1. Introduction to Environmental Engineering

Environment is defined as all of the things effect on living organisms. The term of “biosphere” is environment in practice. It involves in the earth and atmosphere. Human has got a right to life in an unpolluted environment. We should not allow the factors that pollute the environment to be formed to preserve this right. Engineers claim that environmental pollution occurs when a material reaches into a natural environment; on the contrary ecologists claim that a material is a pollutant when it disturbs the natural balance of the environment depending on their different education discipline. Some of the engineers believe that a Benefit/Cost (B/C) analysis should be carried out to control the pollution. According to these engineers control studies are accepted if B/C >1. However, control studies are not accepted if B/C <1. This is a nonsense view since the life and human life is more valuable than money. The pollution definition of “is an extreme interference with beneficial use of a source” has been adopted by most of the engineers nowadays.

World Health Organization (WHO) defines the air pollution as “everything that damages human, animals and plants”. Unfortunately, the same organization sprayed DDT, a highly toxic material to the organisms, from the planes for fighting with mosquito before DDT has been forbidden. As it is clearly seen that a clear definition of environmental pollution could not be made since various definitions were made by different disciplines. Anyway there is no need to make a definition. We should know that environmental engineering is the application of science and engineering principles to improve the environment (air, water, and/or land resources), to provide healthy water, air, and land for human habitation and for other organisms, and to remediate polluted sites. Major reason of the environmental pollution is rapid population growth and increasing of consumption demand as a consequence of this.

Look at Figure 1

2. Water Pollution

2.1. Hydrological cycle

Hydrological cycle is presented as given below:
97% of hydrosphere water is in oceans and seas, 2% in lakes, rivers and groundwaters, 1% as snow and ice formation.

2.2. Physical and Chemical Morphology of Unpolluted Water

Water has a maximum density at a temperature of +4°C. This property of water provides breaking of the rocks as a consequence of freeze, bedding of the lakes and conserving of aquatic organisms which live in deep waters at cold seasons. Viscosity of water is high at this temperature, as a consequence of this, suspended solids are transported and silt and clay soils are formed. Water has a high boiling point and low freezing point, an ability of joining to acid-base reactions, and good electrical conductivity. Water is dipolar. Chemical activity of water is convenient for various metallic salts and gases to be solved. Water can carry soluble nutrients to animals and plants owing to its chemical activity.

An unpolluted water bed is:
1. a natural medium to have a rest and fun
2. a habitat for aquatic organisms
3. a power source which should be controlled
4. a receiving environment for waste discharge
5. a nutritional source for humans

2.3. Effect of Pollutants on Organisms

Main sources of water pollution are wastewaters discharged from homes and industry to the water beds. In addition to this, irrigation water leakages which are rich in terms of nitrogen and phosphorus transported from the agricultural areas, rain waters which transport the erosion soils, shipbuilding yards, replenished coasts and solid wastes can be
assumed as other pollution sources. Pollution sources are presented in the Table given below.

<table>
<thead>
<tr>
<th>Type of the pollution source</th>
<th>Pollutant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural sources</td>
<td>Pollutants formed in atmosphere</td>
</tr>
<tr>
<td></td>
<td>Dissolved minerals</td>
</tr>
<tr>
<td></td>
<td>Decomposed plants</td>
</tr>
<tr>
<td></td>
<td>Rain waters</td>
</tr>
<tr>
<td></td>
<td>Extreme growing in aquatic medium</td>
</tr>
<tr>
<td>Agricultural sources</td>
<td>Soil erosion</td>
</tr>
<tr>
<td></td>
<td>Wastes of farm animals</td>
</tr>
<tr>
<td></td>
<td>Fertilizers</td>
</tr>
<tr>
<td></td>
<td>Conservative drugs (pesticides)</td>
</tr>
<tr>
<td>Wastewaters</td>
<td>Municipal channel waters</td>
</tr>
<tr>
<td></td>
<td>Rain waters from residential areas</td>
</tr>
<tr>
<td></td>
<td>Liquid wastes from industry</td>
</tr>
<tr>
<td></td>
<td>Wastewaters from ships</td>
</tr>
<tr>
<td>Storage constructions</td>
<td>Sweeping of the sediments by leakages</td>
</tr>
<tr>
<td></td>
<td>Oxygen deficiency</td>
</tr>
<tr>
<td>Other sources</td>
<td>Minings</td>
</tr>
<tr>
<td></td>
<td>Waste dumping areas</td>
</tr>
</tbody>
</table>

2.3.1. Toxic Pollutants

Entrance of toxic materials into the water beds causes cumulative fish deaths. Serious poisonings occurs at low concentrations of the material has high toxic effect or high concentrations of the material has little toxic effect on organisms and plants. Also, toxic effects depend on the contact time of the pollutants and organisms. It is known that, some of the pesticides, heavy metals and radioactive elements are transported from the organism to other organism at increasing concentrations by accumulating in the food chain. For instance; DDT at a concentration of 0.02 ppm accumulates in the microorganism up to the concentration of 5 ppm. DDT of 2000 ppm accumulates in fishes which eat these microorganisms. Sea birds eat these fishes die at the end of this food chain. Researches showed that DDT concentration was calculated to be 1600 ppm in these died birds. The same condition is recognized for cadmium and mercury elements. Algae store arsenic and lead 2000 and 40.000 fold higher in comparison to the concentrations founded in aquatic medium, respectively. Radioactive materials are stored in the aquatic organisms 200.000 fold higher in comparison to the concentrations founded in water.

2.3.2. Settleable Solids

If a solid material is transported into a water medium:

1. it is lowered the water storage capacity of the dam
2. lakes and pools fill
3. water channels are blocked
4. productive soils are covered
5. water medium is damaged for life
6. photosynthetic activity is decreased depending on increasing turbidity
7. effective water usage decreases
8. the cost of water treatment increases
9. water distribution systems damage
10. pesticides, heavy metals, conservative drugs and nutrients are transported by these solids to the water beds.
11. bacteria and virus which cause disease are transported in the same way

Because the settleable solids are light, they travel to the long distances with high flow rates. However, they precipitate when the flow rate is decrease or in dead water. Growing of fish eggs and larva is blocked owing to the coverage of those with the settled solids at the bottom of water bed. As a consequence of this, nutrition of the organisms which eat these eggs and larva is prevented. If these settled solids are organic, their biodegradation cause the consumption of dissolved oxygen of water, thus, an anaerobic environment occurs at the bottom of the water bed and undesirable methane, carbon dioxide and hydrogen sulfide gasses release into the water bed. Suspended solids increase the turbidity; prevent the entrance of sun rays into the water hence aquatic plants. This situation causes to lower the concentration of dissolved oxygen.

2.3.3. Organic Materials

An organic compound is comprised of carbon, hydrogen and nitrogen elements. When organic materials reach to water bed, they are attacked by microorganisms which need energy for living and growing. During this biodegradation dissolved oxygen of water is used by the microorganisms as last electron acceptor of the biological reaction. If the organic material is at higher concentration, more dissolved oxygen is consumed depending on the biological reaction stoichiometry. This is an undesirable condition for water life. Organic materials not only enter to water bed by discharges but also are synthesized by the photosynthetic microorganisms in water (anabolism). Then the synthesized organics are used as energy source of microorganisms which biodegrade it (catabolism). These two conditions are the basic steps of the carbon cycle. Photosynthesis and respiration mechanisms are presented below superficially:
General food cycle in nature is shown below: Here A is the first food material of the chain. First organism uses A as an energy source then produces B which then is used as an energy source of second organism. Finally, food material A is produced by 2nd organism community. This cycle is repeated constantly unless a negative effect damages this cycle.

