Principle of Environmental Engineering

1ST year
Sanitary & Environmental Engineering Branch

Building and Construction Engineering Department

University of Technology

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LECTURE No. 1
(Human in the environment, Epidemiology& Communicable Disease)

INTRODUCTION

In many parts of the world, simple survival and the prevention of disease and poisoning are still serious concerns. As urbanization increases, our impact on the environment and the impact of the environment on us, must be controlled to protect the human and natural resources essential to life

The goal of environmental health programs is not only the prevention of disease, disability, and premature death but also the maintenance of an environment that is suited to humanity's efficient performance and the preservation of comfort and enjoyment of living today and in the future.

This requires better identification and control of the contributing environmental factors in the air, water, and food.

Epidemiology

The study of the occurrence, frequency, and distribution of disease (communicable and noncommunicable) in selected human populations leading to the discovery of the cause and an informed basis for preventive action—social, biological, chemical, or physical. epidemicity is thus relative to usual frequency of the disease in the same area, among the specified population, at the same season of the year. A single case of a communicable disease long absent from a population or the first invasion by a disease not previously recognized in that area requires immediate reporting and epidemiologic investigation; two cases of such a disease associated in time and place are sufficient evidence of transmission to be considered an epidemic

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, foodborne 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.

LECTURE No. 2

(Water pollution)

Why treat water and wastewater?

Reasons for treating:

Protect surface-water quality
Protect public health
Meet legal requirements

Water pollution

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. Radio active 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.

Radio active

Radio active 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 radio active 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.

LECTURE No. 3
(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

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

Constituent Or Characteristic	Unit	Drinking Water	
		Iraqi 2001	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

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

LECTURE No. 4

(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
k_a = arithmetic growth rate constant

Rearrange and integrate the above equation, p_1 and p_2 are the populations at time t_1 and t_2 respectively.

$$\int_{p_1}^{p_2} dp = \int_{t_1}^{t_2} k_a dt$$

We get

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

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

Or

$$p_t = p_0 + k_a t$$

where

p_t = population at future time
p_0 = present population, usually use p_2

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

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

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

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

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

Rearranging

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

The future population *P* is

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

Where P_0 = population of the base year

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 t_1 and t_2 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 p_t for January 1999 from t_2

$$t = 8.75 \text{ yr}$$

$$p_t = p_2 + k_a t$$

$$= 129{,}000 + 1600 \times 8.75$$

$$= 143{,}000$$

Step2. Solve with constant percentage method

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

$$= 0.013243$$

$$\ln P = \ln P_2 + k_p (t - t_2)$$

$$= \ln 129{,}000 + 0.013243 \times 8.75$$

$$= 11.8834$$

$$p = 144{,}800$$

Solve with declining growth method

Assuming

$$p_s = 200{,}000$$

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

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

$$= 0.02032$$

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

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

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

$$= 140{,}600$$

LECTURE No. 5

(WATER REQUIREMENTS)

The uses of water include domestic, commercial and industrial, public services such as fire fighting and public buildings, and unaccounted pipeline system losses and leakage. The average usage for the above four categories are 220, 260, 30, and 90 liters per capita per day (L/ (c. d)), respectively. These correspond to 58, 69, 8, and 24 gal/ (c. d), respectively. Total municipal water use averages 600 L/ (c. d) or 160 gal/ (c. d)

The maximum daily water use ranges from about 120 to 400 percent of the average daily use with a mean of about 180 percent. Maximum hourly use is about 150 to 12,000 percent of the annual average daily flow; and 250 to 270 percent are typically used in design.

Fire Demand

Fire demand of water is often the determining factor in the design of mains. Distribution is a short-term, small quantity but with a large flow rate. Fire flow rate and population relationship:

$$Q = 3.86\sqrt{p}\,(1 - 0.01\sqrt{p}) \quad \text{(SI units)}$$

Where Q = discharge, m^3/min

P = population in thousands

The required flow rate for firefighting must be available in addition to the coincident maximum daily flow rate. The duration during the required fire flow must be available for 4 to 10 h. For determination of required fire flow for area recommends the formula

$$F = 320\,C\sqrt{A}$$

Where F= required fire flow m^3/d

C= coefficient related to the type of construction

A = total floor area, m^2

C value	Construction	Maximum flow, gpm (m^3/d)
1.5	wood frame	8000 (43,600)
1.0	ordinary	8000 (43,600)
0.9	heavy timber type building	
0.8	noncombustible	6000 (32,700)
0.6	fire-resistant	6000 (32,700)

EXAMPLE 1: A four-story building of heavy timber type building of 715 m^2 of ground area. Calculate the water fire requirement.

