making use of such policy instruments as pricing strategies and pretreatment requirements to encourage or discourage joint treatment.
- The municipality will compare the additional benefits and costs of joint treatment in order to determine its policies.
- EPA describes several benefits a municipality may anticipate from joint treatment.

Advantages

- One such benefit is the potential economies of size associated with small-scale treatment facilities which serve rural communities.
- The increased flow from industrial participation is expected to result in lower average treatment costs.
- The increased flow may also result in a reduced peak-to average flow ratio, thereby increasing capacity utilization.
- Treatment of combined wastes also allows the use of nutrients available in domestic wastes for biological treatment of industrial wastes that may be nutrient deficient.

Disadvantages

- Inclusion of industrial wastes in municipal wastewater treatment systems can, however, lead to additional system costs.
- Many industrial wastewaters, while compatible with common treatment processes, are more highly concentrated, in terms of constituents such as BOD and suspended solids, than normal domestic sewage.
- The inclusion of these wastes, therefore, may require longer detention times and/or equipment with larger capacities, resulting in higher per unit treatment costs.
- Industrial wastes often contain high levels of pollutants, such as heavy metals, grease, cyanide, and many organic compounds, which are incompatible with certain biological treatment technologies.

Disadvantages

- The efficiency of biological processes may be lowered with the presence of certain pollutants, thereby creating the potential for increased pass-through of pollutants and possible violation of the municipality's National Pollutant Discharge Elimination System (NPDES) permit for direct discharge
- Sufficient levels of some pollutants may even cause a complete breakdown. To prevent such a breakdown, the treatment facility may have to substitute higher cost treatment alternatives or require additional treatment processes not otherwise necessary for treatment of the municipal wastes, and therefore, not subject to Federal subsidies.

Disadvantages

- In addition, industrial pollutants are likely to become concentrated in the wastewater sludge. This may lower the quality of resultant sludge, making them unsuitable for certain disposal methods and possibly increasing disposal costs.

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- Finally, incompatible wastes from industrial sources may simply pass through the treatment plant without affecting its operations and associated costs, but may cause the plant to violate its NPDES permit with respect to the corresponding pollutants

Principle of raw , partially treated and combined treated wastewater to stream

raw wastewater to stream

- Discharge of untreated wastes (although almost an academic problem in 1968) should be per mitted only after a detailed survey, by competent and certified sanitary engineers, of the existing condition and future uses of the receiving stream
- As our population grows and industry expands to meet the needs of the people, fewer opportunities will exist for the discharge of untreated wastes to rivers. since there will be more competition for water and more use of streams

raw wastewater to stream

- The need for and extent of) waste treatment will increase, probably more rapidly than the population.
- An industry is usually liable legally for any wastes originating on its property and reaching public water courses and the public shows little mercy for an industry which provides no treatment of wastewater which may be a nuisance
- An industry, therefore, should carefully consider the possibility of lawsuits and adverse public opinion before it decides on direct discharge of raw waste to a nearby stream.

partially treated wastewater to stream

- Large industries located outside city limits often have water requirements so great that they must develop their own sources of water and likewise they must dispose of their own wastes
- Wastes from these large plants contain so much pollution that some treatment is required before discharge into the stream
- Since treatment of large volumes of waste water is expensive, an industry should investigate many alternative methods of protecting the receiving waters
- Although such studies require time-consuming survey, analysis, and evalua tion, an industry cannot bypass these steps without spending an excessive amount of money for waste treatment.

Completely treated wastewater to stream

- Complete treatment of wastes prior to direct do charge to a receiving stream is gradually receiving more and more consideration.
- With the population explosion and industrial expansion, we can expect more extensive waste-treatment requirements. At present, complete treatment is required only in special instances and in the case of the large, wet industries-for example, textiles, pulp and paper, steel, and chemicals
- It is generally con ceded that complete treatment refers to secondary treatment; that is, the removal of about 85 to 90 per cent of the BOD by a combination of physical, biology logical, and/or chemical means

Completely treated wastewater to stream

- According to this definition, one is removing only two polluting con stituents: suspended solids and dissolved organic matter (including colloidal solids)
- An industry requiring complete treatment for its waste usually discharges a large volume of waste and is located outside, and some distance from, a municipality, on a stream requiring the maintenance of high standards of water quality
- complete treatment" as that which renders waste waters reusable for industrial and in some cases) municipal water supplies This Normally will mean a fairly complete removal of all suspended, dis solved, and colloidal solids, including both inorganic and organic fractions