Biological degradation of the organic materials is carried out by 3 main mechanisms:

1. aerobic respiration: dissolved oxygen is used by the microorganisms
2. anaerobic mechanism: reaction is carried out in oxygen-free medium
3. anoxic mechanism: bound oxygen is used in the reaction

Carbon dioxide, which is produced by the biodegradation of carbonaceous (organic) compound, is the final product of the aerobic respiration. It is stable, has a low energy level and used in the photosynthetic mechanism. If sulphurous and phosphorous materials join to the aerobic reaction, sulphate and phosphate ion is produced as the last most stable final product, respectively. Biodegradation of nitrogenous compounds in aerobic
mechanism is different. As a consequence of a series of reactions which stability increase gradually, nitrate is produced as a final product. These series can be seen below:

\[
\text{Organic nitrogen} \rightarrow \text{NH}_4^+ \rightarrow \text{NO}_2^- \rightarrow \text{NO}_3^- \quad (\text{nitrification})
\]

Anaerobic respiration is carried out with different types of microorganisms. Methane, which is produced by the biodegradation of carbonaceous (organic) compound, is the final product of the anaerobic respiration.

Let’s look at carbon (Figure 2), nitrogen (Figure 3) and phosphorus cycle (Figure 4):

Energy is transported by electron transfers via an electron donor in the biochemical reactions. Electron donor is food material (organic compound) for most of the biochemical reaction. In addition to this, electron donors are ammonia, sulphur, iron (II) for the various types of microorganisms. The key compound is ADP (adenosine diphosphate) for energy transport. General reaction mechanism:

\[
\text{ADP} + \text{energy} + \text{phosphate} \rightarrow \text{ATP} \quad \text{(adenosine triphosphate)} + \text{H}_2\text{O}
\]

According to this reaction generated ATP enters to the cell and leaves the required energy. The transferred electrons should be accepted by another molecule defines as electron acceptor. Oxygen is the final electron acceptor of aerobic respiration. The final electron acceptors are nitrate, sulphate and carbon dioxide (bound oxygen) for oxygen-free mediums. This type of mechanism is defined as anoxic metabolism. The electron acceptor is organic compound for the anaerobic mechanism. Aerobic and anaerobic carbon, nitrogen and sulphur cycle is shown in Figure 5 and Figure 6.

2.3.4. Heat Pollution

Heat is mainly effect of the biological activity in water. Heat is proportional with biological reactions up to an optimal temperature. The biological activity decreases then stops over this optimum temperature since cell membrane of the microorganisms damage, cytoplasm and organelles flow out, and the catalytic activity is blocked. Chemical reactions are affected by temperature directly too. Chemical reaction rate increases by increasing temperature. Solubility of gasses decreases by increasing temperature. Dissolved oxygen is important for water life as mentioned before. A limited concentration of dissolved oxygen blocks the biological activity. Temperature of water increases by discharges of cooling waters of industries. Therefore, heat of waters should be controlled to maintain the ecological life.

2.3.5. Lipids (Fat and Oil)

Lipids reach to water by tankship crashes and petrochemical industries. Effects of the fatty substances to the water life are presented below:
• Algae and phytoplanktons damage since free fats and emulsions cover them
• Oxygen transfer is blocked since the fats cover the water surface as layer
• Some of the fats are toxic substances and poisons the water organisms
• Branchias of fishes are covered with fats in fatty waters, respiration of the fishes become difficult.

2.3.6. Nutrients

Nutrients are chemical substances which are essential to maintain the metabolic activities of the living organisms and for growth of them. These substances are supplied by green plants and released to the environment by joining to the food chain again. Essential nutrients for the microscopic plants in the surface water are classified in two groups:

- Biogenic substances for the generation and the energy of microscopics: phosphorus, nitrogen and carbon
- Trace substances for the activities of living organisms

Extreme growth of algae occurs with the excess concentration of nitrogen and phosphorus in waters is called as “eutrofication”. Large amount of waste water discharge to the receiving waters cause the eutrofication since it includes nitrogen and phosphorus at higher concentrations. Because, nitrogen and phosphorus are foods of algae and microorganisms. Taste, smell and the color of and eutrophic water changes and water quality damages. Water inlet constructs, water-treatment plants and shadoofs are plugged then their performances become worst. When algae die, oxygen is consumed for decomposition of them by the other microorganisms. As a result of this, hydrogen sulphur (H₂S) which is a toxic and evil-smelling gas releases into the water.

2.4. River (Stream) Pollution

River is a receiving medium for waste waters. Therefore, it is polluted. When waste water discharges to a river, the maximum pollution occurs at the discharge point in the river. When the river flows with a velocity, this pollution decreases since the microorganisms decompose the organic materials which caused the pollution. In addition to this dissolved oxygen decreases by flow of the river since the aerobic microorganisms consume it.

Aerobic respiration:

\[
\text{Organic substance} + \text{oxygen} \xrightarrow{\text{microorganisms}} \text{carbon dioxide} + \text{water}
\]

\[
C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O
\]
Nitrogenous compounds indicate the water pollution too. Organic nitrogen is converted to ammonium in aerobic and anaerobic respiration then to nitrite and nitrate in the aerobic respiration. Consequently, when a nitrogeneous pollutant enters to the river the conversion of nitrogen in the river is carried out as given in Figure 7.

2.4.1. Effect of a Small City on a River

Look at Figure 8 which shows a city and a river passing from inside of the city. City discharges of the waste waters into the river. Let’s investigate the pollution parameters in the river at various points. Table shows the pollutant parameters at various points of the river shown in Figure 8. A is a measurement point placed before the city/ before wastewater discharge. The aim of choosing A is the determination of the water quality before the city. Generally the river water is clean on the A point (look at the table). B is the closest point to the discharge. The pollutant concentrations on point B are much than the other points. When the river is flowing away from the city, it is cleaning itself by the aeration and biodegradation. Therefore on the point of C, D and E is becoming cleaner, respectively. Dissolved oxygen concentration reaches the biggest value on E point since side arm fresh water enters to the river on E point.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspended solids (mg/L)</td>
<td>10</td>
<td>19</td>
<td>17</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>Phosphate (mg/L)</td>
<td>0.37</td>
<td>0.75</td>
<td>0.61</td>
<td>0.43</td>
<td>0.41</td>
</tr>
<tr>
<td>BOD (biological oxygen demand) (mg/L)</td>
<td>1.8</td>
<td>3.2</td>
<td>3.1</td>
<td>2.6</td>
<td>2.1</td>
</tr>
<tr>
<td>Dissolved oxygen (mg/L)</td>
<td>60</td>
<td>70</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen (mg/L)</td>
<td>20</td>
<td>260</td>
<td>240</td>
<td>210</td>
<td>60</td>
</tr>
<tr>
<td>Coliform (100 mL)</td>
<td>10</td>
<td>370</td>
<td>360</td>
<td>240</td>
<td>80</td>
</tr>
</tbody>
</table>

2.4.2. Effect of Agricultural Area on a River

River presented in Figure 9 is flowing through a large agricultural area. 5 measurement stations have been chosen to investigate the effect of this agricultural area on the river. A is a measurement point placed before the agricultural area. Here, the river flows through the agricultural area from A to E point. Therefore, pollutant concentrations increase up to the E point.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspended solids (mg/L)</td>
<td>22</td>
<td>28</td>
<td>36</td>
<td>61</td>
<td>62</td>
</tr>
<tr>
<td>Phosphate (mg/L)</td>
<td>0.04</td>
<td>0.09</td>
<td>0.16</td>
<td>0.75</td>
<td>1.1</td>
</tr>
<tr>
<td>BOD (mg/L)</td>
<td>1.8</td>
<td>2.2</td>
<td>2</td>
<td>1.8</td>
<td>1.9</td>
</tr>
<tr>
<td>Dissolved oxygen (mg/L)</td>
<td>6.5</td>
<td>6.3</td>
<td>6.1</td>
<td>6.6</td>
<td>6.2</td>
</tr>
<tr>
<td>Nitrogen (mg/L)</td>
<td>0.22</td>
<td>0.61</td>
<td>0.83</td>
<td>1.01</td>
<td>1.73</td>
</tr>
</tbody>
</table>
2.4.3. Oxygen Equilibrium in the Polluted Rivers

An organic pollutant decomposes by microorganisms; dissolved oxygen is consumed in this reaction simultaneously. Atmospheric oxygen is transferred to the river at the same time. As a consequence of this, oxygen is both consumed and increased in the river. Oxygen equilibrium can be written for a river piece at a definite time.

