الجامعة التكنولوجية

قسم الهندسة الكيمياوية

المرحلة الثانية

مباديء هندسة البيئة

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Water pollution:

INTRODUCTION, Epidemiology, Communicable Disease ,Contamination ,

Disinfection

Communicable Disease:

An illness due to a specific infectious agent or its toxic products arises through transmission of that agent or its products from an infected person, animal, or inanimate reservoir to a susceptible host, either directly or indirectly through an intermediate plant or animal host, vector, or the inanimate environment. Illness may be caused by pathogenic bacteria, bacterial toxins, viruses, protozoa, parasitic worms , poisonous plants and animals, chemical poisons, and fungi, including yeasts and molds. Communicable diseases are grouped and discussed under respiratory diseases, waterborne diseases, food borne diseases, zoonoses, and miscellaneous diseases.

The communicable diseases (malaria, yellow fever, pneumonia, tuberculosis, cholera, schistosomiasis, onchocerciasis, trachoma, intestinal parasitosis, and diarrheal diseases) and malnutrition are considered the core health problems of developing countries, many of which are aggravated by contaminated drinking water, unhygienic housing, and poor sanitation.

Contamination:

The presence of an infectious agent on a body surface; also on or in clothes, bedding, toys, surgical instruments or dressings, or other inanimate articles or substances, including water and food. *Pollution is* distinct from contamination and implies the presence of offensive, but not necessarily infectious.

Disinfection:

The application of microbicidal chemicals to materials (surfaces as well as water), which come into contact with or are ingested b humans and animals, for the purpose of killing pathogenic microorganisms. Disinfection may not be totally effective against all pathogens.

Water pollution:

Why treat water and wastewater?

- *Reasons for treating:*
- Protect surface-water quality
- Protect public health
- Meet legal requirements.

Water is considered polluted if some substance or condition is present to such degree that water cannot be used for a specific purpose.

Types and source of water pollution:

1. Domestic swage

2. Disease causing agents (bacteria, virus)

3. Inorganic chemicals and minerals

4. Synthetic organic chemical and oil

5. Nutrients (Nitrates, Phosphate)

6. Radioactive substance

7. Heat from industrial and power plants.

Domestic swage:

These wastes are usually destroyed by bacteria if there is sufficient oxygen dissolved in the water. However, if lakes or slow moving rivers are overloaded with these wastes, then the oxygen caused in decomposing them depletes the overall dissolved oxygen content until many of forms of plant and animal life are killed or forced to migrate to other areas. More sophisticated and expensive secondary and tertiary treatment sewage treatment plants are the major way to solving this problem.

Disease causing agents:

Disease causing agents are the infections organisms such as bacteria and viruses carried into surface and ground water. This form of pollution will require continual vigilance and expensive research to find method for removing bacteria and virus.

Inorganic chemicals and minerals:

Inorganic chemicals and minerals are the vast arrays of acids, salts and metals compounds that may increase the acidity, salinity and toxicity of water. They reach our waters from industrial activities, irrigation and oil fields. These substances can be controlled by removing them through waste treatment and preventing some chemicals (for example, mercury) from reaching water supplies.

Synthetic organic chemicals:

Synthetic organic chemicals include pesticides, plastics, detergents, industrial chemicals and oil. The analysis of polluted waters shows the

presence of wide variety of these compounds. These compounds can be controlled by removing them through different type of waste treatment.

Nutrients:

Nutrients include nitrogen, phosphorus and other substances that support and stimulate the growth of aquatic plant such as algae. They are contributed from fertilizer, detergents and effluents from industrial waste and sewage treatment plants. In excess they can cause algae blooms producing odor and taste. Agriculture runoff is difficult to control because the sources are diffuse. Phosphate from sewage and industrial waste can be removed at considerable cost and removal of nitrate is difficult.

Radioactive:

Radioactive waste includes radium, strontium and uranium. Pollution can be result from mining, testing and using nuclear weapons, poorly designed and operated nuclear power plant, the use of radioactive materials in medicine and research. Because of their harmful effects must be prevent them from reaching out water air and soil.

Heated water:

Heated water is being returned in large quantities to streams, lakes and oceans by power and industrial plants. Excess heat reduces the amount of dissolved oxygen, lowering the capacity of a water system to degrade oxygen demanding waste, decrease the survival changes of some forms of aquatic life. It can be minimized by addition of expensive cooling towers and holding ponds.

(Water Quality Standards):

High water quality is defined as water that contains no pathogenic organisms and free from biological forms that may be aesthetically objectionable. It is clear and colorless and has no objectionable taste or odor. It does not contain concentration of chemicals that may be physiological harmful, aesthetically objectionable or economically damaging. It also is not corrosive, nor does it leave excessive or undesirable deposits on water-conveying structures, including pipes, tanks, and plumping fixtures. Any country can evaluate its positive and negative implications in terms of water quality, health status and environmental conditions, which will lead to the establishment of standards that are really appropriate to local conditions

Iraqi Drinking Water Standards:

It is essential that each country undertake a review of its needs and capacity for drinking-water standards. Iraqi Central Organization for Standardization and Quality Control *(ICSQC, 2001) set down standards for Drinking Water. These are shown* in Table

Constituent Or Characteristic	Unit	Drinking Water Iraqi 2001	Drinking Water WHO 2004
Physical:			
Color	C.U	10	15
Turbidity	NTU	5	5
Microbiological:			
Colioform organ.	MPN	0.	0
Fecal Coliform	/100ml	0.	0
Inorgan. Chemicals:			
Aluminum(Al)	mg/L	0.2	0.2
Arsenic(As)	mg/L	0.01	0.01
Cadmium(Cd)	mg/L	0.003	0.003
Chloride(Cl)	mg/L	200	250
Chlorine(Res.Cl)	mg/L	0.5-2	0.6-1
Chromium(Cr^{+6})	mg/L	0.05	0.05
Copper(Cu)	mg/L	1.0	2.0
Fluoride(F)	mg/L	1.0	1.5
Iron(Fe)	mg/L	0.3	0.3
Lead(Pb)	mg/L	0.05	0.05
Manganese (Mn)	mg/L	0.1	0.05
Mercury(Hg)	mg/L	0.001	……..
pH(range)	…….	6.5 - 8.5	6.5 - 8.5
Sulfate(SO_4)	mg/L	200	250
Zinc(Zn)	mg/L	0.5	5

World Health Organization Guidelines:

The aim of general drinking water guidelines, such as those set by the World Health Organization, is the ultimate protection of public health. They are intended to be used as the basis for the development of national standards and the development of risk management strategies in the context of environmental, social, economic and cultural conditions for the different countries of the world. *(World Health Organization, WHO, 2004) set down Guidelines for* Drinking Water Quality. The guideline values are shown in table

Most important indicator in water treatment:

1. Turbidity: ***Potential health effects:***

Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of Disease-causing microorganisms such as viruses, parasites, and some bacteria.

- *Sources:* Soil runoff

2. Total Coliforms: ***Potential health effects:***

Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present

Sources:

- Coliforms are naturally present in the environment
- **3. Chlorine:** ***Potential health effects:***

  Eye/nose irritation; stomach discomfort

- *Sources:*

  Water additive used to control microbes

(POPULATION ESTIMATES):

Prior to the design of a water treatment plant, it is necessary to forecast the future population of the communities to be served. The plant should be sufficient generally for 25 to 30 years. It is difficult to estimate the population growth due to economic and social factors involved. However, a few methods have been used for forecasting population.

1. **Arithmetic Method:**

This method of forecasting is based upon the hypothesis that the rate of increase is constant. It may be expressed as follows:

$$\frac{dp}{dt} = k_a$$

where

p = population

t = time, yr

ka = arithmetic growth rate constant

Rearrange and integrate the above equation, *p1 and p2 are the populations* at time *t1 and t2 respectively.*

$$p_2 - p_1 = k_a(t_2 - t_1)$$

$$k_a = \frac{p_2 - p_1}{t_2 - t_1} = \frac{\Delta p}{\Delta t}$$

$$p_t = p_0 + k_a t$$

pt = population at future time

p0 = present population, usually use p2

2. **Constant Percentage Growth Rate Method**:

The hypothesis of constant percentage or geometric growth rate assumes that the rate increase is proportional to population. It can be written as:

Mechanism of acid formation in atmosphere:

$$\frac{dp}{dt} = k_p p$$

Integrating this equation yields

$$\ln p_2 - \ln p_1 = k_p (t_2 - t_1)$$

$$k_p = \frac{\ln p_2 - \ln p_1}{t_2 - t_1}$$

The geometric estimate of population is given by

$$\ln p = \ln p_2 + k_p (t - t_2)$$

3. Declining Growth Method

This is a decreasing rate of increase on the basis that the growth rate is a function of its population deficit. Mathematically it is given as

$$\frac{dp}{dt} = k_d (p_s - p)$$

Where

ps = saturation population, assume value

Integration of the above equation gives

Control strategies for acid rain:

$$\int_{p_1}^{p_2} \frac{dp}{p_s - p} = k_d \int_{t_1}^{t_2} dt$$

$$-\ln \frac{p_s - p_2}{p_s - p_1} = k_d (t_2 - t_1)$$

Rearranging

$$k_d = -\frac{1}{t_2 - t_1} \ln \frac{p_s - p_2}{p_s - p_1}$$

The future population *P is*

$$P = P_0 + (P_s - P_0)(1 - e^{-k_d t})$$

EXAMPLE: A mid-size city recorded populations of 113,000 and 129,000 in the April 1980 and April 1990 census, respectively. Estimate the population in January 1999 by comparing (a) arithmetic method, (b) constant percentage method, and (c) declining growth method.

Solution:

Step1. Solve with the arithmetic method Let *t1 and t2 for April 1980 and April 1990, respectively*

$$\Delta t = t_2 - t_1 = 10 \text{ yr}$$

$$K_a = \frac{p_2 - p_1}{t_2 - t_1} = \frac{129{,}000 - 113{,}000}{10} = 1600$$

Predict *pt for January 1999 from t2*

$$\begin{aligned} t &= 8.75 \text{ yr} \\ p_t &= p_2 + k_a t \\ &= 129{,}000 + 1600 \times 8.75 \\ &= 143{,}000 \end{aligned}$$

Step2. Solve with constant percentage method

$$\begin{aligned} k_p &= \frac{\ln p_2 - \ln p_1}{t_2 - t_1} = \frac{\ln 129{,}000 - \ln 113{,}000}{10} \\ &= 0.013243 \end{aligned}$$

$$\begin{aligned} \ln P &= \ln P_2 + k_p (t - t_2) \\ &= \ln 129{,}000 + 0.013243 \times 8.75 \\ &= 11.8834 \\ p &= 144{,}800 \end{aligned}$$

Solve with declining growth method Assuming

$$p_s = 200{,}000$$

$$k_d = -\frac{1}{t_2 - t_1}\ln\frac{p_s - p_2}{p_s - p_1}$$

$$= -\frac{1}{10}\ln\frac{200{,}000 - 129{,}000}{200{,}000 - 113{,}000}$$

$$= 0.02032$$

$$P = P_0 + (P_s - P_0)(1 - e^{-k_d t})$$

$$= 129{,}000 + (200{,}000 - 129{,}000)(1 - e^{-0.02032\times 8.75})$$

$$= 129{,}000 + 71{,}000 \times 0.163$$

$$= 140{,}600$$

SUBSURFACE OR UNDERGROUND SOURCES

The rainwater that gets infiltered and percolated inside the earth to form a uniform water surface is known as the ground water. This water is comparatively pure because of the natural filtration as it passes through the soil. Many impurities are retained by the soil through the actions like screening, sedimentation, adsorption etc. But it dissolves many soluble salts as it passes through the soil containing those salts. So the total dissolved solids of the underground water are much more than the surface water. The flow of rain water from surface of earth to the underground depends upon the porosity of the soil, the rate of water loss by evaporation, seepage to surface sources and withdrawal by us.

Porosity

The porosity of a stratum (soil or rock) is a quantitative measurement of the interstices of the voids present in a given volume.

Mathematically porosity = Volume of voids/total volume

So the porosity | = Vv/V×100 (per cent)

Where Vv = Volume of voids

V = total volume

Porosity depends upon shape and arrangement (packing) of the solid particles. Uniformly graded (same size and shape) particles are more porous whereas those with different size and shape are well packed and thus have poor porosity. Sands may have 30 to 40% porosity whereas the slate or granite may have 1 to 4% porosity only.