Solution:

$$F = 320\, C\sqrt{A}$$
$$= 320 \times 0.9\sqrt{4 \times 715}$$
$$= 15{,}400 \ \ (m^3/d)$$

EXAMPLE 2: Assuming a high-value residential area of 100 ha (247 acres) has a housing density of 10 houses/ha with 4 persons per household, determine the peak water demand, including fire, in this residential area.

Solution:

Step 1. Estimate population P

$$P = (4 \text{ capita/house})\ (10 \text{ houses/ha})\ (100 \text{ ha})$$
$$= 4000 \text{ capita}$$

Step 2. Estimate average daily flow Q_a

$$Q_a = \text{residential} + \text{public service} + \text{unaccounted}$$
$$= (220 + 30 + 90)$$
$$= 340\ (\text{L}/(\text{c} \cdot \text{d}))$$

Step 3. Estimate maximum daily flow Q_{md} for the whole area

Using the basis of Q_{md} is 180 percent of Q_a

$$Q_{md} = (340 \text{ L}/(\text{c} \cdot \text{d}))(1.8)\ (4000 \text{ c})$$
$$= 2{,}448{,}000 \text{ L/d}$$
$$\cong 2400 \text{ m}^3/\text{d}$$

Step 4. Estimate the fire demand

$$\begin{aligned} Q_f &= 3.86\sqrt{p}\,(1 - 0.01\sqrt{p}) \text{ m}^3/\text{ min} \\ &= 3.86\sqrt{4}\,(1 - 0.01\sqrt{4}) \\ &= 7.57 \text{ m}^3/\text{min} \\ &= 7.57 \text{ m}^3/\text{min} \times 60 \text{ min/h} \times 10 \text{ h/d} \\ &= 4540 \text{ m}^3/\text{d} \end{aligned}$$

Step 5. Estimate total water demand Q

$$\begin{aligned} Q &= Q_{md} + Q_f \\ &= 2400 \text{ m}^3/\text{d} + 4540 \text{ m}^3/\text{d} \\ &= 6940 \text{ m}^3/\text{d} \end{aligned}$$

Note: In this area, fire demand is a control factor. It is measuring to compare *Q* and peak daily demand.

Step 6. Check with maximum hourly demand Q_{mh}

The Q_{mh} is assumed to be 250% of average daily demand

$$\begin{aligned} Q_{mh} &= 2400 \text{ m}^3/\text{d} \times 2.5 \\ &= 6000 \text{ m}^3/\text{d} \end{aligned}$$

Step 7. Compare Q versus Q_{mh}

$$Q = 6940 \text{ m}^3/\text{d} > Q_{mh} = 6000 \text{ m}^3/\text{d}$$

Use $Q = 6940 \text{ m}^3/\text{d}$ for the main pipe to this residential area.

EXAMPLE 4: Estimate the municipal water demands for a city of 225,000 persons.

Solution:

Step 1. Estimate the average daily demand Q_{avg}

$$\begin{aligned} Q_{avg} &= 600 \text{ L/(c} \cdot \text{d)} \times 225{,}000 \text{ c} \\ &= 135{,}000{,}000 \text{ L/d} \\ &= 1.35 \times 10^5 \text{ m}^3/\text{d} \end{aligned}$$

Step 2. Estimate the maximum daily demand Q_{md} (f =1.8)

$$\begin{aligned} Q_{md} &= 1.35 \times 10^5 \text{ m}^3/\text{d} \times 1.8 \\ &= 2.43 \times 10^5 \text{ m}^3/\text{d} \end{aligned}$$

Step 3. Calculate the fire demand Q_f

$$
\begin{aligned}
Q_f &= 3.86\sqrt{p}\,(1 - 0.01\sqrt{p})\ \text{m}^3/\text{min} \\
&= 3.86\sqrt{225}\,(1 - 0.01\sqrt{225})\ \text{m}^3/\text{min} \\
&= 49.215\ \text{m}^3/\text{min}
\end{aligned}
$$

For 10 h duration of daily rate

$$Q_f = 49.215\ \text{m}^3/\text{min} \times 60\ \text{min/h} \times 10\ \text{h/d} = 0.30 \times 10^5\ \text{m}^3/\text{d}$$