Oxygen utilization rate of microorganisms is given below:

Oxygen utilization rate = \( k_1 \times (L_0 - y) \)

\( L_0 \): total oxygen concentration for the decomposition of the organic substances (mg/L) (initial BOD)
\( y \): consumed oxygen concentration up to a \( t \) time (mg/L)
\( k_1 \): oxygen utilization rate constant (day\(^{-1}\))

Oxygen transferred to the river = \( k_2 \times \text{DOD} \)

\( \text{DOD} \): Dissolved oxygen deficiency at a definite \( t \) time (mg/L)
\( k_2 \): oxygen transfer rate constant from air to water (day\(^{-1}\))

\( \text{DOD} = \text{DOS} - \text{DO} \)

\( \text{DOS} \): Dissolved oxygen saturation (mg/L)
\( \text{DO} \): Dissolved oxygen concentration in water (mg/L)

\[
\frac{d\text{DOD}}{dt} = k_1 (L_0 - y) - k_2 \text{DOD}
\]

\( L_0 \xrightarrow{k_1} L \) is a first order reaction, therefore;

\[
\frac{dL}{dt} = -k_1 \times L
\]

\[
\int_{L_0}^{L} \frac{dL}{L} = -k_1 \int_{0}^{t} dt
\]

\[
\ln\frac{L}{L_0} = -k_1 \times t
\]

\( L = L_0 \times e^{-k_1 \times t} \)
DOD = \frac{k_1 L_0}{k_2 - k_1} (e^{-k_2 t} - e^{-k_1 t}) + DOD_1 e^{-k_1 t} \quad \text{Streeter-Phelps Equation}

DOD_1 = \text{Dissolved oxygen deficiency at the discharge point before the discharge (mg/L)}

While DOD is decreasing, oxygen transfer rate \((k_2 \times \text{DOD})\) is increasing.

**Dissolved oxygen curve in a polluted river**

When pollution is discharged to the river, dissolved oxygen decreases by the time or distance via the biological activity (decomposition of organic materials with microorganisms). When organic material decrease by the time, oxygen utilization rate decreases then oxygen transfer rate increases. Dissolved oxygen concentration is zero at critical time \((t_{cr})\) or critical distance \((x_{cr})\). In this condition;

\[ k_2 DOD_{cr} = k_1 L = k_1 L_0 e^{-k_1 t_{cr}} \]

\(DOD_{cr} = \text{Dissolved oxygen deficiency at the critical point (mg/L)}\)
We mentioned before that oxygen equilibrium in water is mainly affected by the organic materials (BOD) and oxygen transfer from the air. In addition to this, other parameters effect on oxygen equilibrium are presented as:

1. Decrease of BOD by adsorption and sedimentation.
2. Entrance of substances with high BOD via the side arms of the river.
3. Oxygen utilization by organisms living at the bottom of the river.
4. Having oxygen by planktons via photosynthesis
5. Oxygen consuming by planktons via respiration

2.5. Lake Pollution

Effect of light and temperature on lake pollution is dominant compared to other receiving mediums. Light is source of energy for photosynthetic mechanism. Permeation of light into the lake is poor. Maximum density of water is at +4°C. Water is a weak conductor for heat transport. A large amount of the heat is stored in water mass. Temperature of lake water changes with seasons. It is assumed that temperature does not change with depth for unfrozen lakes in winter. When hot seasons approach, the top water mass starts to warm. Because water is a poor heat conductor and density of warm water is low temperature layers are formed in lakes referred as “thermal stratification”. This condition is considerably stable and runs on to the end of the summer. Thermal stratification in lake is shown in figure below.
Since water circulation is only observed at top layer during the thermal stratification, the most of the chemical and biochemical reactions occur in epilimnion layer. Together with coming cold seasons, the top layer becomes cold, heavy then moves to the bottom of the lake (water cycle in lakes). Changing of temperature effects on dissolved oxygen concentration in lakes. Dissolved oxygen profile in lakes is given below.

Biochemical reactions in natural lakes are presented in figure given below. Rivers and agricultural areas feed the lakes with rich organic materials including nitrogen and phosphorus. Algae store C, N and P in its body by using sun light as an energy source, and synthesize molecules with high energy. Algae are food of zooplanktons, zooplanktons are food of fishes. Wastes with rich organic materials are formed by these activities. Bacteria are used dissolved organic carbon in these wastes, and generate CO$_2$ for algae. Other sources of CO$_2$ are zooplanktons, fish respiration and atmosphere. An unpolluted lake does not contain C, N and P. Therefore, algae quantity is limited in this medium. If a lake receives N and P at high concentrations, algae community grows rapidly. This is called as “eutrophication”. Molecular formula of algae is
C_{106}H_{263}O_{110}N_{16}P. Thus, algae contains C:N:P = 106:16:1. Even C and N is discharged at high concentrations to a lake, algae is not formed since there is no P.

*Trophic food level of lakes*

It is classified in 3 category:
1. Oligotrophic
2. Mesotrophic
3. Eutrophic
Table. Nitrogen and Phosphorus weights to be allowed in lakes.

<table>
<thead>
<tr>
<th>Average depth (m)</th>
<th>Allowed N (g/m²-year)</th>
<th>Allowed P (g/m²-year)</th>
<th>Dangerous N weight (g/m²-year)</th>
<th>Dangerous P weight (g/m²-year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1</td>
<td>0.07</td>
<td>2</td>
<td>0.13</td>
</tr>
<tr>
<td>10</td>
<td>1.5</td>
<td>0.1</td>
<td>3</td>
<td>0.2</td>
</tr>
<tr>
<td>50</td>
<td>4</td>
<td>0.25</td>
<td>8</td>
<td>0.5</td>
</tr>
<tr>
<td>100</td>
<td>6</td>
<td>0.4</td>
<td>12</td>
<td>0.8</td>
</tr>
<tr>
<td>150</td>
<td>7.5</td>
<td>0.5</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>200</td>
<td>9</td>
<td>0.6</td>
<td>18</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Mass Balance for Quantification

\[ \text{Mass Balance} \text{ } = \text{input} - \text{output} \pm \text{reaction} \]

Mass Balance on Water in a Lake

\[ \text{[accumulation]} = [\text{input}] - [\text{output}] \pm [\text{reaction}] \]

- change in lake volume per unit time = inflow rate + precipitation rate - outflow rate - evaporation rate

\[ \text{Lake Volume } V, \text{ ft}^3 \]

\[ \text{Precipitation } P \text{ (inches)} \]

\[ \text{Evaporation } E \text{ (inches)} \]
PROBLEMS

1. A river flowing with a velocity of 5 km/hour is at dissolved oxygen saturation value of 10 mg/L. Pollutant concentration of the river right after a discharge point is 60 mg/L (BOD). Saturated oxygen concentration of the river is 10 mg/L. If oxygen utilization rate constant is 0.1 day\(^{-1}\) and oxygen transfer rate constant 0.3 day\(^{-1}\), what is dissolved oxygen concentration after 30 km away from the discharge point?