Permeability

The permeability is defined as the ability of rock or soil stratum to transmit or pass water through itself. Water enters in the pores (voids) of the rocks, and is stored there until it is drained off. The 'porosity' of the rock thus defines the maximum amount of water that can be stored in the rock. The porosity in itself does not ensure the storage of underground water. Actually the water can enter into a rock (with any porosity) only if the rock permits the flow of water through it, i.e. it depends upon whether the rock is permeable or not. So a rock that is porous may not be permeable. For example shale is a porous rock but not permeable. Its pore spaces are so minute and not well connected to each other that the shale is impermeable. The permeability is defined in terms of coefficient of permeability k (m/sec.). It has been well defined by the Darcy's law. Darcy's Law:- Scientist H. Darcy demonstrated on the basis of experiments that for the laminar flow conditions (Reynolds number < 1) the discharge, passing through a soil is proportional to the head loss ⊗H and the area of cross section A of the soil and inversely proportional to the length (L)

So Q □ ⊗H/L. A (⊗H/L can be designated as hydraulic gradient i)

or Q □ i A

or Q = k i A

The above equation gives the dimensions of k as m/sec. That is the unit of velocity.

One more term is transmissibility. Scientist This defined transmissibility as the rate of flow of water through a vertical strip of water bearing stratum (aquifer) of unit width and full depth (d) under a unit hydraulic gradient and a temperature of 60o F.

Thesis' T = k d

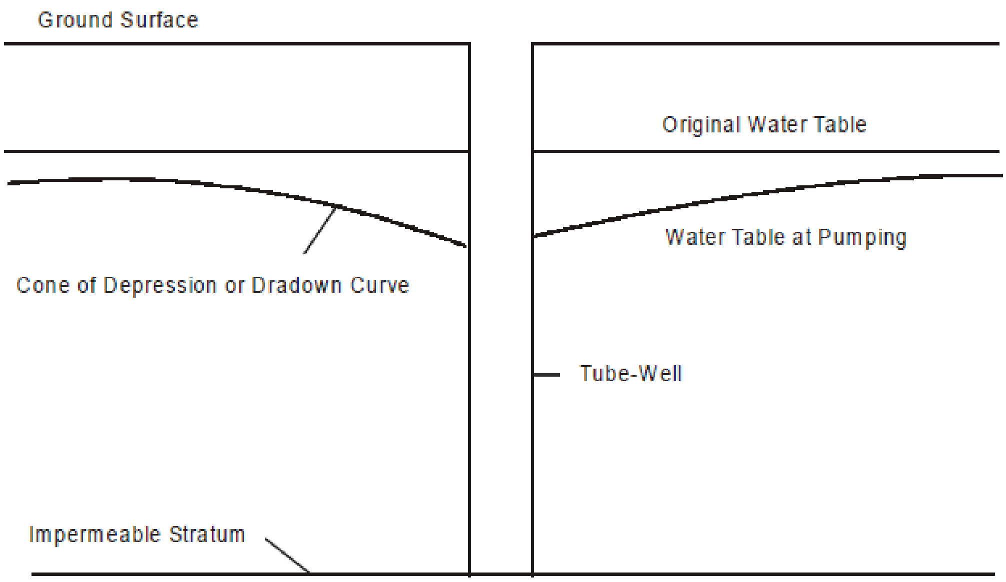
The following table gives the porosity and permeability of some of the formations

Table 2.1 Porosity and Permeability of Some Soils

S. No.	*Type of formation*	*Porosity*	*Permeability*
1	Granite, Quartzite	1.5%	
2	Slate, Shale	4%	
3	Limestone	5 to 10%	
4	Sandstone	10 to 15%	
5	Gravel	25%	1.0 or more
6	Sand and gravel	20 to 30%	1-0.1
7	Only fine sand	35%	0.05-0.001
8	Silty sand	-	0.002-0.0001
9	Silt	-	0.0005-0.00001
10	Clay	45%	0.000001 or lesser

GROUND WATER YIELD

The ground water is present in the water bearing stratum. Those soil formations through which it can be easily and economically extracted is known as aquifers. The top layer of ground water is known as water table. The ground water may come out by itself either through springs or sometimes as artisan wells, but generally extracted out through the wells. Larger diameter wells are known as open wells whereas the smaller diameter wells (30 cm or so) are known as tube-wells. Tube-wells are drilled by machines and fitted with blank or perforated pipes (strainers to draw water). Different type of pumps is installed in the wells to get the water on ground surface. These days generally submersible pumps are lowered in the tube-wells and open wells capable of drawing water for various heads and discharges. As soon as the pumping is started the ground water table goes down and a cone of depression is formed as shown below



After sometime the equilibrium is achieved, depending upon the yield (capacity to provide water) and the withdrawal capacity of the pump set. If the yield of the aquifer is more than the capacity of the pump installed we get continuous supply of water, but if the pump has larger withdrawal capacity than the yield, then the supply of water shall stop. The supply shall start again after sometime after further accumulation of water from distant places in the aquifer. So the yield is known as the quantity of ground water that can be extracted from a saturated (all voids filled up with water) water bearing stratum. The ratio of this volume of water to the total volume of the stratum is known as the specific yield. It is expressed in percentage that this much per cent of water may be extracted from the soil economically. The water that cannot be extracted is known as the specific retention or field capacity.

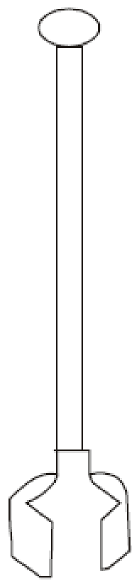
This specific retention is the amount of water held between the grains due to molecular attraction. This film of water is thus held by molecular adhesion on the walls of the intrices. Therefore the amount of this water will depend upon the total interstitial surface in the rock. If the total interstitial surface is more, the specific retention will be more and vice-versa. In soils like clay as the specific area is more, the specific retention would be more and hence it will result in a small specific yield. Similarly in large particle soil like coarse gravels, the specific retention would be smaller and it will give large specific yields.

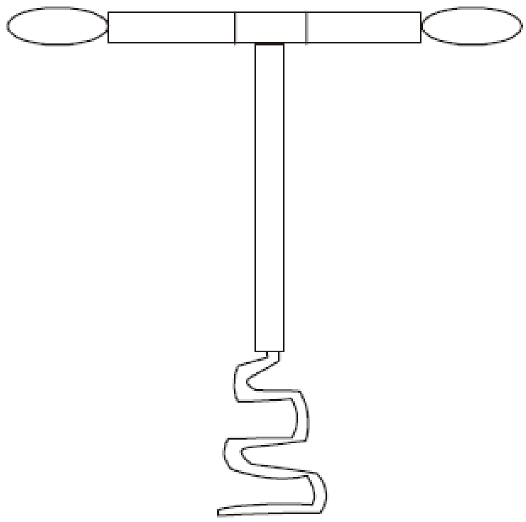
After drilling the tube-wells by drilling machines the hydro-geologists make a log chart of the stratum and then decide the position of blank and perforated pipes depending upon the rock formation (aquifer). Tube-wells may be shallow or deep depending upon the depth of water table, yield of the aquifer and the requirement of water. The drilling operation of the well depends upon the expected soil structure.

1 Drilling of Tube-Wells

Tube-wells can be drilled by following methods:

(i) Auger Drilling (upto 15 m) For smaller depths and smaller diameters auger drilling can be used in clay silt or sand. The auger may be hand operated or power operated. Some of them are as shown below.





This type of drilling is possible only in soft soils. To support the soft soil casing pipe are lowered simultaneously.

(ii) Water jet or Wash Boring In water jet boring method, a drill bit with nozzles is attached to the drill pipe at its bottom. Water under high pressure is pumped into the drill pipe. The force of water jet coming out of the nozzle loosens the subsurface soil. The returning water flow through the annular space between the borehole and the drill pipe carries the cuttings along with it to the ground surface. Here also the soft soil is supported by the casing pipe to avoid collapsing in. The method is not suitable for hard soils.

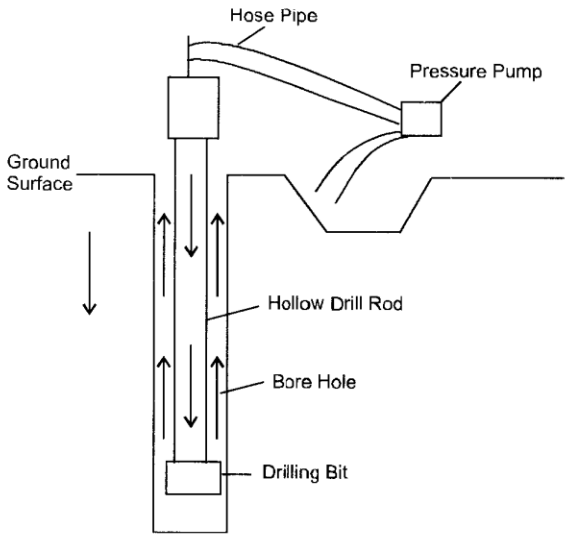
(iii) Core Drilling This method is used for hard soil. In this method a core cutter with steel teeth (drill bit) attached to a drill rod rotates and thus cuts the hard soil. As the soil is cut and the hole is formed water supplied through the drill rod removes the cuttings. For extremely hard and strong soils diamond bits are used.

(iv) Percussion Drilling In this method a drill tool string constituting of a drill bit, a drill stem, and a drill jar is lifted up and dropped down by connecting it to a diesel engine and a wintch. The cable tool bit acts as a mini crusher that chops the

consolidated formations. After the bit has chopped the formation for 1 to 1.5 m it is taken out of the hole and a bailer is inserted to remove the cuttings. Water makes slurry with pulverized materials that is bailed out. As the bailer is lifted, the flap valve closes and it brings with it the cuttings to the ground. Casing is used simultaneously in soft (unconsolidated) formation. The method is suitable for drilling holes 20 to 50 cm in diameter and upto 150 m deep.

(v) *Rotary Drilling*

This method is suitable for unconsolidated clay and sand formations as well as coarse gravel and boulders including soft rocks. In this method the rotating drill bit makes the bore hole. The mud slurry, generally bentonite is pumped down through the drill pipe as the drilling proceeds. This mud rises to the ground surface along the walls of the hole and carries with it the cuttings. The mud also strengthens the walls of the hole to prevent falling in. The following figure shows the schematic diagram of the Rotary drilling.



(vi) *Down the Hole Hammer Drilling (DTH)*

In this method of drilling a pneumatically (by air pressure) operated hammer is used at the lower end of the drill pipe. Thus it combines the percussion effect of the cable tool method and the rotary action of the rotary drilling. As the drilling proceeds the hammer crushes the rock into small chips. A flush pump is used to flush out the hole and bringing the cuttings to the ground surface through the annular (circular) space between the bore hole and the drill pipe. Small diameter holes upto 30 cm can be successfully drilled in medium to hard

soil by this method. After drilling the hole and taking samples of the cuttings (removed soil) at regular intervals the pipe assembly is designed for blank and perforated pipes. Specially designed perforated pipes are known as strainers. They are designed to allow water to come inside the hole and the soil is prevented to get inside it by their special shape. That is why they are costlier than the blank pipes, so they are placed only in water bearing and yielding stratum (aquifer). There are many type of strainers like Cook Strainer, Ashford Strainer, Legget Strainer, Phoenix Strainer etc.

2 Lowering of Pipes and Gravel Packing

The pipe assembly consisting of blind pipes (without hole) and strainers (with well-designed holes) are lowered in the drilled hole to a depth as designed by the hydro geologist. The design of assembly is based on the depth of static water table, expected Draw-down (lowering of water table in a conical shape), expected yield and the requirement of water. The diameter of the drilled hole is bigger than this pipe assembly and thus some space is left between the walls of the hole and the tube-well pipe. This space is filled up with gravel of suitable size. The casing pipe to retain the hole is taken out simultaneously. The process of filling gravel (to stop entry of fine particles at pumping) is known as shrouding. This also increases the effective well diameter and hence the yield of the well. After shrouding the well is developed for use.

3 Development of Tube-wells

Development of a tube-well is the process of removing fine material from the aquifer surrounding the strainer pipe so that it does not cause choking at the time of pumping. It increases the yield from a tube-well and increases the useful life of the well. Following methods may be used for developing a tube-well:-

(i) Pumping Method

In this method the fine particles surrounding the well are agitated by the working of a variable discharge pump that gives jerks by its irregular motion. Slowly the speed of the pump is increased until no more fine particles come out with water.

(ii) Surging Method

In this method a hollow surge block or a bailer moves down the hole, already filled up with Calgon (Sodium hexa meta phosphate) a dispersing agent, forces it to the holes of the soil. When the bailer is moved upwards, a suction pressure is developed and the water calgon solution brings with it fine particles into the well. The surge block (bailer) is connected to a hollow pipe through which the water charged with fine particles is pumped out. This operation is repeated till clear water comes out from the well.