Step 4. Sum of Q_{md} and Q_f (fire occurs coincident to peak flow)

$$
\begin{aligned}
Q_{md} + Q_f &= (2.43 + 0.30) \times 10^5\ \text{m}^3/\text{d} \\
&= 2.73 \times 10^5\ \text{m}^3/\text{d}
\end{aligned}
$$

Step 5. Estimate the maximum hourly demand Q_{mh} ($f = 2.7$)

$$
\begin{aligned}
Q_{mh} &= f\,Q_{avg} \\
&= 2.7 \times 1.35 \times 10^5\ \text{m}^3/\text{d} \\
&= 3.645 \times 10^5\ \text{m}^3/\text{d} = 96.3\ \text{MGD}
\end{aligned}
$$

Step 6. Compare steps 4 and 5

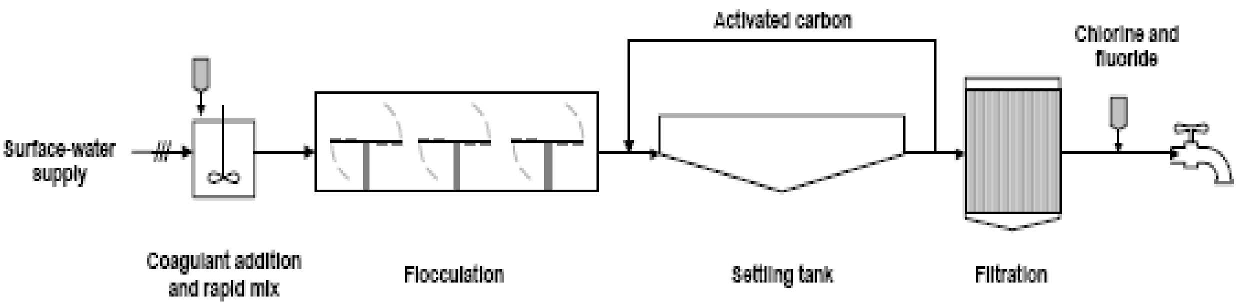
$$Q_{mh} = 3.645 \times 10^5\ \text{m}^3/\text{d} > Q_{md} + Q_f = 2.73 \times 10^5\ \text{m}^3/\text{d}$$

Use $Q_{mh} = 3.65 \times 10^5\ \text{m}^3/\text{d}$ to design the plant's storage capacity.

LECTURE No. 6

(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.

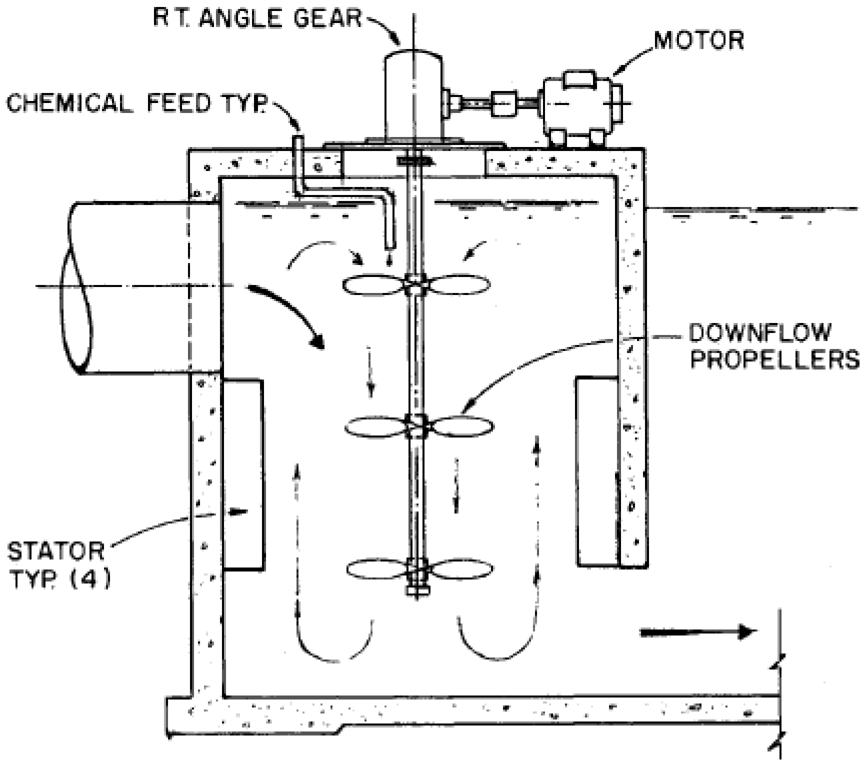


COAGULATION

Coagulation is a chemical process to remove turbidity and color producing material that is mostly colloidal particles (1 to 200 millimicrons, 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.