2. Wastewater amount is 400 L/ population-day for a city with 20000 people. BOD and dissolved oxygen concentration of these waters is 28 mg/L and 1.8 mg/L, respectively. Wastewaters are discharged to a river flowing with a flow rate of 7 m\(^3\)/s and a velocity of 0.4 m/s. The river is saturated with 90% of oxygen and has a BOD value of 3.6 mg/L. Saturated oxygen concentration of the river is 8.5 mg/L oxygen utilization rate constant is 0.5 day\(^{-1}\) and oxygen transfer rate constant 0.06 day\(^{-1}\).

   a) What is the flow rate of wastewater as m\(^3\)/s?
   b) What is dissolved oxygen concentration of wastewater-river mixture?
   c) What is dissolved oxygen deficiency right after the discharge point?
   d) What is the distance where dissolved oxygen concentration is at minimum level?
   e) What is the minimum dissolved oxygen concentration after the discharge point?

3. Wastewater of a city with a flow rate of 40.000 m\(^3\)/day is being discharged to a river flowing with 10 m\(^3\)/s flow rate. Dissolved oxygen deficiency just before the discharge point is at a saturated level of 9 mg/L. Oxygen utilization rate and oxygen transfer rate constant is 0.2 day\(^{-1}\) and 0.3 day\(^{-1}\), respectively. Calculate the maximum discharge BOD as mg/L to get dissolved oxygen concentration below 4 mg/L at any point of the river.

4. Analysis results of a lake is; C: 60 mg/L, N: 1.4 mg/L and P: 0.62 mg/L. Which of these parameters is the limiting parameter for eutrophication?

5. Wastewater of a city with a flow rate of 20.000 m\(^3\)/day is being discharged to a river which flows into a lake just after the discharge point. Phosphorus and nitrogen concentration of the discharge is 7 and 18 mg/L, respectively. The flow rate of the river is 6 m3/s, nitrogen concentration is 0.2 mg/L and phosphorus concentration is 0.02 mg/L at the lake input. Surface area of the lake is 130 km\(^2\) and the mean depth is 10 m. 2000 kg of phosphorus and 12.000 kg of nitrogen is reaching into the lake per year diffusively

Calculate nitrogen and phosphorus loading from the lake environment, river and discharge water. How much should be the standard nutrient concentrations in the discharge water to prevent the excessive algae growing in the lake?
HOMEWORK 1: Treated wastewater of a city with a population of 200,000 involves 28 mg/L BOD and 1.8 mg/L dissolved oxygen. The wastewater is being discharged at a flow rate of 37 ft$^3$/s to a river which has a flow rate of 250 ft$^3$/s and a mean velocity of 1.2 ft/s. BOD value of the river before the discharge is 3.6 mg/L and dissolved oxygen value is 7.6 mg/L. Dissolved oxygen saturation is 8.5 mg/L, oxygen utilization rate constant and oxygen transfer rate constant is 0.6 day$^{-1}$ and 0.76 day$^{-1}$, respectively.

a) Calculate the critical distance and dissolved oxygen concentration at this point
b) Calculate dissolved oxygen concentration at 10 miles after the discharge point

Hints:

\[
C_{\text{mix}} = \frac{Q_{\text{wastewater}} \times C_{\text{wastewater}} + Q_{\text{river}} \times C_{\text{river}}}{Q_{\text{wastewater}} + Q_{\text{river}}}
\]

1 mile = 5280 ft
1 day = 86400 s

3. Water Supply and Treatment

The first goal of an environmental engineer is to conserve the water sources and to control the pollution. A water source should be selected firstly to supply water to human demands. Three main factors to make this selection are:

1. Quality
2. Amount
3. Cost

Selected water source should have high quality and large quantities. Most of the water sources are rivers and lakes. These kinds of sources have large quantities and are not suitable for direct use. The other sources of water are well and source waters. These waters have high qualities but little amounts. Therefore, the water supply of big cities is carried out from surface waters. The table given below shows the water sources.

<table>
<thead>
<tr>
<th>Type of water source</th>
<th>Source content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain</td>
<td>Reservoirs</td>
</tr>
<tr>
<td></td>
<td>Melting of snow and ice</td>
</tr>
<tr>
<td>Surface flow waters</td>
<td>Lakes</td>
</tr>
<tr>
<td></td>
<td>Rivers</td>
</tr>
<tr>
<td>Ground waters</td>
<td>Source</td>
</tr>
<tr>
<td></td>
<td>Wells</td>
</tr>
<tr>
<td></td>
<td>Infiltration galleries</td>
</tr>
<tr>
<td>Salt waters</td>
<td>Sea</td>
</tr>
<tr>
<td></td>
<td>Brackish and salt ground waters</td>
</tr>
<tr>
<td>Reuse of wastewaters</td>
<td></td>
</tr>
</tbody>
</table>

Surface waters should be treated for removing taste and smell and dangerous substances which are toxic to health. Drinking water properties are given with TS 266 standard in our country. For instance;
Waters intaken from lakes and rivers have high turbidity due to the pipe clays. These particles are removed from water by sedimentation treatment process. Sedimentation of these particles which have natural electrostatic charges is difficult. Therefore, some chemicals (coagulant) are added into the water to precipitate these particles by neutralization. This process is defined as “coagulation”. The commonly used coagulant chemical is aluminum sulphate (Al$_2$SO$_4$). When Al$_2$SO$_4$ is added into the water Al(OH)$_3$ is generated and particles are neutralized. Then, Al(OH)$_3$ and neutralized particles adhere with each other. Adhered mass is defined as flock. These flocks precipitate since they are big and heavy. This process is called “floculation”. Water in the flocculation reactors are mixed slowly for not to damage the flocks. Water flows from the flocculation tank to settling tank then sand filters. Flocks are settled in the settling tank then thin particles are filtered in the sand filter. Water is chlorinated after these treatment processes then piped to drinking water reservoirs for city water supply. This process is presented in the figure below.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Advised value</th>
<th>Maximum value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turbidity</td>
<td>5 units</td>
<td>-</td>
</tr>
<tr>
<td>Color</td>
<td>15 units</td>
<td>-</td>
</tr>
<tr>
<td>Smell</td>
<td>3 units</td>
<td>-</td>
</tr>
<tr>
<td>Coliform</td>
<td>1 piece /100 mL</td>
<td>-</td>
</tr>
<tr>
<td>Arsenic</td>
<td>0,01 mg/L</td>
<td>0,05 mg/L</td>
</tr>
<tr>
<td>Chloride</td>
<td>250 mg/L</td>
<td>-</td>
</tr>
<tr>
<td>Copper</td>
<td>1 mg/L</td>
<td>-</td>
</tr>
<tr>
<td>Cyanide</td>
<td>0,01 mg/L</td>
<td>0,2 mg/L</td>
</tr>
<tr>
<td>Iron</td>
<td>0,3 mg/L</td>
<td>-</td>
</tr>
<tr>
<td>Phenol</td>
<td>0,001 mg/L</td>
<td>-</td>
</tr>
<tr>
<td>Sulphate</td>
<td>250 mg/L</td>
<td>-</td>
</tr>
<tr>
<td>Zinc</td>
<td>5 mg/L</td>
<td>-</td>
</tr>
</tbody>
</table>
Coagulation & Flocculation

This is generally a middle step in water preparation for municipal distribution, after basic screening for the removal of debris and pH adjustment. The objective is to remove particles that would otherwise take too long to settle. It also offers the advantage of being able to remove some of the dissolved organic matter. Coagulation is a charge neutralization step that is achieved by the addition of a chemical such as

- Alumina $\text{Al}_2(\text{SO}_4)_3$
- Sodium aluminate $\text{Na}_2\text{Al}_2\text{O}_4$
- Aluminum chloride $\text{AlCl}_3$
- Ferric sulfate $\text{Fe}_2(\text{SO}_4)_3$
- Ferric chloride $\text{FeCl}_3$
Treatment process is varied in accordance with the water source. Figure 10, 11 and 12 show a treatment process for well waters, eutrophic lake waters and river waters, respectively.