(iii) Compressed Air Method

In this method, the development of the tube-well is done with an air compressor discharge pipe and an air pipe. The air pipe is placed in the discharge pipe such that its lower end projects out of it by a small length. This assembly is lowered into the well till it reaches the bottom of the strainer pipe. After building a high pressure of air in the compressor (800 kN/m2) the air valve is opened suddenly to release the air with high pressure. This loosens the fine particles in the formation surrounding the slots. When the air valve is closed the pressure decreases and water enters the well alongwith the loosened fine particles. This water is pumped out of the well. The same operation is repeated at different levels along the strainer sections of the tube-well so that the whole well is fully developed.

(iv) Dry Ice Method (Chemical Method)

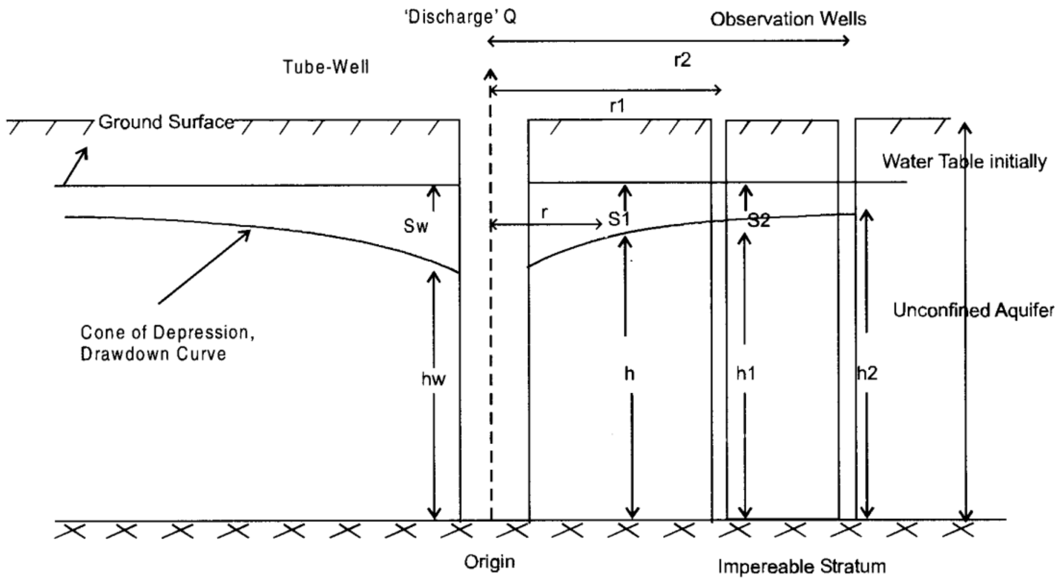
In this method sodium dioxide (dry ice) and hydrochloric acid are used. First of all HCl is poured in the well and the well is closed from the top. Compressed air is supplied which pushes the HCl into the voids of the soil. The top plug is then removed and dry ice blocks are dropped which sublimate to release CO2 which builds up a high pressure. This high pressure gas comes out of the tube-well with pressure followed by the water mixed with mud in the form of a jet. This way the fine material; are removed and the well starts giving clean water.

4 Yield of a Tube-Well

The yield (discharge) of a tube-well depends upon the depth and capacity of aquifer (water bearing stratum) and the drawdown. As the water comes to the tube-well from all directions the Dupuit- Theim equations can be used to obtain the yield from it. There are two cases, first in which the water bearing stratum has no upper impermeable layer (confining it to some limited depth), and there is only one impermeable layer at the bottom of the aquifer. This type is known as the unconfined aquifer. In the second case there are two impermeable layers, one at the top and other at the bottom of the aquifer, known as confined aquifer.

1 Yield of a tube-well in an unconfined aquifer

Let there be a well of radius rw fully penetrating an unconfined aquifer of thickness H below the water table (top surface of ground water) that is horizontal in the beginning. As soon as the water is pumped out of the well the water level near the tube-well goes down and this horizontal surface is converted into a conical curved surface as shown below.



When the water is pumped through the well at a constant rate Q for sometime, the lowering of water table near the tube-well (drawdown) comes to some final constant level, depending upon the capacity of supplying water by the soil and the power of the pump to draw water (discharge). Higher is the withdrawl capacity (discharge) of the pump and lesser is the supplying capacity of aquifer more will be the depth of the drawdown. In extreme case if this drawdown curve reaches the bottom of the aquifer means the demand is more than supply, water will stop coming out of the tube-well until it again gets filled up by resuming water from far places. Keeping this in mind the submersible pump should be lowered at a depth which is more than the worst expected drawdown. This is the reason that sometimes water mixed with air comes out from tube-wells and hand pumps (a type of small diameter tube-well operated manually). Or in extreme cases only air comes out. Here lies the necessity of recharging the aquifer by rain water. The over exploitation of underground water without, or less, recharging by rainwater has converted the good aquifers into dark zones. Presently we are drawing more and more water with tube-wells for irrigation and drinking purposes as the demand is growing exponentially. Nobody cares about the penetration of rainwater (runoff) through the soil to the under ground water. We have made houses, roads and other pucca structures which increases the flow of water (runoff) to the rivers from which most of it goes to sea and gets converted into useless saline, brackish water. Otherwise if it is collected in ponds or reservoirs it gets evaporated easily as it is exposed to atmosphere i.e. about 1.7 m/year in northern India. Had it been stored below the ground as underground water there would have not been any evaporation etc. In this case it would have been away from the surface pollution and rather it would have been automatically purified due to the natural filtration process. So it is wise to conserve rain water under the ground and use it only in a calculative, judicious manner. Unfortunately in most of the areas in India the underground water is either going deep and deep or has become so polluted to be useless for human consumption.

Actually we have to spent much more electricity if the water is to be lifted from a greater depth. The horse power of the pump that is directly related to the electric consumption (1H.P. = 0.746 kW) is based upon the discharge and head (depth of water) as follows:-

Horse Power = Q H/75 x |

Where Q = discharge in liters per second

H = head in meters

| = efficiency of the pump

So deeper is the water higher is the head and there is a larger requirement of the HP of the pump. As 1 HP = 0.746 kW and when 1 kW motor runs for one hour it consumes 1 kWh. i.e. one unit of electricity, the consumption of electricity increases directly with depth of water.

Now let us derive a mathematical expression for the estimation of discharge from a tube-well. For this derivation let us consider a cylindrical soil mass around the well (the wells are circular for the ease in construction and stability). Let the origin of the cylindrical co-ordinates (r, \ and h) be at the center of the bottom of the well. Let P be a point on the drawdown curve at a radial distance of r and at a height h above the impermeable stratum. Water flows to the vertical sides of the tube well passing through the point P. The area of flow A = 2∠ rh

Darcy's law gives the velocity of flow $V = ki = kdh/dr$

Where k is the co-efficient of permeability

And I is the hydraulic gradient

Discharge $Q = A.\ V$

$= 2\Pi\ rhkdh/dr$

or $h\ dh = Q/2\Pi k dr/r$

Integrating between limits $r = r_1$ and $h = h_1$ to $r = r_2$ and $h = h_2$

$$\int_{h_1}^{h_2} h\,dh = Q/\ 2\Pi k \int_{r_1}^{r_2} dr/r$$

or $(h_2^2 - h_1^2)/2 = Q/2\Pi k\ \log_e(r_2/r_1)$

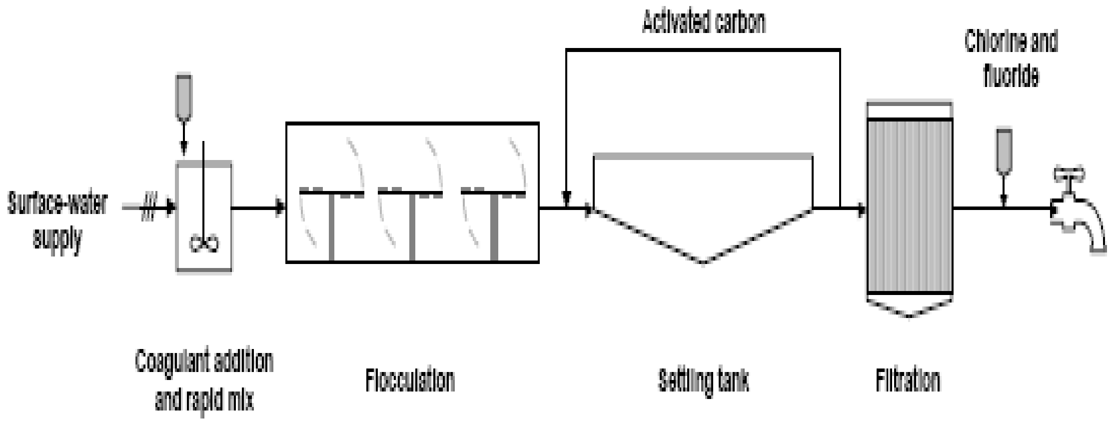
So
$$Q = \frac{\Pi k(h_2^{\ 2} - h_1^{\ 2})}{\log_e(r_2 / r_1)}$$

or $$Q = \frac{\Pi k(h_2^{\,2} - h_1^{\,2})}{2.303 \log_{10}(r_2/r_1)}$$

or $$Q = \frac{1.36k(h_2^{\,2} - h_1^{\,2})}{\log_{10}(r_2/r_1)}$$

(WATER TREATMENT):

As the raw surface water comes to the treatment plant, physical screening is the first step to remove coarse material and debris. Thereafter, following the basic treatment process of clarification, it would include coagulation, flocculation, and sedimentation prior to filtration, then disinfection (mostly by the use of chlorination). With a good quality source, the conventional treatment processes may be modified by removing the sedimentation process and to just have the coagulation and flocculation processes followed by filtration.

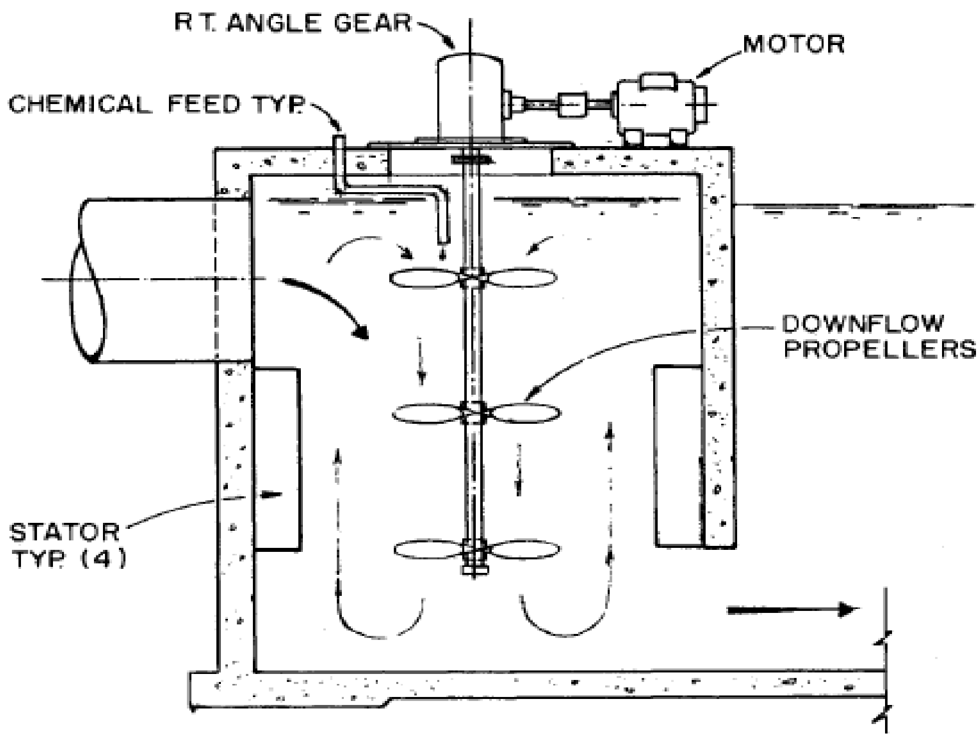


COAGULATION:

Coagulation is a chemical process to remove turbidity and color producing material that is mostly colloidal particles (1 to 200 mill microns, m) such as algae, bacteria, organic and inorganic substances, and clay particles.

Mixing:

Mixing is an important operation for the coagulation process. In practice, rapid mixing provides complete and uniform dispersion of a chemical added to the water. Then follows a slow mixing for flocculation (particle aggregation). The time required for rapid mixing is usually 10 to 20 s.