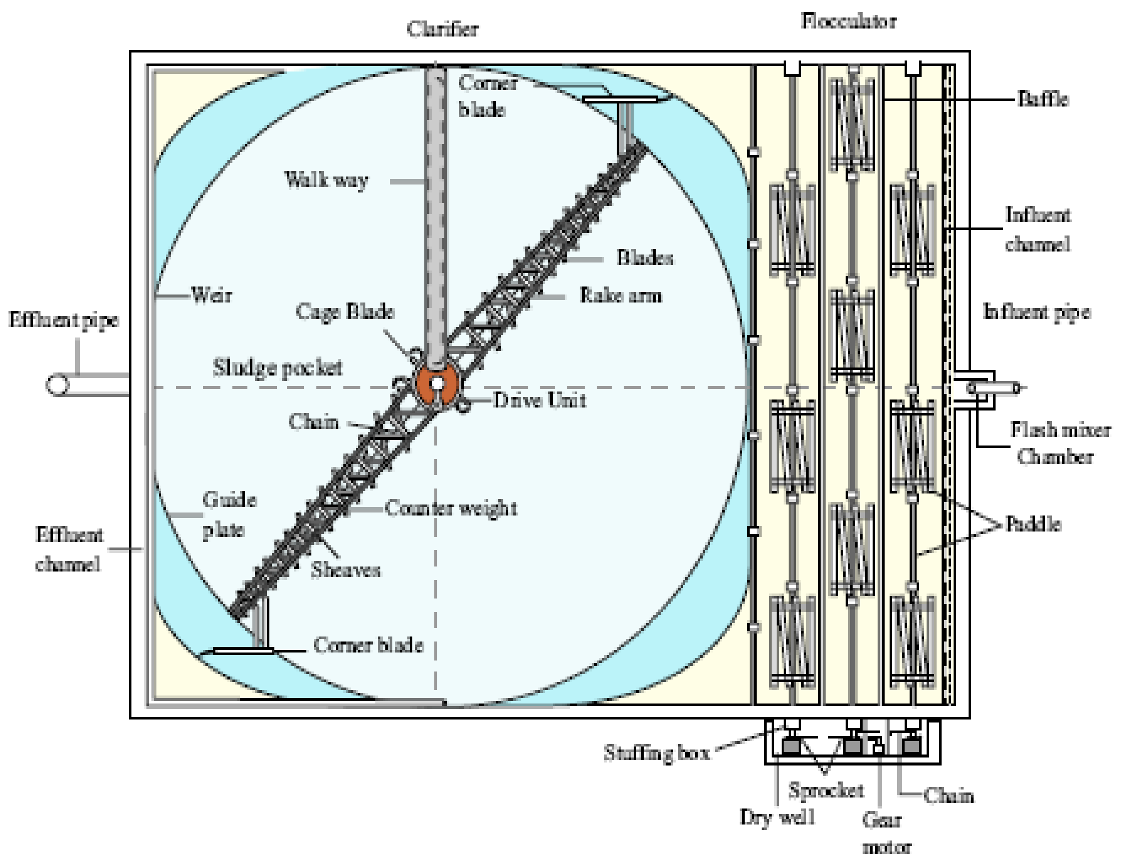


FLOCCULATION

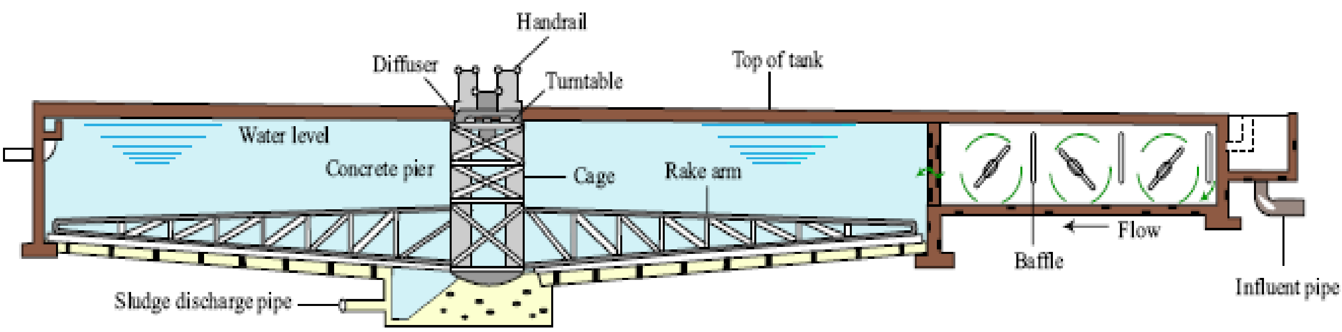
After rapid mixing, the water is passed through the flocculation basin. It is intended to mix the water to permit agglomeration of turbidity settled particles (solid capture) into larger flocs.