3.1. Wastewater Catchments

Wastewaters are collected by two systems:
1. Combined system
2. Separated system

In a combined system, domestic wastewaters and rain waters are collected together whereas domestic and rain waters are collected separately in a separated system. Rain waters are both clean and more than wastewaters. Therefore, a wastewater treatment plant constructed for wastewaters coming from a combined system should have large area than a wastewater treatment plant constructed for wastewaters just coming from homes. In addition, wastewater treatment plants for combined systems are operated difficult since the flow rates change by time distinctly. In brief, wastewater treatment plants for combined systems have high cost for construction and operation. To overcome this problem, separated systems are being constructed in new cities.

3.2. Wastewater Treatment

Wastewater Treatment Plant (WWTP) – System Overview

Primary treatment: Physical Removal (Mechanical Treatment)

The first stages of waste water (sewage) treatment are commonly physical and aimed to remove larger suspended solids from waste water, primarily using gravity to allow larger (heavy) particles to settle while allowing the remaining liquid to continue through the plant. Primary wastewater treatment uses simple mechanical and physical processes to remove nearly half of the solid contaminants from waste water. Primary treatment consists of units like coarse screening, grit removal, flow equalization and primary sedimentation tanks.
Secondary Treatment: Activated Sludge (Biological Treatment)

An activated-sludge reactor is a system in which pre-treated sewage (i.e. having passed through primary treatment – settling) is aerated to promote the growth of bacteria (cells) that gradually consume the organics in the sewage. The result is the development of cells acclimated to the particular mix of substances present in the sewage and a significant consumption of the organic material. The effluent is a mixture of water with suspended cells and drastically reduced BOD content. This mixture is then passed through a clarifier (settling tank) where the solids (mostly cells, called sludge at this stage) are separated from the water. The system is commonly operated in continuous mode (as opposed to batch mode). The system is properly speaking an activated sludge system when a portion of the sludge (cells) collected from the bottom of the clarifier is returned to the aerator. Not only are these cells already acclimated to the sewage, but by the time they are collected from the clarifier, they are also oxygen starved and therefore really "hungry" for another meal!
The activated sludge system consists of two components, an aerator, where cells ($X$) consume the sewage ($S$), and a clarifier, where cells are then removed from the treated water. Because cells need oxygen for their metabolism, air is injected from the bottom of the aerator. Rising bubbles agitate the water well and create good contact between the three ingredients: cells, sewage and oxygen.

Secondary Treatment Alternative 1: Trickling Filter

A trickling filter consists of a substrate (rocks or other material) on which cells (slime) can grow and over which the pre-treated sewage is sprayed. The spraying action creates contact between BOD in sewage, oxygen in the air and cells on the substrate. Cells grow and degrade the sewage. Excess cells need to be periodically removed from the substrate.
Secondary Treatment Alternative 2: Rotating Biological Contactors

In this process, cells are attached to disks that rotate in the vertical plane. Cells are then alternatively exposed to sewage (their food) and air (their oxygen supply).
Secondary Treatment Alternative 3: Fixed-film Reactors

In this process, cells are attached to vertical plates that are immersed by the flowing sewage and air is injected from the bottom to provide the oxygen.

Tertiary Treatment (Advanced Treatment)

Primary and secondary treatment removes the majority of BOD and suspended solids found in wastewaters. However, in an increasing number of cases this level of treatment has proved to be insufficient to protect the receiving waters or to provide reusable water for industrial and/or domestic recycle. Thus, additional treatment steps have been added to wastewater treatment plants to provide for further organic (N, P) and solids removals or to provide for removal of nutrients and/or toxic materials. Advanced wastewater treatment will be defined as any process designed to produce an effluent of higher quality than normally achieved by secondary treatment processes.

Oxidation Ponds (Aerated Lagoons/ Stabilization Ponds)

In this process, nature is essentially left to run its course, with or without a little help from aeration. The system looks less technological and is thus better integrated in the landscape, but it occupies much more real area. Odor may also be a problem.
Adsorption on activated carbon finds growing use as an effective and economical process for purifying liquids by separating low concentrations of absorbable molecules from liquids. Examples of some large volume applications of this process are the decolorization, removal of taste and odor from drinking water, and the removal of dissolved organics from industrial and municipal wastewaters. In these applications, the liquid is typically passed through a static (non-fluidized) bed of the carbon until the adsorptive capacity of the carbon is so exhausted that the treated liquid no longer meets the purity requirement. At that time, all or part of the carbon is replaced with fresh carbon, and the spent carbon discarded or reactivated for reuse.
4. Water Quality Control

The term "water quality" is a widely used expression, which has an extremely broad spectrum of meanings. Each individual has vested interests in water for his particular use. The term quality therefore, must be considered relative to the proposed use of water. From the user's point of view, the term "water quality" is defined as "those physical, chemical or biological characteristics of water by which the user evaluates the acceptability of water". For example for the sake of man's health, we require that his water supply be pure, wholesome, and potable. Similarly, for agriculture, we require that the sensitivity of different crops to dissolved minerals and other toxic materials is known and either water quality other type of crops is controlled accordingly. Textiles, paper, brewing, and dozens of other industries using water, have their specific water quality needs.

What is water quality monitoring?

Did you ever stop to wonder how we get our information on the condition of our Nation's streams, lakes, estuaries, and coastal waters? On whether these waters are safe enough to swim in, fish from, or use for drinking? Monitoring provides this basic information.

There are many ways to monitor water conditions. Monitoring specialists sample the chemical condition of water, sediments, and fish tissue to determine levels of key constituents such as dissolved oxygen, nutrients, metals, oils, and pesticides. They also monitor physical conditions such as temperature, flow, sediments, and the erosion potential of stream banks and lake shores. Biological measurements of the abundance and variety of aquatic plant and animal life and the ability of test organisms to survive in sample water are also widely used to monitor water conditions.

Why monitor?

Monitoring can be conducted for many purposes. Five major purposes are to:
• characterize waters and identify changes or trends in water quality over time;
• identify specific existing or emerging water quality problems;
• gather information to design specific pollution prevention or remediation programs;
• determine whether program goals, such as compliance with pollution regulations or implementation of effective pollution control actions, are being met; and
• respond to emergencies, such as spills and floods.

Some types of monitoring activities meet several of these purposes at once; others are specifically designed for one reason.

Who monitors?

The responsibility to monitor water quality rests with many different agencies. State pollution control agencies have key monitoring responsibilities and conduct vigorous monitoring programs. They receive pollution control and environmental management grants from the U.S. Environmental Protection Agency (EPA) that help them establish and maintain monitoring programs and report the results of monitoring activities to the EPA. Interstate commissions, like states and tribes, may also receive grants and maintain monitoring programs. Many local governments, such as city and county environmental offices, also conduct water quality monitoring within their boundaries.

The scope of monitoring quality of water intended for human consumption in accordance with regulation covers the following range of indicators:

Physical parameters
- color
- turbidity
- pH
- conductivity
- odour
- taste
- flow rate

Chemical parameters
- ammonium ion
- nitrite
- nitrate
- chlorine
- Total chlorates and chlorites
- Fe and Mn for water from underground intakes
- Dissolved oxygen
- Chemical oxygen demand (COD)
- BOD
- Total organic carbon (TOC)
**Microbiological parameters**

- Escherichia coli
- Enterococcus
- coliform bacteria
- Clostridium perfringens for water from surface water intakes

**Water Quality Standards**

1. **Wastewater Discharge Standards**

   The limits need to be fixed on water use and wastewater generation per unit production for each industry. In order to achieve this goal, guidelines are to be evolved and the industry should be forced to adopt recycling and reuse through legislation and vigilance monitoring. New measures such as imposing charges on residual pollution once the prescribed limits are complied will have to be introduced to encourage recycle and reuse of effluents and adoption of the zero-discharge concept.