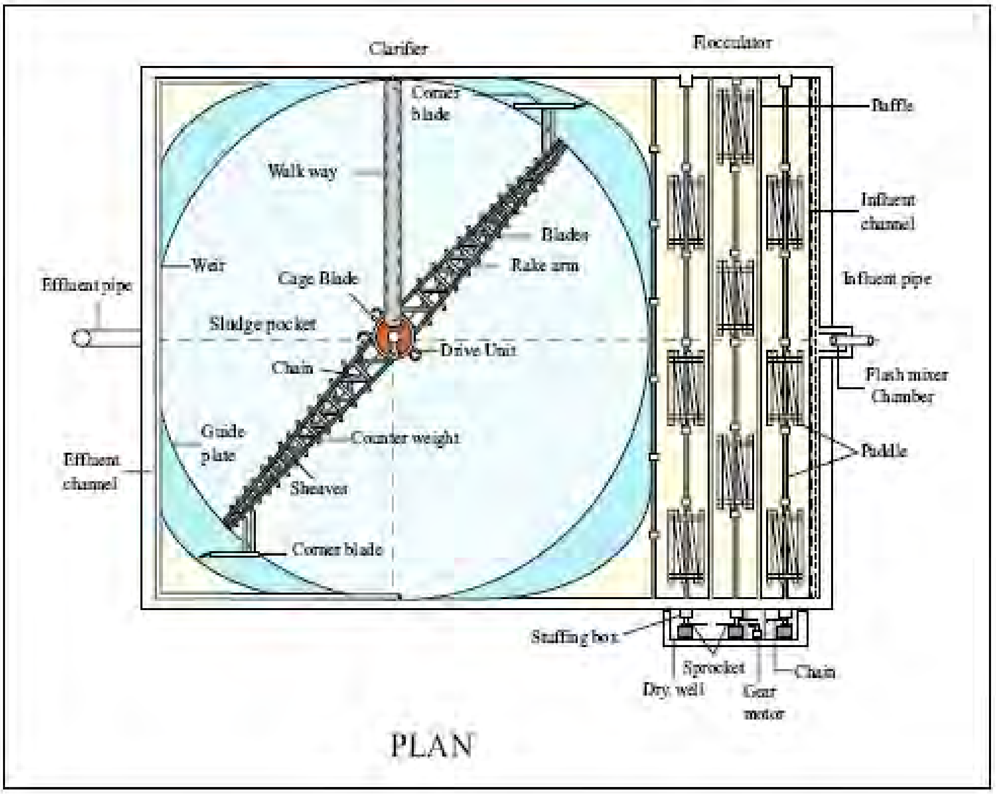
FLOCCULATION:

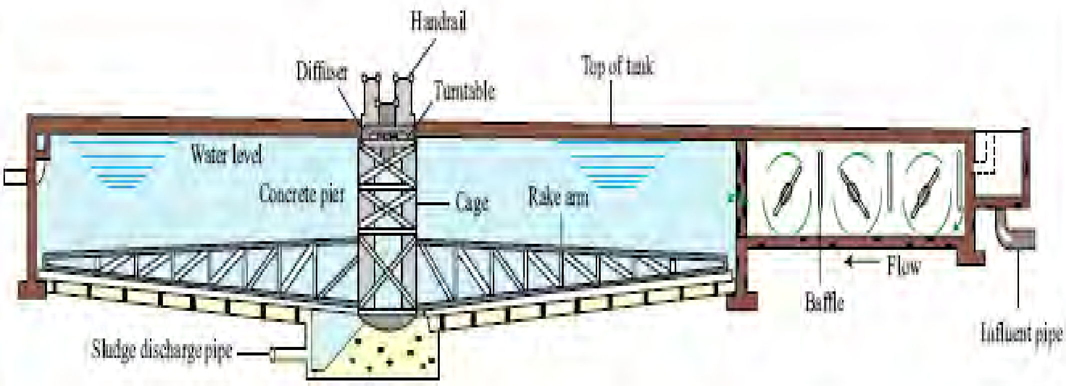
After rapid mixing, the water is passed through the flocculation basin. It is intended to mix the water to permit agglomeration of turbidity settled particles (solid capture) into larger flocs.

SEDIMENTATION:

Sedimentation is one of the most basic processes of water treatment. sedimentation tank (or basin) following coagulation—flocculation, is most commonly used in water treatment facilities. Sedimentation is a solid–liquid separation by gravitational settling. There are four types of sedimentation: discrete particle settling (type 1);

flocculants settling (type 2); hindered settling (type 3); and compression settling (type 4).

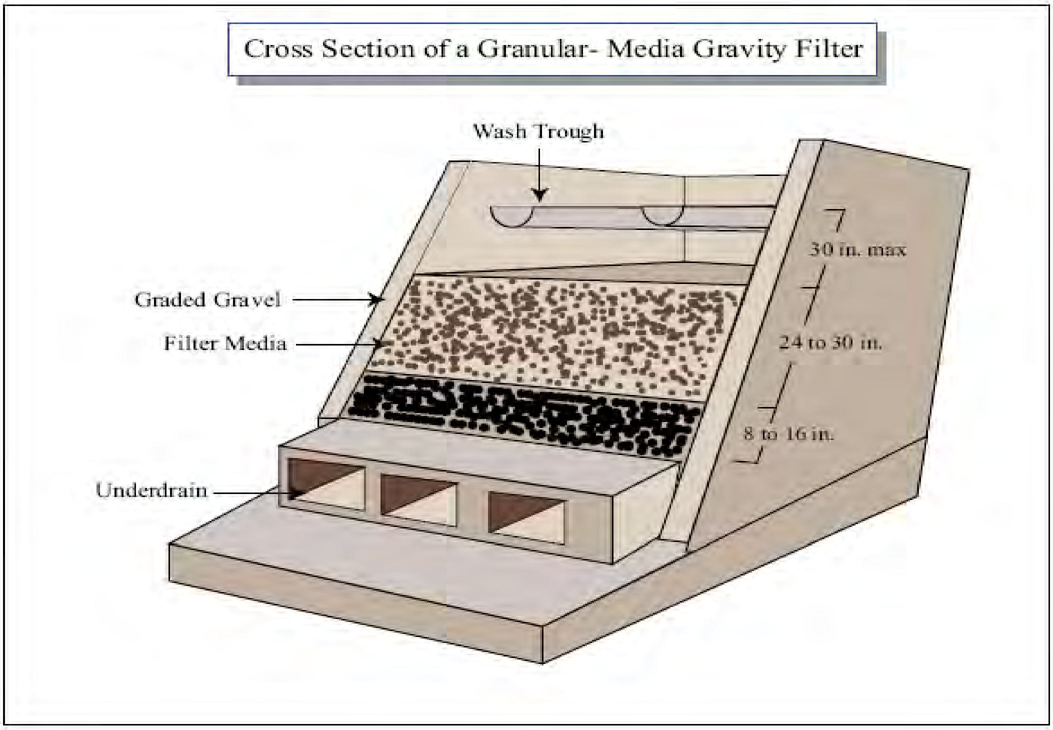




Flocculator & square sedimentation tank for water clarification, illustrating ceoss-flowoperation.

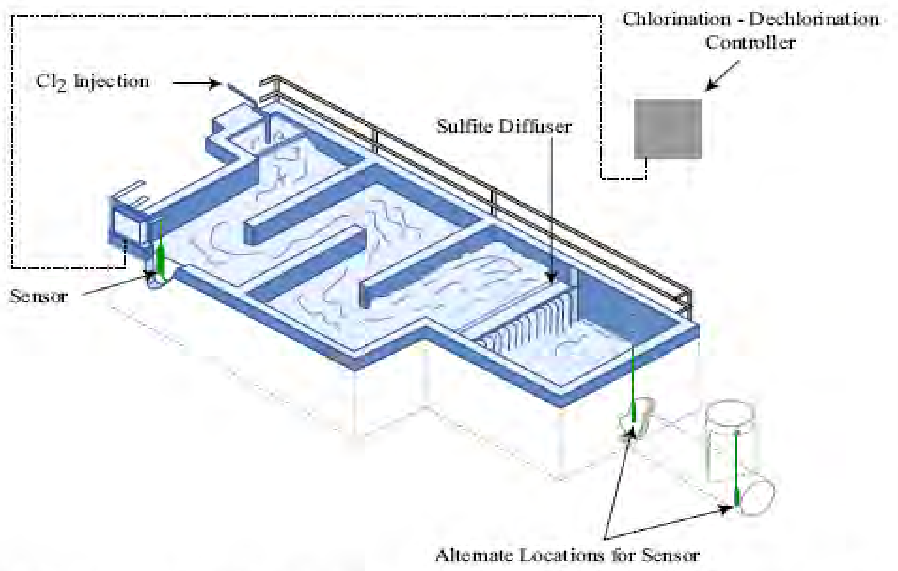
FILTRATION:

The conventional filtration process is probably the most important single unit operation of all the water treatment processes. It is an operation process to separate suspended matter from water by flowing it through porous filter medium or media. The filter media may be silica sand, anthracite coal, diatomaceous earth, garnet, ilmenite, or finely woven fabric.

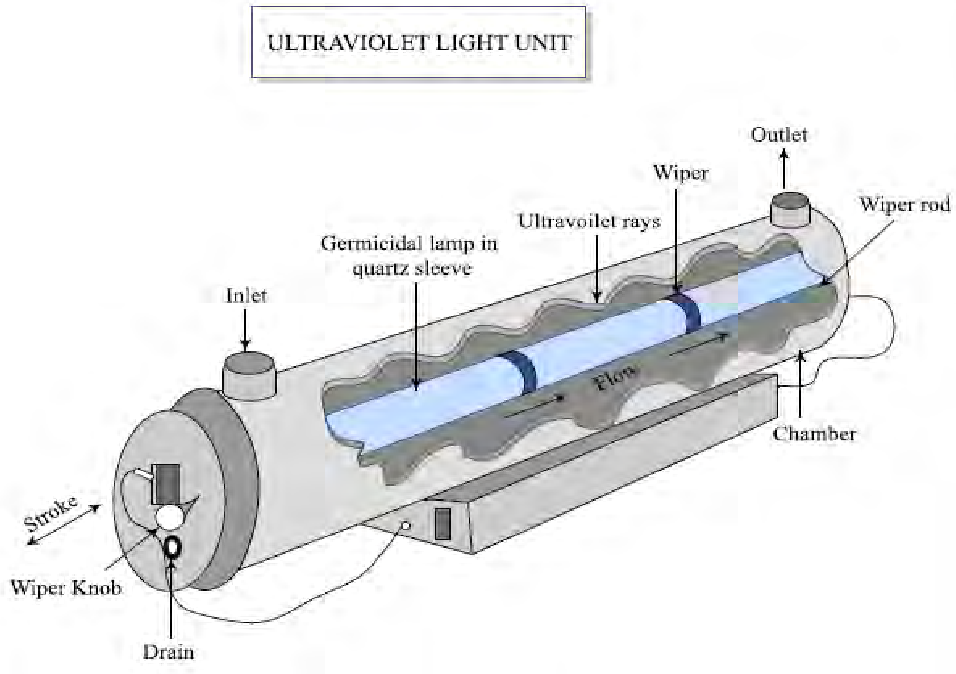


DISINFECTION:

Disinfection is a process to destroy disease-causing organisms, or pathogens. Disinfection of water can be done by boiling the water, ultraviolet radiation, and chemical inactivation of the pathogen. In the water treatment processes, pathogens and other organisms can be partly physically eliminated through coagulation, flocculation, sedimentation, and filtration, in addition to the natural die-off. After filtration, to ensure pathogen-free water, the chemical addition of chlorine (so called chlorination), rightly or wrongly, is most widely used for disinfection of drinking water. For the public health standpoint, chlorination of drinking water provides more benefits than its shortcoming due disinfection by-products (DBPs). The use of ozone and ultraviolet for disinfection of water and wastewater is increasing in the world.



Typical contact chamber for chlorination. Baffles are provided to promote plug flow. When chlorine has been applied at elevated concentrations, sulfite is added to reduce chlorine to levels that will not cause consumer reaction to chlorine taste and odor.



(WASTEWATER):

WHAT IS WASTEWATER?

Wastewater," also known as "sewage," originates from household wastes, human and animal wastes, industrial wastewaters, storm runoff, and groundwater infiltration. Wastewater, basically, is the flow of used water from a community. It is 99.94 percent water by weight. The remaining 0.06 percent is material dissolved or suspended in the water. It is largely the water supply of a community after it has been fouled by various uses.

CHARACTERISTICS OF WASTEWATER:

Physical Properties of Wastewater: When fresh, wastewater is gray in color and has a musty and not unpleasant odor. The color gradually changes with time from gray to black. Foul and unpleasant odors may then develop as a result of septic sewage. The most important physical characteristics of wastewater are its temperature and its solids concentration. Temperature and solids content in wastewater are very important factors for wastewater treatment processes. Temperature affects chemical reaction and biological activities. Solids, such as total suspended solids (TSS), volatile suspended solids (VSS), and settleable solids, affect the operation and sizing of treatment units.