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



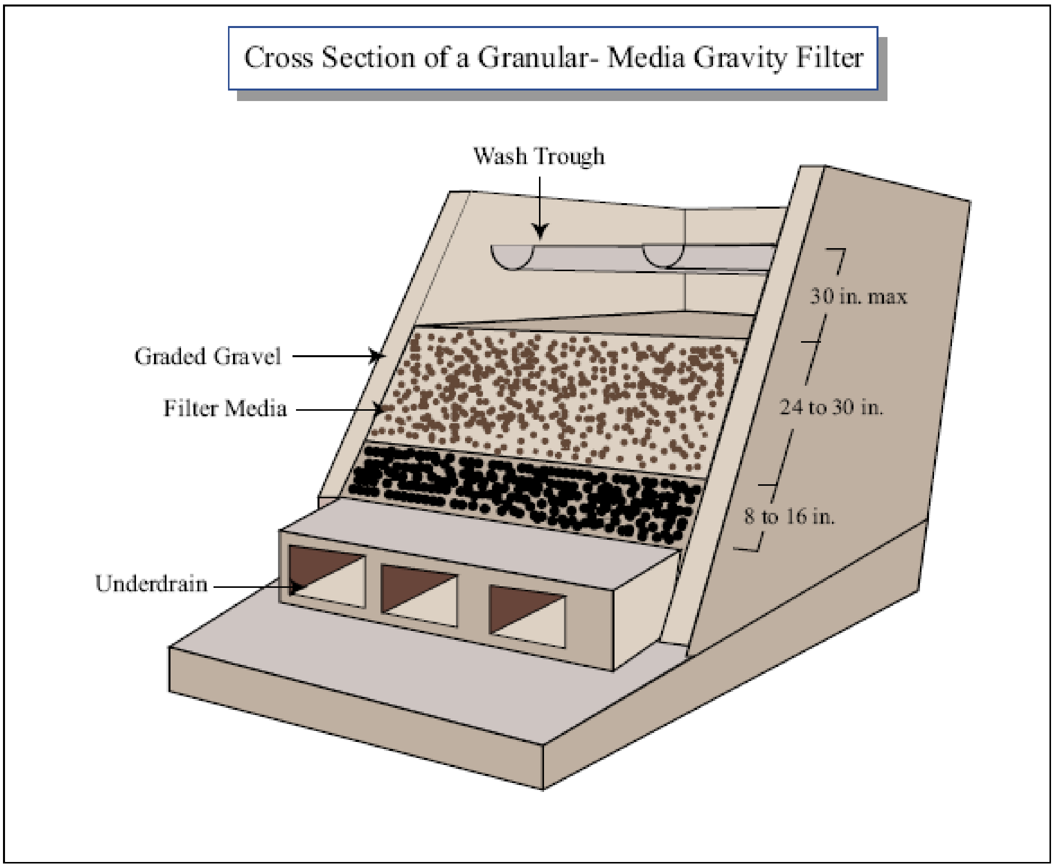
PLAN



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

FILTRATION

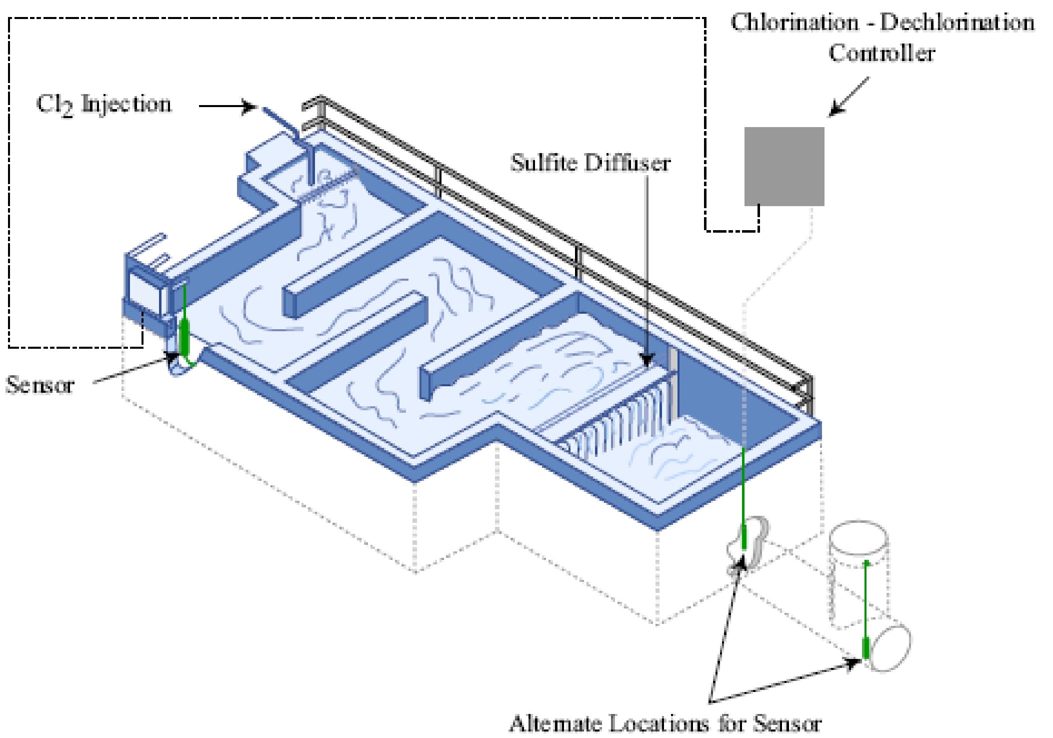
The conventional filtration process is probably the most important single unit operation of all the water treatment processes. It is an operation process to separate suspended matter from water by flowing it through porous filter medium or media. The filter media may be silica sand, anthracite coal,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



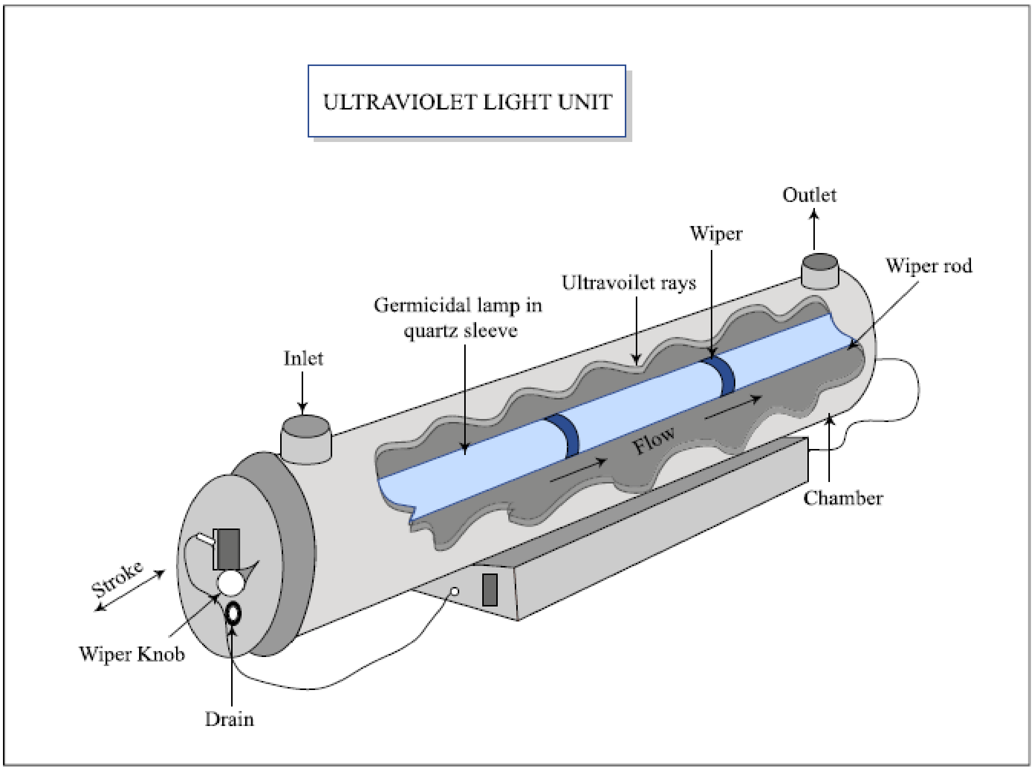
DISINFECTION

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.



LECTURE No. 7
(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 public concern.

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 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.

- 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 flowmeters, chemical-feed systems, and pumping systems.

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

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

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

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.