2. **Receiving Medium Standards**

   Receiving medium standard is based on the quality parameters of waterbeds. For instance; if dissolved oxygen concentration of a receiving medium should not be decreased below 4 mg/L, industries which will discharge their wastewaters to this receiving medium should take precautions to actualize this condition.

Table. Some of the receiving medium quality parameters for rivers, lakes, estuaries and seas.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Allowed values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>It should not be increase above 30°C after discharges (20°C for waters where salmons are living).</td>
</tr>
<tr>
<td>Dissolved oxygen</td>
<td>It should not be decrease below 4 mg/L in the daytime, and should not be below 2 mg/L at night absolutely. If a stratification is formed, sub-layer should not be below 2 mg/L.</td>
</tr>
<tr>
<td>pH</td>
<td>It can be in the range of 6-9</td>
</tr>
<tr>
<td>Ammonia nitrogen (NH₃-N)</td>
<td>It should not be higher than 0,5 mg/L</td>
</tr>
<tr>
<td>Fecal coliform</td>
<td>10 pieces in 100 mL of water (just for 20% of sample piece)</td>
</tr>
</tbody>
</table>

**Water Quality Measurements**

Because the main goal of a comprehensive measurement work is the collection of the basic knowledge, it would be enough to measure the essential quality parameters. To understand the environmental conditions, both pollutant concentrations and pollutant amounts (mass) discharged to water sources should be known. To calculate these, flow rates at measurement stations should be known. Therefore, sampling stations should be selected close to the flow rate measurement stations or at the same place. Sampling
stations should be selected at different points of water source, and sampling should be made at different time periods of each sampling point. The points and sampling time of the sampling stations are important since pollutant source and action of the each pollutant is different in receiving waters. If sampling station number is more, error margin of measurement would be low. However, using more station, is increased the cost of the work. Figure 13 presents sample collection stations for a lake.

Figure 13. Sampling stations in a natural lake.

Sampling stations are selected at;
- point pollutant sources
- places where water quality varies
- points where significant flow rate changes
- region borders of important organizations
- sensitive usage places (with respect to people health)

**PROBLEMS**

6. Chlorinated waters are being discharged to a river flowing with a flow rate of 14 m³/s, including 10 mg/L of chloride.
   a. If chloride concentration in the river should be up to the concentration of 250 mg/L, calculate chloride amount will be discharged per day by neglecting the discharge flow rate.
   b. If the discharge flow rate is 1 m³/s, calculate chloride amount will be discharged per day.
   c. If the discharge flow rate is 1 m³/s, calculate chloride concentration in the discharge water.
To control of water quality of the river, samples have been taken from the measurement stations given above. As consequence of measurements, it was observed that the dissolved oxygen standard had decreased below quality standard value of 4 mg/L. Industry flow rate is 43000 m$^3$/day and BOD value is 350 mg/L. BOD, flow rate and velocity of the river is 2 mg/L, 10 m$^3$/s and 12 m/day, respectively before the discharge. Water intake is being conducted after 45 km later from the industrial discharge for the city water supply. ($k_1$: 0.43 day$^{-1}$, $k_2$: 0.5 day$^{-1}$, dissolved oxygen saturation of the river is 9,2 mg/L ).

<table>
<thead>
<tr>
<th>Stations</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (km)</td>
<td>0.1</td>
<td>-</td>
<td>0</td>
<td>15</td>
<td>30</td>
<td>-</td>
<td>30</td>
<td>1</td>
</tr>
<tr>
<td>Flow rate (m$^3$/s)</td>
<td>10</td>
<td>0.5</td>
<td>10.5</td>
<td>10.5</td>
<td>10.5</td>
<td>1.5</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Time (day)</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>0.87</td>
<td>1.74</td>
<td>-</td>
<td>1.74</td>
<td>2.2</td>
</tr>
<tr>
<td>Dissolved oxygen (mg/L)</td>
<td>7.3</td>
<td>0</td>
<td>6.9</td>
<td>3.2</td>
<td>2.2</td>
<td>7.2</td>
<td>2.8</td>
<td>3</td>
</tr>
<tr>
<td>BOD (mg/L)</td>
<td>2</td>
<td>350</td>
<td>18.5</td>
<td>-</td>
<td>8.7</td>
<td>5</td>
<td>8.23</td>
<td>7</td>
</tr>
</tbody>
</table>

a) If dissolved oxygen concentration at E point should not be decreased under 4 mg/L, how much % BOD should be removed from the industry wastewater?

b) If aerator performance is 1.3 kg O$_2$/kw-hour, how much power is necessary to aerate the point E?

5. Solid Wastes

Solid Waste Sources

- Municipal Solid Waste
- Industrial Waste
- Hazardous Waste
- Hospital Waste
- Construction and Demolition Waste
- Waste from electrical and electronic equipment
- End-of-Life Vehicles and Tyres
- Agricultural Waste
**Municipal Solid Waste**

Such waste comprises household waste, construction and demolition debris, sanitation residue and waste from the street. The consumer market has grown rapidly leading to products being packed in cans, aluminium foils, plastics, and other such non-biodegradable components which cause immeasurable harm to the environment. Types of the municipal solid wastes are:

1. Biodegradable waste: food and kitchen waste, green waste, paper (can also be recycled).
2. Recyclable material: paper, glass, bottles, cans, metals, certain plastics, etc.
3. Inert waste: construction and demolition waste, dirt, rocks, debris.
4. Composite wastes: waste clothing, Tetra Paks, waste plastics such as toys.
5. Domestic hazardous waste (also called “household hazardous waste”) & toxic waste: medication, e-waste, paints, chemicals, light bulbs, fluorescent tubes, spray cans, fertilizer and pesticide containers, batteries, shoe polish.

Composition of municipal wastes is shown in the figure given below:

![Composition of municipal wastes](image)

**Industrial Solid Waste**

Some of the largest waste generated by industrial sectors includes the production of basic metals, food, beverage, tobacco products, wood products and paper products. Waste from manufacturing sector continues to rise, despite national and international declarations to reduce waste from manufacturing industries.

**Hospital Solid Waste**

Hospital waste is generated during the diagnosis, treatment or immunization of human beings or animals and also in the research activities in these fields as well as in the production and testing of biologicals.

**Agricultural Solid Waste**

It is composed of organic wastes and wastes such as plastic, scrapped machinery, fencing, pesticides, waste oils and veterinary medicines.
**Hazardous Waste**

Hazardous waste could be highly toxic to humans, animals, and plants; are corrosive, highly inflammable, or explosive; and react when exposed to certain things such as gases. Industrial and hospital waste is considered hazardous. In addition, certain types of household waste are also considered as hazardous. The main disposal route for hazardous waste is landfill, incineration, and physical or chemical treatment.

**Construction and Demolition Waste**

Such waste arises from activities such as the construction of buildings and civil infrastructures, total or partial demolition of buildings and civil infrastructure, road planning and maintenance. It is made up of numerous materials including concrete, bricks, wood, glass, asbestos and plastic, many of which can be recycled in one way or another.

**Electrical and Electronic Equipment Waste**

It consists of end of life products and comprises of a range of electrical and electronic items such as: refrigerators, telecommunication equipment, freezers, washing machines, medical equipment, hairdryers and televisions.