Chemical Constituents of Wastewater:

The dissolved and suspended solids in wastewater contain organic and inorganic material. Organic matter may include carbohydrates, fats, oils, grease, surfactants, proteins, pesticides and other agricultural chemicals, volatile organic compounds, and other toxic chemicals (household and industrial). Inorganic may include heavy metals, nutrients (nitrogen and phosphorus), pH, alkalinity, chlorides, sulfur, and other inorganic pollutants. Gases such as carbon dioxide, nitrogen, oxygen, hydrogen sulfide, and methane may be present in a wastewater.

Biological Characteristics of Wastewater:

The principal groups of microorganisms found in wastewater are bacteria, fungi, protozoa, microscopic plants and animals, and viruses. Most microorganisms (bacteria, protozoa) are responsible and are beneficial for biological treatment processes of wastewater. However, some pathogenic bacteria, fungi, protozoa, and viruses found in wastewater are of publicconcern.

SEWER SYSTEMS:

Sewers are underground conduits to convey wastewater and stormwater to a treatment plant or to carry stormwater to the point of disposal. Sewers can be classified into three categories: sanitary, storm, and combined. Community sewer systems, according to their discharging types, can be divided into separated and combined sewer systems.

QUANTITY OF WASTEWATER:

The quantity of wastewater produced varies in different communities and countries, depending on a number of factors such as water uses, climate, lifestyle, and economics. A typical wastewater flow rate from a residential home in the world might average 70 gal (265 L) per capita per day (gal/(c . d). Approximately 60 to 85 percent of the per capita consumption of water becomes wastewater.

Design Flow Rates:

The average daily flow (volume per unit time), maximum daily flow, peak hourly flow, minimum hourly and daily flows, and design peak flow are generally used as the basis of design for sewers, lift stations, sewage (wastewater) treatment plants, treatment units, and other wastewater handling facilities. Definitions and purposes of flow are given as follows.

The design average flow is the average of the daily volumes to be received for a continuous 12-month period of the design year. The average flow may be used to estimate pumping and chemical costs, sludge generation, and organic-loading rates.

• The maximum daily flow is the largest volume of flow to be received during a continuous 24-hour period. It is employed in the calculation of retention time for equalization basin and chlorine contact time.

• The peak hourly flow is the largest volume received during a one hour period, based on annual data. It is used for the design of collection and interceptor sewers, wet wells, wastewater pumping stations, wastewater flow measurements, grit chambers, settling basins, chlorine contact tanks, and pipings. The design peak flow is the instantaneous maximum flow rate to be received. The peak hourly flow is commonly assumed as three times the average daily flow.

- The minimum hourly flow is the smallest hourly flow rate occurring over a 24-hour period, based on annual data. It is important to the sizing of wastewater flow meters, chemical-feed systems, and pumping systems.
- The minimum daily flow is the smallest volume of flow received during a 24-hour period. The minimum daily flow is important in the sizing of conduits where solids might be deposited at low flow rates.

EXAMPLE: Estimate the average and maximum hourly flow for a community of 10,000 persons. ***SEWER***

Step 1. Estimate wastewater daily flow rate
Assume average water consumptiom = 200 L/(c · d)
Assume 80% of water consumption goes to the sewer

$$\text{Average wastewater flow} = 200\ \text{L/(c} \cdot \text{d)} \times 0.80 \times 10{,}000\ \text{persons} \times 0.001\ \text{m}^3\text{/L}$$
$$= 1600\ \text{m}^3\text{/d}$$

Step 2. Compute average hourly flow rate

$$\text{Average hourly flow rate} = 1600\ \text{m}^3\text{/d} \times 1\ \text{d/24 h}$$
$$= 66.67\ \text{m}^3\text{/h}$$

Step 3. Estimate the maximum hourly flow rate
Assume the maximum hourly flow rate is three times the average hourly flow rate, thus

$$\text{Maximum hourly flow rate} = 66.67\ \text{m}^3\text{/h} \times 3$$
$$= 200\ \text{m}^3\text{/h}$$

SEWER CONSTRUCTION:

Conduit material for sewer construction consists of two types: rigid pipe and flexible pipe. Specified rigid materials include asbestos—cement, cast iron, concrete, and vitrified clay.

Flexible materials include ductile iron, fabricated steel, corrugated aluminum, thermoset plastic (reinforced plastic mortar and reinforced thermosetting resin), and thermoplastic.

Sample of questions:

Q1 : explain the major pollutants for water and its allowable levels.

Q2 :explain the most indicator in water treatment

Q3 : explain the types of methods of water treatment .

Cont…

1. Describe the various water resources.
2. Sketch and describe simon's rain gauge.
3. Describe the surface sources of water supply with illustrations.
4. Describe the various constructions required for making a suitable source of surface water supply.
5. What do you mean by storage capacity of reservoirs ?
6. Describe the subsurface or underground sources of water supply.
7. Define porosity and permeability.
8. Tabulate the porosity and permeability of some common soils.
9. Explain the methods of assessment of the ground water yield.
10. Describe the various methods of drilling of tube-wells.
11. Describe the various methods of development of tube-wells.
12. What do you mean by yield of a tube-well?
13. Develop the expression for finding yield of tube-well in unconfined aquifer.
14. Develop the expression for finding yield of tube-well in confined aquifer.
15. Discuss the various water supply schemes with suitable examples.
16. Describe the term quality of water.

17. Tabulate the physical and chemical standards of water and their permisible limits.

18. What are the bacteriological & virological standards of potable water ?
19. Tabulate the various toxicological materials found in water and their limits.
20. Describe the physical characteristics of water.
21. Describe the chemical characteristics of water.
22. What do you mean by treatment of water? Briefly explain the various methods of treatment.
23. What is the importance of disinfection? Describe the various methods of disinfection.
24. What are the waterborne diseases?
25. What are the suitability criteria of good disinfectant?
26. What is residual chlorine? How do you measure it on site?
27. Describe the various water softening processes.
28. What is the requirement of pressure of water to be supplied to the residences?
29. What is aeration of water? Why and how is it done?
30. What is the purpose of water softening? Explain various methods of water softening.

Cont…

1. What do you understand by wastewater management?
2. Describe the statutory water and sanitation boards.
3. Describe the method of design of sewer line alongwith the hydraulics of sewers.
4. What do you mean by treatment of wastewater?
5. Define biochemical oxygen demand and chemical oxygen demands.
6. What are the various unit operations and processes in water treatment?
7. What are the various unit operations and processes in wastewater treatment?
8. Describe the various methods of treatment of wastewater.
9. Tabulate the functions and efficiencies of various treatment units.
10. Explain the anaerobic digestion and the biogas.
11. Describe the disposal of treated wastewater.
12. Write a short note on Eutrophication.
13. Describe the disposal of wastewater in water bodies.

14. Describe the disposal of wastewater on land.
15. What are the various methods of onsite sanitation.
16. Describe the septic tanks and soakpits.
17. Explain the inhouse treatment of wastewater and saving of water.

Solid wastes:

Anything that is not of further use in a process is known as waste for that process. That can be useful for other process and can be termed as raw material for that process. So actually waste is a misplaced resource. When this waste is in a comparatively solid form it is known as the solid waste. Whatever may be the form of waste, it deteriorates the environment if it is disposed in an offensive manner. The waste water and its treatment and disposal have already been discussed Solid waste is defined as discarded solid fraction produced from domestic, commercial, trade, industrial, agricultural, institutional, mining activities and public services. The waste is a term that means useless, unwanted or discarded material. According to the American Public Works Association the solid waste is classified in twelve categories as, garbage, rubbish, ashes, Street sweepings, dead animals, abandoned vehicles, construction/demolition waste, industrial refuse, special waste such as hospital waste, bulky waste, animal and agricultural waste, and sewage treatment residue (semi solid fraction known as sludge).

CLASSIFICATION OF SOLID WASTE

The solid waste can be classified as per the Manual on Municipal Solid Waste Management, Government of India publication as follows:

(i) Domestic/Residential waste: This type of waste is originated from single or multifamily household units. These wastes are generated from the household activities such as cooking (ashes) cleaning (dust) repairs (residues), hobbies (unuseables), redecoration, empty containers, used packets, old clothes, books, papers, broken glass, plastic items, broken and useless furniture.

(ii) Municipal waste: Municipal waste includes waste resulting from municipal activities and services such as street sweepings, dead animals, market waste and abandoned vehicles. Generally, this term 'Municipal Waste' is used in a wider sense to incorporate domestic wastes, institutional wastes and commercial wastes.

(iii) Commercial waste: This category includes solid wastes that originate in offices, wholesale and retail markets, restaurants, hotels, warehouses (godowns) and other commercial establishments.

(iv) Institutional waste: These are those wastes generated from institutions such as schools, colleges, universities, hospitals and research institutes. Some of these wastes (like hospitals) may be hazardous (more bad, offensive, strong, disease producing) waste.

(v) Garbage: Garbage is the term applied to animal and vegetable wastes generated from the handling, storage, sale, preparation, cooking and serving of food. Such wastes contain putrescible (easily and quickly biodegraded with bad smell) organic matter. This attracts rats, flies, mosquito and other vermin, which is why it requires immediate attention.

(vi) Rubbish: It is a general term applied to solid wastes originating in households, commercial establishments and institutions excluding garbage and ashes.

(vii) Ashes: These are the residues from the burning of wood, coal, charcoal, coke and other combustible matter for cooking and heating in houses institutions and small industries. When produced in large quantities in thermal power plants (fly ash) they are known as industrial wastes. Ashes consists of fine powdery residue, cinders and clinkers often mixed with small pieces of metal and glass.

(viii) Bulky waste: Bulky wastes are large household wastes that cannot be accomodated in the normal storage containers of the household and thus they require special collection. Actually in India there is hardly any waste collected in this category as it is sold to the kabaries.

(ix) Street sweepings: The waste collected from streets, walkways, parks etc. is known as street sweepings. In developing countries like our country manual street sweeping is done and it makes the largest portion of the municipal solid waste as we are in a habit of throwing everything on the streets. It includes mainly dust, dirt, plastic bags (thin), dry leaves, useless papers, cardboard, rags, tyres, vegetable matter etc. In our country most of the usable portion of the waste like rags, paper, thick plastic bags, plastic utensils, any form of metal is collected by the rag pickers. The organic matter including the paper and even plastic sheets is consumed by cows and other stray animals. Only in big cities or the developed countries they form the part of waste. That is why the calorific value of Indian solid waste is far less in comparison to the other countries.

(x) Dead animals: This term includes the dead animals that die naturally or by accidents on roads. It does not include the animal parts from slaughter houses which are regarded as industrial waste. There are two types of dead animals, large and small. The smaller ones like dogs cats rabbits, rats etc., are either consumed by the other animals or can be easily lifted and disposed. The large ones like cows, horses, camels etc. require special and immediate attention as traffic is affected and they emit foul smell.

(xi) Construction and demolition waste: These are the wastes generated by the residue of the construction, refurnishment, repair and demolition of houses, commercial buildings and other structures. Generally, the demolition waste is used by the contractors in filling low lying areas and the plinth filling of new houses and nothing is left on the sites. Even then some small quantity of sand, stone or concrete may be left.

(xii) Industrial wastes: The discarded solid material of manufacturing processes and industrial operations comes in this category. There is a vast range of substances that are unique for each industry so they are considered separately from municipal wastes.

(xiii) Hazardous waste: Hazardous waste is defined as wastes of industrial, instutional or consumer origin that, because of their physical, chemical or biological characteristics are potentially dangerous to human beings and the environment. In some cases the active agents may be liquid or gaseous, they are classified as solid waste because they are confined in solid containers.

Typical examples are solvents, paints, and pesticides whose spent (empty) containers are frequently mixed with municipal wastes and become part of the urban waste stream. Certain hazardous waste can explode in the incinerators (controlled large kilns) and cause fires at land fill sites. Others such as pathological (disease producing) wastes from hospitals and radioactive waste, require special handling at all times. Proper management practice should ensure that hazardous wastes are collected, stored, transported and disposed off seprately, preferably after treatment to make them harmless.

(xiv) Sewage waste: The solid by-products of sewage treatment are classified as sewage wastes. They are mostly organic and produced from the treatment of organic sludge from both the raw and treated sewage. The inorganic fraction of raw sewage such as grit is separated at the preliminary stage of treatment, but because it entrains putrescible organic matter that may contain disease producing bacteria (pathogens), must be buried or disposed of quickly.

Table 4.1 Classification of Solid Waste in Tabular Form

Type of solid waste	***Description***	***Sources***
Food Waste (garbage)	Waste from preparation, cooking and serving of food market refuse, waste from handling, storage and sale of meat and vegetables	Households, institutions and commercial centers such as hotels, stores, restaurants, markets etc.
Rubbish	Combustible (primarily organic) paper, cardboards, cartons, wood boxes, plastics, rags, clothes, beddings, lather rubber grass, leaves yard trimmings. Non comb-ustible (primarily inorganic) metals, tin cans, metal foils, dirt, stones bricks, ceramics, crockery, glass bottles, other mineral refuse	As above
Ashes and residues	Residues from fires used for cooking and for heating buildings, cinders, clinkers, thermal power plants.	As above
Bulky waste	Large auto parts, tyres stoves, refrigerators, other large appliances, furniture, large crates, branches of trees etc.	As above
Street waste	Street sweepings, dirt, leaves, catch basin dirt animal droppings content of litter receptacles dead animals	Streets, sidewalks, alleys, vacant plots
Dead animals	Small animals: cats, dogs, poultry etc. Large animals: horses, cows etc.	Same as above
Construction and demolition waste	Plumber, roofing and sheathing scrap, rubble broken concrete plaster, conduit pipes, insulating wires etc.	Construction and demolition sites, remodeling, repairing sites
Industrial waste & sludges	Solid wastes resulting from industry processes and manufacturing operations, such as food processing wastes, boiler house cinders, wood plastic and metal scraps and shavings etc., sludge of sewage treatment plants and septic tanks, coarse screenings grit etc.	Factories, power plants, treatment plants etc.
Hazardous waste	Hazardous wastes: pathological waste, explosives, radioactive material toxic waste etc.	Households, hospitals, institutions, stores, industry etc.
Horticulture wastes	Tree trimmings, leaves, waste from parks and gardens etc.	Parks gardens roadside trees etc.

Simple Diagram of a Solid Waste Stream:

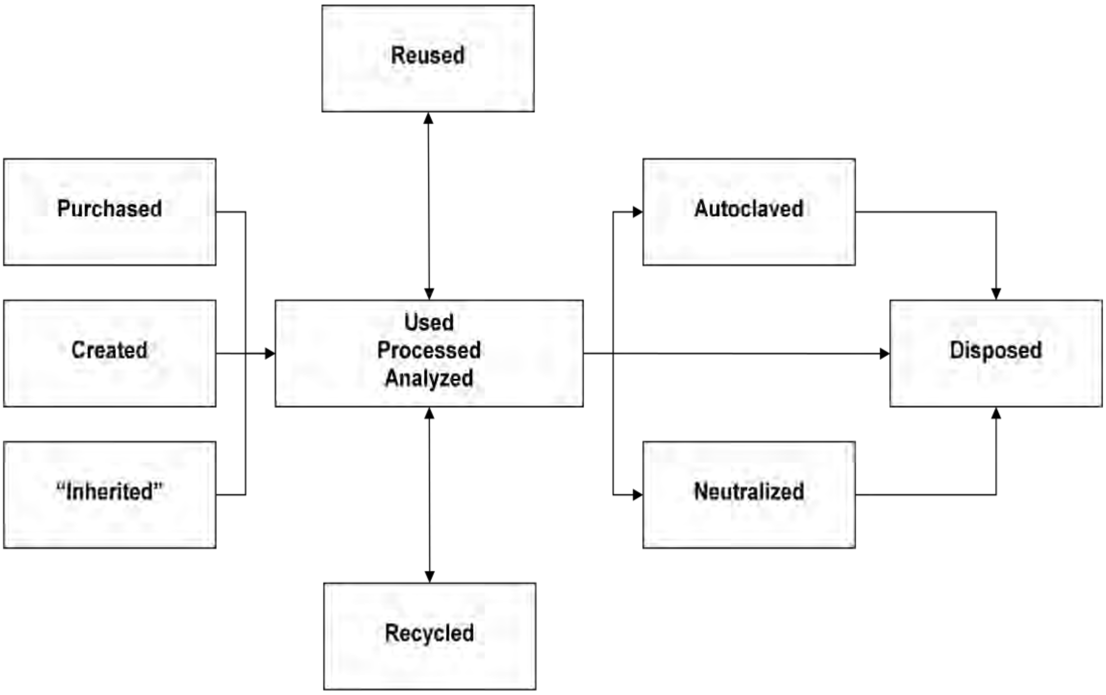
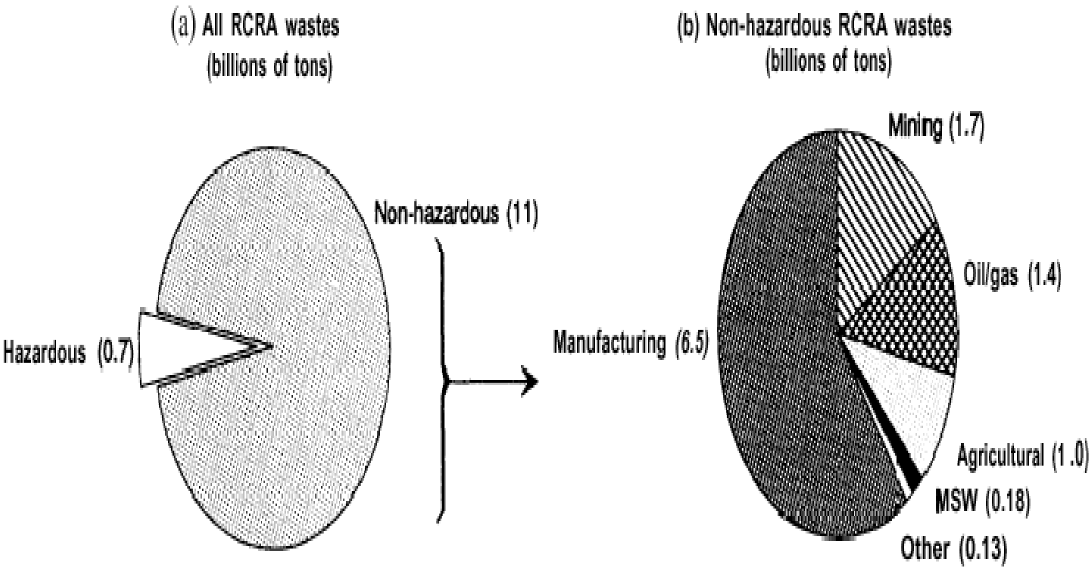


Figure 1-2–"Solid" Wastes as Defined Under the Resource Conservation and Recovery Act (RCRA)



PHYSICAL CHARACTERISTICS

(i) Density: The knowledge of density is important for the design of all elements of the solid waste management systems like storage, transport and disposal. For example for a known volume of the solid waste its density gives us the idea about the requirement of the truck in tonnage. Every truck or similar vehicle has a permitted load capacity say 12 ton or so which it can carry according to law. In developed countries as their waste is light so compaction reduces the cartage charges substantially. The density varies significantly from source to the disposal site because of handling, change in moisture content, densification due to vibration of movement, disturbance by animals and birds (scavengers) etc. The following table gives some data from MSWM for density of municipal solid waste in some Indian cities. It is evident from the above table that density is more in Jaipur waste as because of dessert conditions there is more sand and other inorganic heavy matter. These figures are only indicative and are to be verified before the actual design of a system. Actually it is very important that the solution to any SWM problem should be site specific and time specific. The same city may show different composition after some years.

(ii) Moisture content: Moisture content of the solid waste is expressed as the weight of moisture per unit weight of wet material. Moisture content varies generally from 20 to 45% depending upon the climatic conditions and level of city (income group) etc. The increase of moisture content increases the weight and thus the cost of transportation and thus the storage section should take care of it.

(iii) Calorific value: Calorific value is the amount of heat generated from combustion of a unit weight of a substance, expressed as kilo calorie per kilogram. The calorific value is determined in the laboratory by Bomb Calorimeter. Table 4.3 shows typical values of the residue and calorific value for the different components of the municipal solid waste. If the energy is to be recovered or the waste is to be disposed, by incineration (controlled burning) the following points should be considered:

• Organic matter gives energy only in dry condition.

• The moisture content as free water reduces the dry organic matter per kilogram and hence requires a significant amount of energy for evaporation.

• The ash content of the waste reduces the proportion of dry organic material per kilogram of waste. It also retains some heat. So for economic recovery of energy the waste should contain minimum amount of moisture, ash and other inorganic matter.

These are the significance of determination of physical characteristics.

CHEMICAL CHARACTERISTICS

The chemical characteristics of solid waste are determined for assessing the treatment process. Mainly three chemical characteristics are determined, chemical, bio-chemical and toxicological.

• Chemical quantities of solid waste in Indian urban centers are pH, nitrogen, phosphorus, and potassium (N-P-K), total carbon, carbon/nitrogen ratio, calorific value.

• Bio-chemical characteristics include carbohydrate, proteins, natural fiber, and biodegradable factor.

• Toxic characteristics include heavy metals, pesticides, insecticides etc.

Consideration of lipids (fats, oils and grease) should also be done as they are of a very high calorific value (about 38000 Kcal/kg). These days synthetic organic materials like plastic have become a significant component of solid waste accounting for 5-7%. Non-biodegradable and thus poses a great problem. It chokes the drains and if burnt it produces poisonous gases. The thin plastic sheets and bags are not recycled as the cost of making it dirt & oil free makes the process uneconomical.

All the above considerations of characteristics are required to design, conceive and assess the most appropriate ways of transportation, the requirements of treatment, extraction of energy and the safe, sanitary way of disposal for the protection of environment.

WASTE MANAGEMENT APPROACH

The solid waste management has a twofold approach. First is the minimization of waste at the source and other is the control on environmental pollution during its storage, conveyance and disposal. Prevention is always better than cure. If the production of waste can be reduced at the source level it shall reduce the cost of conveyance treatment, disposal and shall save the environment. The waste minimization techniques are grouped in four major categories for hazardous as well as non-hazardous waste, as follows:

1 Inventory Management and Improved Operation

• Inventorisation (making stock registers) and tracing of all raw materials.

• Purchasing of lesser toxic and more non-toxic production material.

• Implementation of employee’s training and management feedback.

• Improving material receiving, storage and handling practices.

Modification of equipment

• Installation of equipment that produce minimum waste.

• Modification of equipment to enhance recovery or recycling options.

• Redesigning of equipment or production lines to produce less waste.

• Improving operating efficiency of equipment.

• Observing strict preventive maintenance programme.

Modifications in Production Process

• Selection of non-hazardous raw material.

• Segregation of waste for recovery.

• Identification and elimination of leakages.

• Optimization of reactions and raw material use.

Recycling and reuse

• Installation of closed-loop systems

• Recycling off site for another use

• Exchange of wastes

By adopting the above waste minimization techniques the waste is minimized at the source so that its handling and transportation charges are reduced and lesser efforts are to be done in disposal.

2 Utilization of Waste

After minimizing the waste at source one can think about the utilization of waste of one operation in the other operations as shown in the table below.

Table 4.7 Utilization of Waste

S. No.	Waste	Areas of application
1	Flyash (fine coal ash generated by combustion of coal in power plants etc. One portion is the bottom ash another is the one collected in the separators from the flue gases.)	i As raw material in manufacturing of cement ii As binding material with cement iii As filler in mines iv As plasticizer v As an aggregate in cellular concrete bricks and blocks vi For stabilization of soil
2	Blast furnace slag	i Manufacturing slag cement, super sulphated cement ii Making expansive cement, coloured cement and high early-strength cement iii In refractory and ceramic industry iv As a structural fill v As aggregate in concrete
3	Ferro-alloy and other metallurgical slag	i As structural fill ii In making pozzolana metallurgical cement
4	Byeproduct gypsum	i Gypsum plaster ii As retarder in cement setting iii As mineraliser
5	Lime sludge (phos-phochalk, paper and sugar sludges)	i As a sweetener for lime in cement manufature ii Manufacturing of lime pozzolana brick/ binders iii For recycling in parent industry iv Manufacturing of building lime
6	Chromium sludge	i As a raw material component in cement sludge

Contd....

		ii Manufacturing of coloured cement as a chromium bearing material
7	Red Mud	i As a binder ii Making construction blocks iii As a cellular concrete additive iv Coloured composition for concrete v In making floors and other tiles vi Red mud polymer door
8	Pulp and Paper	Lignin

After having all this information let us examine the present status of solid waste management and what should have been done.