**Solid Waste Treatment**

- Waste Prevention and Minimisation
- Re-use
- Recycle
- Composting
- Incineration
- Land filling

**Land filling**

All definitions of “sanitary landfill” call for the isolation of the landfilled wastes from the environment until the wastes are rendered innocuous through the biological, chemical, and physical processes of nature. Major differences between the various definitions are in the degree of isolation and means of accomplishing it, as well as in the requirements for monitoring and closing the fill and in maintaining the fill after its active life. In industrialised nations, the degree of isolation required usually is much more complete than would be practical in developing nations. In order to be designated a sanitary landfill, a disposal site must meet the following three general but basic conditions:

1) compaction of the wastes
2) daily covering of the wastes (with soil or other material) to remove them from the influence of the outside environment
3) control and prevention of negative impacts on the public health and on the environment (e.g., odours, contaminated water supplies, etc.).

The basic design and operating aspects of a sanitary landfill in terms of routes of impact outside the fill and of meeting the three basic conditions are illustrated in Figure given below.

**Physical process in landfill area**

In general, significant physical reactions in the fill are in one of three very broad forms: compression (compaction), dissolution, and sorption. Compaction is an ongoing phenomenon that begins with compression and size reduction of particles by the compacting machinery and continues after the wastes are in place. The continuing compression is due to the weight of the wastes and that of the soil cover (burden). Sifting of soil and other fines is responsible for some consolidation. Settling of the completed fill is an end result of compression. This settling is in addition to the settlement brought about by other reactions (e.g., loss of mass due to chemical and biological decomposition). The amount of water that enters a fill has an important bearing on physical reactions. Water acts as a medium for the dissolution of soluble substances and for the transport of unreacted materials. The unreacted materials consist of animate and inanimate particulates. Particle sizes range from colloidal to several millimetres in cross-section. In a typical fill, the broad variety of components and particle sizes of the wastes provides conditions that lead to an extensive amount of adsorption. Absorption is another of the physical phenomena that takes place in a fill. It is significant in large part because it immobilises dissolved pollutants by immobilising the water that could transport them and suspended pollutant particulates out of the confines of the fill. Absorption is the process whereby substances are taken in by capillarity. Most of the absorption potential of landfilled municipal waste is attributable to its cellulosic content.
**Chemical process in land filling area**

Oxidation is one of the two major forms of chemical reaction in a fill. Obviously, the extent of the oxidation reactions is rather limited, inasmuch as the reactions depend upon the presence of oxygen trapped in the fill when the fill was made. Ferrous metals are the components likely to be most affected. The second major form of chemical reaction includes the reactions that are due to the presence of organic acids and carbon dioxide (CO$_2$) synthesized in the biological processes and dissolved in water (H$_2$O). Reactions involving organic acids and dissolved CO$_2$ are typical acid-metal reactions. Products of these reactions are largely the metallic ions and salts in the liquid contents of the fill. The acids lead to the solubilization and, hence, mobilization of materials that otherwise would not be sources of pollution. The dissolution of CO$_2$ in water deteriorates the quality of the water, especially in the presence of calcium and magnesium.

**Biological process in land filling area**

The importance of biological reactions in a fill is due to the following two results of the reactions:

- The organic fraction is rendered biologically stable and, as such, no longer constitutes a potential source of nuisances.
- The conversion of a sizeable portion of the carbonaceous and proteinaceous materials into gas substantially reduces the mass and volume of the organic fraction.

At this point, it should be remembered that a fraction of the nutrient elements in the waste is transformed into microbial protoplasm.

**Aerobic decomposition:**

The greater part of decomposition that occurs directly after the wastes are buried is aerobic. It continues to be aerobic until all of the oxygen (O$_2$) in the interstitial air has been removed. The duration of the aerobic phase is quite brief and depends upon the degree of compaction of the wastes, as well as the moisture content since the moisture displaces air from the interstices. Microbes active during this phase include obligate as well as some facultative aerobes. Because the ultimate end products of biological aerobic decomposition are “ash”, CO$_2$, and H$_2$O, adverse environmental impact during the aerobic phase is minimal. Although intermediate breakdown products may be released, their amounts and contribution to pollution usually are small.

**Anaerobic decomposition:**

Because the oxygen supply in a landfill soon is depleted, most of the biodegradable organic matter eventually is subjected to anaerobic breakdown. This anaerobic decomposition is biologically much the same as that in the anaerobic digestion of sewage sludge. Microbial organisms responsible for anaerobic decomposition include both
facultative and obligate anaerobes. Unfortunately, the breakdown products of anaerobic decomposition can exert a highly unfavourable impact on the environment unless they are carefully managed. The products can be classified into two main groups: volatile organic acids and gases. Most of the acids serve as substrates for methane-producing microbes. The two principal gases formed are methane (CH₄) and CO₂. Gases in trace amounts are hydrogen sulphide (H₂S), hydrogen (H₂), and nitrogen (N₂).

Re-use of wastes

Reuse is using an item more than once. This includes conventional reuse where the item is used again for the same function, and new-life reuse where it is used for a new function. The classic example of conventional reuse is the doorstep delivery of milk in reusable bottles; other examples include the retreading of tires and the use of plastic delivery trays (transit packing) in place of cardboard cartons. Re-use has certain potential advantages which can be summarized:

- Energy and raw materials savings as replacing many single use products with one reusable one reduces the number that need to be manufactured.
- Reduced disposal needs and costs.
- Refurbishment can bring sophisticated, sustainable, well paid jobs to underdeveloped economies.
- Cost savings for business and consumers as a reusable product is often cheaper than the many single use products it replaces.
- Some older items were better handcrafted and appreciate in value

Incineration

Incineration is a disposal method that involves combustion of waste material. Incineration and other high temperature waste treatment systems are sometimes described as "thermal treatment". Incinerators convert waste materials into heat, gas, steam, and ash. Incineration is carried out both on a small scale by individuals, and on a large scale by industry. It is used to dispose of solid, liquid and gaseous waste. It is recognized as a practical method of disposing of certain hazardous waste materials (such as biological medical waste). Incineration is a controversial method of waste disposal, due to issues such as emission of gaseous pollutants.
Composting

Composting is the aerobic decomposition of biodegradable organic matter, producing compost. (Or in a simpler form: Composting is the decaying of food, mostly vegetables or manure.) The decomposition is performed primarily by facultative and obligate aerobic bacteria, yeasts and fungi, helped in the cooler initial and ending phases by a number of larger organisms, such as springtails, ants, nematodes and worms. Benefits of composting are:

- Keeps organic wastes out of landfills.
- Provides nutrients to the soil.
- Increases beneficial soil organisms (e.g., worms).
- Suppresses certain plant diseases.
- Reduces the need for fertilizers and pesticides.
- Protects soils from erosion.
- Assists pollution remediation
Recycling

Recycling involves processing used materials into new products in order to prevent the waste of potentially useful materials, reduce the consumption of fresh raw materials, reduce energy usage, reduce air (from incineration) and water (from landfilling) pollution by reducing the need for "conventional" waste disposal, and lower greenhouse gas emissions as compared to virgin production. Recycling is a key component of modern waste management and is the third component of the "Reduce, Reuse, Recycle" waste hierarchy.

PROBLEMS

8. Future population of a town is 110000, and annual solid waste per person is 350 mg/ population-year. Density of the waste is 0.25 ton/m$^3$. Total volume of the garbage trucks is 10 m$^3$. Wastes are compressing with a ratio of 1/2 in the tracks. If garbage trucks can ply to 3 times per day to the dumping area, how many garbage tracks are necessary to collect the wastes?

6. Air Pollution

Atmosphere

The atmosphere consists of several layers with different temperatures, pressures, and composition. The atmosphere is a thin layer of gases divided into several spherical sublayers. Density and atmospheric pressure vary throughout the atmosphere due to gravitational forces that pull the gas molecules toward the earth’s surface. Air at sea level has a higher density than air at the top of a mountain. Atmospheric pressure is a measure of the mass per unit of air. It decreases with height. About 75–80% of the earth’s air mass is found in the troposphere, the atmospheric layer closest to the earth’s surface. About 99% of the volume of air is made up of nitrogen (78%) and oxygen (21%) with the rest consisting of water vapor, argon, carbon dioxide, and traces of several other gases. This layer is also responsible for short-term weather and long-term climate.
**Stratosphere**

The stratosphere is the second layer of the atmosphere. The concentration of ozone in this layer is much higher than in the troposphere.