SOLID WASTE MANAGEMENT: AN OVERVIEW

The solid waste management has the following components:

(i) Identification of waste and its minimization at the source

(ii) Collection, segregation and storage at the site of collection

(iii) Transportation

(iv) Treatment

(v) Energy recovery

(vi) Disposal

1 Identification of Waste and its Minimization at the Source

By the above described classification methods one can identify the waste easily. Identification helps in further processes of transportation, treatment and disposal, for example the hazardous waste is to be tackled in a different manner than the ordinary MSW. The minimization of the waste production is the best strategy. For this, first of all the process should be such that there is a least production of waste. For example if in a footwear making industry if the cut on the rubber sheet is made in such a way that alternate piece of the pair are placed one by the side of other; there shall be least production of waste sheet. Then the next step is to reuse the remaining waste sheet in the same process. But now there is a limit beyond which this cannot be used to maintain the required quality. This further remaining portion of the sheet comes as real waste to this process of footwear making. Now if a toy making machine is installed in the same factory which can use this remaining rubber sheet as the raw material. Then there shall be no waste production in the first factory and only the second unit shall produce some waste. Thus, the waste has been minimized at the source. This reduces the cost of transportation etc. everything. The second example is the production of flyash as the waste in the thermal power plants. A huge quantity of flyash is produced where coal is burnt for making electricity. This flyash requires a large valuable land for disposal. As this flyash can be used for making of flyash bricks, making of cement and can be used with cement as binder etc; if sold or supplied free of cost from the site itself ; shall reduce the burden of disposal. The third example is the utilization of waste food products in a hostel or a hotel for making bio-gas. By the anaerobic digestion of this organic matter (waste food) the biogas can be produced easily. This gas can be used there itself for cooking or heating purposes. This shall reduce the biodegradable waste at the source itself. The fourth example is the utilization of kitchen waste in a household in making the compost and utilizing it in the kitchen garden itself. If more advanced techniques like Vermi-composting are adopted this can be done in a more beneficial way.

The above mentioned methods can be adopted on a large scale also, but for that the waste is firstly collected, transported and then utilized. This incurs a large cost. So it is always preferable that if the waste production is minimized or the waste is reused, recycled at the source itself. Thus, the waste minimization is achieved through careful planning, changing attitude, sometimes special investments (as the toy factory in the above example), and most important is a real commitment. The self-motivated willing reduction of waste is generally not possible, so strict enforcement of the law should be there. The waste reduction and reuse, recycling should be given incentives from the government in the form of tax reduction and soft loans.

2 Collection, Segregation and Storage at the Site of Collection

The main problem of solid waste management is the collection of solid waste. The household waste consists of all types of general waste. At present there is no scientific, clean, hygienic, efficient practice of waste collection including the metro cities. There is no practically imposed penalty on throwing of waste on the streets. Even defecating on open plots, sides of roads, railway lines; spitting on roads is a very common practice and nobody bothers about it. The ugly unhygienic scenes, and the bad smell (due to anaerobic digestion of organic matter) worsen the situation. Actually we are in a bad habit of either throwing the waste in front of the neighbor's door, or on a vacant land or directly on the road. Even if the municipality provides a waste collection bin, nobody bothers to put the waste carefully in it. So the collection of waste is a big problem. In most of the developing countries the waste is handled manually. First of all the sweepers sweep the roads, streets etc. with their age old brooms (with poor designs). Then they will make heaps of the collected waste. The other person then lifts this collected waste to some ill maintained wheel barrows and transport it to the collection depots and make a heap there. Then the rag-pickers shall start their work and pick only most useful items to them as the thick plastic bags or metal if any. The stray animals like dogs, cows, pigs shall find their food from this heap and scatter it on the collectyon site. Then it shall be manually picked up at some irregular interval, transported in open tractor trolleys and then disposed off on some open land.

The industrial waste is also handled in the same way. The collection and storage of waste is the most neglected operation in any industry. The wastewater having harmful colours, dyes, metals, heavy metals, organic matter (having high BOD) is discharged in the open drains to pollute the land and the river water. Similarly, the solid waste is thrown in open areas wherever the nearest site is available (may it be unguarded private land or government land).

The best way would have been the segregation of waste at the generation point. Segregation means collecting it in different bins, or plastic bags. The domestic waste can be broadly separated as reusable (paper, plastic, metal etc.), and non reusable. The non reusable may have organic matter like kitchen waste or inorganic matter like dust, dirt etc. The organic matter is liable to decomposition (putrescible) and thus requires immediate attention. Fortunately in India the usable matter is rarely discarded as solid waste except which cannot be sold to kabaries. So even if only two containers or bags are used for separating organic and inorganic waste the problem is solved. This separated waste should be regularly collected by the worker directly from the houses at some well-defined time. Then it should be transported in (covered vehicles)to some waste collection depots for utilization/transportation to different sites. The organic waste can be used for the production of biogas or for the extraction of energy, incineration (controlled burning or making organic compost, and vermi-composting. The storage in the intermediate collection sites should again be covered and out of the reach of the stray animals. Here it is proposed to make payment to the person collecting waste on the basis of the weight/volume of the waste collected by him/her and not on the daily basis. Here lies the actual problem. Because of the structure of the local municipal corporations and many other pressures this is generally not feasible. This is possible only if this work is given on contract basis and the work is done in a scientific professional way with the people's participation (segregation and proper handing over of the waste).

3 Transportation of Solid Waste

As stated earlier the waste is transported from the storage depots to the disposal sites in tractor trollies or ill designed open trucks. Though it has been instructed by the Hon'ble court that the transportation must be done in closed containers only. The industrial waste must be transported separately and must be disposed in a safe way after suitable treatment. Any type of the hazardous waste should be labeled and coded so that in case of an accident the emergency services know how to handle a spillage Actually the work of transportation of solid waste must be done through the technically competent and well reputed contractors under the strict supervision of the experienced and honest municipal authorities and watchful citizens.

4 Treatment of Solid Waste

The waste has to be treated before disposal for the protection of environment. In the treatment the biodegradable waste can be processed by composting, vermi-composting, anaerobic digestion or any other appropriate biological processing for stabilization of waste. Actually every organic matter has a tendency to be converted into inorganic matter as the later is a stabilized form. If this conversion takes place in absence of oxygen (anaerobic digestion) which is a general case in solid waste processing, foul gases are evolved. During the anaerobic decomposition dirty, offensive dark coloured fluid is also generated that is known as the leachate.

Generally the solid waste contains both municipal and industrial waste. Small scale industries also generate huge quantity of solid waste and they are generally not in a position to treat their waste individually. It is therefore advisable that in a group of small scale industries the different wastes are characterized, identified, quantified and stored for treatment through a combination of recycling, recovery and reuse of resources such as, raw material, bio gas, steam and manure. The combined effluent treatment plants are to be operated by the local bodies where the cost of construction operation and maintenance is to be shared by the industry in proportion to the quality and quantity of their waste. However the assessment of the quality and quantity of waste is very difficult and requires appropriate testing facilities. In any case the solid waste should be reduced in quantity at the source, segregated, then carefully transported and the economically treated before the final disposal.

5 Energy Recovery and Disposal

The most common methods of energy recovery and disposal for non-hazardous solid waste are incineration, composting and landfill. The final disposal of waste should be done in such a way that it remains a waste in actual sense, i.e. nothing can be recovered out of it and it could not be used anywhere. So before putting it on land for landfilling if it has a substantial portion of biodegradable fraction then compost (organic manure) should be made out of it. This shall reduce the final volume of the waste to be disposed on land and shall give us money in terms of the manure. The organic manure is environment friendly and also provides us micronutrients that increase the fertility of the soil. If this work is done more effectively by some special worms this is known as vermi-composting.

5.1 Incineration

Incineration means burning of solid waste in controlled conditions. The most usual practice of disposal of solid waste is burning in open fields. This slow burning at low temperature produces many hazardous gases. Generally the waste is collected in the streets or roads and the heap of this waste is left there itself for drying or collection of more waste on it. Then this waste is either transported to some distant site or burnt there itself. This waste contains inorganic matter also and because of this burning in heaps there is no control of supply of oxygen or rather there is no oxygen supply except that present in the voids. This incomplete combustion at a low temperature produces hazardous gases and these gases pollute the environment very close to us. Particularly the gases produced by the burning of plastic, rubber and other such materials produce very much harmful gases. Incinerator means any enclosed device using controlled flame combustion. Incineration uses heat to convert complex toxic organic compounds into mostly carbon dioxide and water. At temperatures ranging from 400 to 1600°C complex organic molecules break down into basic atoms. The incineration is a good method of disposal and recovery of energy (in the form of heat produced by burning) only if it works properly. The combustion temperatures of conventional incinerators are about 760° C in the furnace and more than 870° C in the secondary combustion chamber. These high temperature are required to avoid odour from incomplete combustion but are not sufficient to burn or even melt the glass. Some modern incinerators use supplementary fuel to produce high temperatures upto 1650° C to convert even metal and glass to ashes. These incinerators reduce waste volume significantly i.e. upto 97%.

There are so many factors like thermal feed rate, waste feed rate, organic chlorine feed rate, minimum combustion gas temperature, gas residence time, adjustment of primary and secondary combustion units, removal of HCl, Suspended Particulate Matter (SPM) and other air pollutants produced; that are to be controlled. Actually, the incineration is best way of disposing hazardous waste, like hospital and other wastes. The incineration is definitely better than open burning but as stated earlier if it is not properly working, with all controls, then it can prove to be more dangerous, as it gasifies the pollutants and sends them to the atmosphere.

In general incinerators comprise of a storage pit, fuel tanks, a furnace, a heat recovery boiler, effluent gas purification unit, an induced draft fan and a stack (chimney).Though incineration is extensively used as a useful method of waste disposal, it is associated with some polluting discharges which are of environmental concern. These can effectively be controlled by installing suitable pollution control measures and by construction of furnace suitably and by controlling the combustion process. For the removal of SPM from the effluent gas a scrubbing water treatment unit or even Electro Static Precipitators are used in good installations.

5.2 Landfill

The most common and easy way of disposal of solid waste is dumping it on land. The inorganic waste like construction and demolition waste can be easily used for filling of low lying areas or plinth filling of buildings or the earthwork of roads. When the combined waste (inorganic and organic) is disposed on the land then the decomposition of the organic matter takes place in due course of time. This decomposition produces gases (like methane) and dark coloured dirty offensive water known as leachate. If the ground on which the waste is disposed is pervious then this leachate percolates and mixes with the ground water and badly pollutes it. If the waste is hazardous means that contains harmful chemicals and heavy metals, or pathogens then the situation becomes more aggravated. The mixing of these pollutant through leachate makes the water polluted and contaminated. Secondly in open landfills the rain water increases the volume of leachate and mixes it with the ground or surface water source more easily. So the landfill should be so designed that it contains an impermeable barrier to stop the mixing of leachate with the water. It should have a diversion for the rain water and proper arrangement of the collection treatment and disposal of leachate. Such type of landfill is known as the sanitary landfill and is the most desirable ones. They may appear costly, but for long lifetime of such works and comparing the end results the cost/ton of waste disposed might be less than any other method of disposal.

5.3 Composting

The organic matter (consisting of carbon, hydrogen, nitrogen, oxygen, and sulfur) has a tendency of being converted into inorganic matter as the later is a stable form. The food, excreta and other organic waste gets decomposed (changed into inorganic form) and produce gases like biogas (mainly methane) and solids of decomposition like sulfates, nitrates, phosphates etc. These solid (nutrient) are extracted by the roots of plants and trees in dissolved form and they again produce the organic matter in the form of their products. Those products come in the food chain and again the organic waste is produced. This way the different natural cycles keep on proceeding. Composting is an organized method of producing compost manure (decomposed organic matter) through this natural phenomenon. Compost is more useful as it contains the nutrients like N, P, K as well as the micronutrients. Micronutrients like iron are very much useful for good health and immunity. As the organic matter can be decomposed in two ways i.e. in the presence of oxygen or in the absence of oxygen, composting can be done aerobically or anaerobically. During aerobic composting aerobic micro-organisms oxidize the organic compounds to carbon dioxide, nitrite and nitrates. The reaction is exothermic and the temperature rises. The nitrates, sulfates etc. are used by the plants and carbon is synthesized in the photosynthesis by the plants. In the anaerobic process the anaerobic bacteria, while metabolizing the nutrients, break down the organic compounds through a process of reduction. The gases evolved are mainly CH4 and CO2 (bio-gas). If collected properly as in a biogas plant the gas can be used for heating or even for driving engines. The composting can be done to the collected organic waste at some site or at the individual house hold.

5.3.1 Vermi-composting

In the case of households or colonies vermi-composting which involves the stabilization of organic solid waste through special earthworm by conversion of the organic matter to worm casting is also done. Vermicomposting involves the culture of earthworms(vermiculture) for the stabilization of different variety of organic solid waste. Earthworms feed on any organic waste and consume two to five times of their body weight, excrete the mucus coatedundigested matter as wormcasts. Wormcasts consists of organic matter that has undergone physical and chemical breakdown through the muscular activity that grinds the material to a particle size of 1 to 3 micron. The nutrient present in the wormcast are easily soluble in water and are thus readily available for the plant growth. Vermi-composting is a rich source of macro and micronutrients, vitamins, enzymes, antibiotics and hormones. As per the MSWM the vermi-composting involves the stabilization of organic solid waste through earthworm consumption which converts the material into worm castings. Vermi-composting is the result of combined activity of micro-organisms and earthworms. Microbiological decomposition of biodegradable organic matter occurs through extracellular enzymatic activities (primary decomposition) whereas decomposition in earthworm occurs in alimentary tract by micro-organisms inhabiting the gut (secondary decomposition). Microbes such as fungi, actinomycetes, protozoa etc. are reported to inhabit the gut of earthworms. Ingested feed substrates are subjected to grinding in the anterior part of the worms gut (gizzard) resulting in particle size reduction. Vermitechnology, a tripartite system which involves biomass, microbes and earthworm as influenced by the abiotic factors like temperature, moisture and aeration etc. Microbial ecology changes according to change of abiotic factors in the biomass but decomposition never ceases. Conditions unfavorable to aerobic decomposition result in the death of earthworms and subsequently on vermi-composting occurs. Hence, preprocessing of the waste as well as providing favourable environmental condition is necessary for vermi-composting. The vermi-compost (manure) is relatively more stabilized and harmonises with soil system without any ill effects. Unfavourable conditions such as particle size of biomass and extent of its decomposition, very high temperature increase, anaerobic condition, toxicity of decomposition products, etc. matter much for the activity and progress of worms. This technology has been used for agriculture waste and is used on organic municipal solid waste also. The worms are special earthworms known as Pheretima sp, Eisenia sp, and Perionyx excavatus sp. These worms survive in the temperature range of 20-40oC and moisture range of 20-80%. The worms do not survive in pure organic substrate containing more than 40% fermentable organic substances. So fresh waste is mixed with partially or fully stabilized waste before it is subjected to vermi-composting. The worms are also adversely affected by high concentrations of such heavy metals as cadmium, chromium, lead and zinc. Due to these problems the vermi-composting is successful more on the household level (vegetables etc, organic waste) than the municipality level.

ENERGY RECOVERY FROM MUNICIPAL SOLID WASTE

The municipal solid waste contains organic (vegetables, food etc.) as well as inorganic matter (dust, dirt etc.). It is desirable that the energy present in its organic portion can be recovered through suitable processing and treatment technologies. Along with the gain of energy the following benefits are also there:

(i) The total quantity of waste gets reduced by nearly 60 to 90% depending upon the characteristics of waste and the adopted process.

(ii) As the quantity reduces the demand for land required for landfill as disposal also reduces.

(iii) The cost of transportation also reduces as the quantity reduces.

(iv) The overall environmental pollution reduces.

Therefore, the energy recovery is as useful as the reuse and recycle of waste at the source. Following are the basic techniques of energy recovery as per the MSWM:

(i) Thermo-chemical conversion: This process entails thermal decomposition of organic matter to produce either heat energy or fuel oil or gas; and

(ii) Bio chemical conversion: This process is based on enzymatic decomposition of organic matter by microbiological action to produce methane gas or alcohol. The thermo-chemical conversion processes are useful for wastes containing high percentage of organic non-biodegradable matter and low moisture content. The main technological option in this category includes Incineration (already explained) and Pyrolysis/ Gasification.

The biochemical conversion processes, are preferred for wastes having high percentage of organic bio-degradable (putrescible) matter and high moisture content.

The main technological option under this category is Anaerobic Digestion also known as Biomethanation.

1 Parameters Affecting Energy Recovery

The main parameters that determine the potential of recovery of energy from waste are physical and chemical characteristics of waste and the recovery of energy also depends upon the process employed. The main physical parameters are:

- Size of constituent
- Density
- Moisture content

Smaller size of the constituents aids in faster decomposition of the waste due to more specific area. Waste of high density shows a high proportion of biodegradable organic matter whereas the low density indicates the higher presence of paper plastic etc. High moisture content causes biodegradable waste fraction to decompose more rapidly than in dry conditions. The high moisture content makes the waste rather unsuitable for thermo-chemical conversion (like incineration, pyrolysis, gasification) for energy recovery as a major amount of heat is wasted in evaporating the moisture.

The important chemical parameters for determining the energy recovery potential and the suitability of waste treatment through bio-chemical or thermo-chemical conversion are as follows:

- Volatile solids
- Fixed carbon content
- Calorific value
- Carbon and nitrogen ratio
- Toxicity
- Inerts

For different processes of energy recovery the desirable range for different parameters s shown in the table given below. Generally for achieving satisfactory extraction of energy sorting, segregation and addition of required parameters is necessary.

Table 4.8 Desirable Range of important Waste Parameters for Technical Viability of Energy Recovery (source manual on MSWM)

Waste treatment method	*Basic principle*	*Important waste parameters*	*Desirable range (suitably processed waste)*
Thermo-chemical Conversion	Decomposition of organic matter by action of heat	Moisture content Organic/Volatile matter	< 45% > 40%
Incineration pyrolysis gasification		Fixed carbon Total Inerts Net-calorific value	< 15% < 35% > 1200 kcal/kg
Bio-chemical conversion	Decomposition of organic matter by microbial action	Moisture content Organic-Volatile matter	> 50% > 40%
Anaerobic digestion/ bio-methanation		C/N ratio	25–30

Like this energy can be recovered from the solid waste which reduces the volume also and makes the waste suitable for final disposal. Now the final disposal may be as landfill, but it has also to be done in such a way to protect the environment from its bad effects (like leachates etc.). That is known as sanitary landfill.

SANITARY LANDFILL

The term 'Landfill' means a unit operation for final disposal of municipal solid waste on land that is designed and constructed with the objective of minimum impact on the environment. The term sanitary landfill is used for a landfill with the provision of liner (protective layer) and leachate collection system to prevent ground water contamination. Landfilling is done for the mixed waste that is not hazardous but not found suitable for waste processing, and recycling. Land fill is not suggested for bio waste as energy can be recovered out of it and its decomposition in the landfill shall produce leachates. Actually landfilling should be used as the final disposal method and should be adopted for the waste from which the recycling is not possible and economic extraction of energy is also not possible. Sometimes it is useful for hazardous waste disposal, but then it has to be done very carefully. The following are the essential components of a MSW landfill as per the manual on MSWM:

(i) A liner system at the base and sides of the landfill which prevents migration of leachate or gas to the surroundings soil.

(ii) A leachate collection and control facility which collects and extracts within and from the base of the landfill and then treats the leachate.

(iii) A gas collection and control facility which collects and extracts gas from within and from the top of the landfill and then treats it or uses it for energy recovery.

(iv) A final cover system at the top of the landfill which enhances surface drainage, prevents infiltrating water and supports surface vegetation.

(v) A surface water drainage system which collects and removes all surface runoff from the landfill site.

(vi) An environmental monitoring system which periodically collects and analyses air, surface water, soil-gas and ground water samples around the landfill site.

(vii) A closure and post closure plan which lists the steps that must be taken to close and secure a landfill site once the filling operation has been completed and the activities for long term monitoring, operation and maintenance of the completed landfill.

HAZARDOUS WASTE MANAGEMENT

It is difficult to define the hazardous waste exactly as it is a very general and wide term. However, it may be defined as any waste in solid, liquid or gaseous form which because of its quantity and concentration or its physical, chemical, radiological, or infectious characteristics, may cause ill effect on the human health or the environment if not properly stored, transported and disposed. The designation of a material to be hazardous is done through the standard tests for the following criteria:

- Radioactivity: If the level of radioactivity exceeds the permissible concentration limits the waste is termed as hazardous.
- Bio-concentration: This criteria is used for chemicals such as chlorinated hydrocarbon pesticides.
- Flammability: The ease with which certain substance catches fire and sustains combustion.
- Reactivity: Chemicals like sodium are extremely reactive with water.
- Toxicity: The capacity of causing damage to the human health and the environment, like the poisonous effect is the measure of toxicity.
- Genetic and carcinogenic potential: The potential of causing cancer etc.

By the above criteria the hazardous waste can be identified but the actual impact is based upon the quantity. It can be suggested that the most suitable method of dealing with hazardous waste is converting it into non-hazardous form, but that is not possible always, and may not be economical and technically possible also. The most commonly used method of disposing of hazardous waste is the hazardous waste landfill. The specially designed landfills are used to provide complete protection for the surface and subsurface waters from the hazardous waste. As they have to carefully deal with, such type of landfills are equipped with clay liners, monitoring wells and ground water barriers. The strategy is strict segregation from the environment and complete care in storage and transportation.

The waste generated from medical activities can also be hazardous, toxic and even lethal because of their high potential of disease transmission. The hazardous and toxic part of waste from hospitals comprising infectious, bio-medical and radioactive materials as well as sharps (needles, knives etc.) creates a great risk if not handled properly. Actually a major part of biomedical waste is non-hazardous, but if proper segregation is not there it makes the whole waste as hazardous. Apart from a part of hazardous waste the biomedical waste should be studied separately.

BIO-MEDICAL WASTE

As per the manual on MSWM the bio-medical waste means any solid and/or liquid waste including its container and any intermediate product, which is generated during the diagnosis, treatment or immunization of human beings or animals or in research pertaining there to or in the production or testing thereof. The physico-chemical and biological nature of these components, their toxicity and potential hazard are different, necessitating different methods/options for their treatment/disposal in schedule I of the bio-medical waste (management and handling) the waste originating from different kinds of such establishment, has been categorized in different categories as below:

Components of bio-medical waste

• Human anatomical waste (tissues, organs, body parts etc.)

• Animal waste (as above from veterinary hospitals etc.)

• Microbiology and biotechnology waste, such as laboratory cultures, microorganisms, human and animal cell cultures, toxins etc.

• Waste sharps, such as hypodermic needles, syringes, scalpels, broken glass etc.

• Discarded medicines and cyto-toxic drugs.

• Soiled waste such as dressings, bandages, plaster casts, material contaminated with blood etc.
• Solid waste (disposable items like tubes, catheters etc. excluding sharps).
• Liquid waste generated from any of the infected areas.
• Incineration ash.
• Chemical waste.

If the above mentioned bio-medical wastes are not handled properly they shall create many hazards. As per the manual on MSWM the following are the main environmental concerns with respect to improper disposal of bio-medical waste management:
• Spread of infection and disease through vectors (fly, mosquito, insects etc.) which affect the in-house as well as surrounding population.
• Spread of infection through unauthorized recycling of disposable items such as hypodermic needles, tubes, blades, bottles etc.
• Reaction due to use of discarded medicines.
• Toxic emissions from defective/inefficient incineration.
• Indiscriminate disposal of incinerator ash/residues.
For safe handling of the biomedical waste it is recommended that proper labeling and colour coding is done. It is desirable to use colour coding means use of specific coloured container with liner/sealed container (for sharps) for particular wastes. The untreated waste should not be stored for a period of more than 48 hours. For this purpose a simple notice in English, Hindi and local language describing clearly about the storage of a particular category of waste in a particularly labeled and coloured container is a must. The container should be sturdy enough, without any puncture and leakage. The container should be covered and preferably operated by foot. In case of plastic bags they should be fitted securely in a container. The sharps must be stored in a puncture proof container and before putting them in the containers they must be mutilated by a needle cutter. The containers should be wheeled and placed in a permanent position tightly. They should be carried for further transportation preferably from the separate corridors and should not cross the regular path of patients and visitors. Different methods of treatment and disposal are useful for the different category of the bio-medical waste. Depending upon the quantity of waste generated small installations may adopt local (in house) disinfections, mutilation/shredding and

autoclaving and off-site incineration at a common facility followed by a sanitary and secured landfill.

Questions:

1. Define the term waste. What do you mean by solid waste?
2. Describe 'solid waste management'.
3. What is the problem of solid waste? How much solid waste is produced in our country?
4. How do you classify the solid waste and what is the importance of classification?
5. What is hazardous waste and its problem?
6. Explain the terms garbage and rubbish.
7. Describe the composition of solid waste.
8. Tabulate and explain the physical characteristics of solid waste.
9. Tabulate and explain the chemical characteristics of solid waste.
10. What are the expected quantities of solid waste?
11. Tabulate the quantities of solid wastes in Indian urban centres.
12. Describe the physical characteristics of solid waste like density, moisture content etc.
13. Describe the chemical characteristics of solid waste.
14. Describe the waste management approach with inventory management etc.
15. How can the solid waste be utilized?
16. Write down the detailed overview on solid waste management.
17. Explain the different ways and means of collection of solid waste.
18. Explain the different ways and means of transportation of solid waste.
19. Explain the different ways and means of treatment of solid waste.
20. Describe the term energy recovery from solid waste.
21. What is incineration? Describe the process of incineration.
22. What is landfill? Describe the problem of leachate.
23. Describe the term composting, its methods and advantages.
24. What is vermi-composting? Explain the process and its advantages.
25. Write in details the method of energy recovery from solid waste. What are the parameters that affect the energy recovery?

26. What is the desirable range of waste parameters for technical viability of energy recovery?

27. What is sanitary landfilling

28. Explain in details the hazardous waste management.

29. What is biomedical waste and what are the special measures to be taken in its management?

30. Write a short note on biomedical waste management.