Ozone is produced when oxygen molecules interact with ultraviolet radiation:

\[ 3O_2 + UV \rightarrow 2 O_3 \]

This “global sunscreen” keeps about 95% of the sun’s harmful UV radiation from reaching the earth’s surface. This ozone layer protects us from sunburn, cataracts, cancer of skin and eye, and damage to our immune system.

**6.1. Outdoor Air Pollution**

Come mostly from natural sources and burning fossil fuels. Chemicals in the atmosphere in concentrations high enough to affect climate, materials, and health are what constitute air pollution. Natural sources of air pollution such as dust particles, organic chemicals released by plant decay, forest fires, etc. rarely reach harmful levels. Increased use of fossil fuels has greatly increased the amount of air.

*Outdoor air pollutants*

Two categories:

- primary pollutants that enter directly into the troposphere (soot, carbon monoxide)
- secondary pollutants that may form when primary pollutants interact with one another or with the air to form new pollutants.

Cities generally have higher pollution levels. Winds can carry these pollutants away from their source. Sources and types of air pollutants are shown the figure below.

![Diagram of air pollutants](image)

**6.1.2. Photochemical Smog Industrial Smog**
Photochemical smog is formed by the reaction of nitrogen oxides and volatile hydrocarbons under the influence of sunlight. A photochemical reaction is any chemical reaction activated by light. Photochemical smog contains more than 100 primary and secondary pollutants. Some NO\(_2\) reacts with hydrocarbons to produce a mixture of ozone, nitric acid, aldehydes, peroxyacyl nitrates (PANs), and other pollutants. These substances are photochemical oxidants and can irritate the respiratory tract and damage crops and trees. Photochemical smog is more common in cities in warm, dry, sunny areas.

![Diagram](https://via.placeholder.com/150)

**Figure.** Nitrogen dioxide forming and distribution in atmosphere

### 6.1.3. Industrial Smog

Industrial smog is a mixture of sulfur dioxide, droplets of sulfuric acid, and a variety of suspended solid particles emitted by burning coal and oil. When coal is burned, it is converted to carbon dioxide, carbon monoxide, and unburned carbon particles (soot). Coal and oil also contain sulfur that is then converted to sulfur dioxide by oxidation in air.

\[
\text{Sulfur dioxide + water} \quad \rightarrow \quad \text{Sulfuric acid + ammonia in air} \quad \rightarrow \quad \text{Ammonium Sulfate}
\]

These various components give the air a gray color.
Outdoor air pollution can be reduced and increased. Three natural factors help reduce outdoor air pollution:

- rain and snow
- salty sea spray
- winds

Each of these factors helps remove pollutants, but they are then deposited elsewhere.

Four factors can increase outdoor air pollution:

- urban buildings
- hills and mountains
- high temperatures
- the grasshopper effect: where volatile compounds are carried from tropical or temperate areas to the poles.

**Inversion Layer**

Turbulence, caused by the mixing of warm and cold air, disperses air pollutants. A temperature inversion, where a layer of warm air sits over a layer of cold air, prevents the mixing, and dense, colder air becomes stagnant and accumulates more pollutants. Two areas are particularly susceptible to inversions:

- a city located in a valley surrounded by mountains that experiences cloudy, cold weather part of the year
- a sunny climate with light winds and mountains on three sides and several million people and vehicles.
The heat adsorbed to the land at daytime releases to the atmosphere by radiation at night. Therefore, the land becomes cooler than the air.

**Acid Rains**

Indoor air pollutants come from infiltration of outside air or produced inside buildings. Formaldehyde is a difficult chemical in common household materials. Radon-222 gas is found in some soils and rocks, and can seep into some homes and increase the risk of lung cancer. Radioactive decay of Radon is smaller than radioactive decay of uranium-238. Radon is thought to be the second leading cause of lung cancer deaths each year in the U.S. Remedies include sealing cracks in foundation and walls, increasing ventilation, and using a fan for cross ventilation.
6.3. Air Pollution Control

Table 7.3.1  Control Devices for Capturing Particulate Air Pollutants

<table>
<thead>
<tr>
<th>Device</th>
<th>Particle size</th>
<th>Collection mechanism and application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Settling chamber</td>
<td>$&gt;20 \mu m$</td>
<td>Separates particles from a gas stream by gravity; used to treat very dirty air streams that contain very coarse particles</td>
</tr>
<tr>
<td>Cyclone</td>
<td>$&gt;1 \mu m$</td>
<td>Separates particles by inertia in a vortex flow; common pretreatment process ahead of electrostatic precipitator or fabric filter</td>
</tr>
<tr>
<td>Scrubber</td>
<td>$&gt;1 \mu m$</td>
<td>Wet collector; induces collisions between particles and water droplets to remove particles from gas stream by inertia; may be used for combined collection of particles and water-soluble gases</td>
</tr>
<tr>
<td>Electrostatic precipitator</td>
<td>All</td>
<td>Creates electrostatic charge on particles so they can be removed by an electric field; high-efficiency device that is used to treat stack gases in industrial processes</td>
</tr>
<tr>
<td>Filter</td>
<td>All</td>
<td>Air flow is forced through matrix of fibers, capturing particles by a combination of Brownian motion, physical straining, interception, and impaction; high efficiency possible; applied for treating waste gases and for removing particles from air before use</td>
</tr>
</tbody>
</table>

6.3.1. Cyclones

Typically, a particulate-laden gas enters tangentially near the top of the cyclone, as shown schematically in the figure below. The gas flow is forced into a downward spiral simply because of the cyclone’s shape and the tangential entry. Centrifugal force and inertia cause the particles to move outward, collide with the outer wall, and then slide downward to the bottom of the device. Near the bottom of the cyclone, the gas reverses its downward spiral and moves upward in a smaller inner spiral. The cleaned gas exits from the top through a “vortex-finder” tube, and the particles exit from the bottom of the cyclone through a pipe sealed by a spring-loaded flapper valve or rotary valve.
6.3.2. Electrostatic Precipitators

Electrodes at high voltage create a corona effect (ionized atmosphere) surrounding them. This charges the passing particles. Once charged, particles are subject to a transverse electrostatic force that pulls them toward the collecting plates. Plates are periodically rapped (vibrated) to make the collected particles fall down into a receiver basket.
6.3.3. Scrubbers

Scrubbers, also called *absorbing towers*, are pieces of equipment installed in power plants to remove selected gases (and sometimes also particulates) from combustion fumes in order to meet emission standards. The usual gas being removed is SO$_2$. The key aspect of the process is the dissolution of the gas from the fumes into a liquid made of water with suitable additives. This is called *stripping*. The outflowing liquid is collected, concentrated, and recycled.

Essentially, the scrubber is a vertical tank (*tower*) in which gas and liquid flow against each other: the liquid solution flows downward while the gas bubbles to the top. To maximize contact between liquid and gas, the tower is also packed with a large number of small objects forcing the liquid to percolate slowly through tortuous paths and the gas to rise in small bubbles. As the liquid and gas compete for space, very intimate contact takes place between the two, and a very large contact area exists through which the transfer of properties can take place. The counter flow with vapor moving upward and liquid downward is very practical for two reasons: (1) It happens naturally by gravity as the liquid trickles down while the gas bubbles up through it, and (2) the fumes encounter increasingly less loaded liquid as they get progressively cleaner on their way upward.
7. Radioactive Pollution

The atom consists of two parts:
1. The nucleus which contains: protons, neutrons
2. Orbiting electrons

Atom of different elements contains different numbers of protons. The mass of an atom is due to the number of protons and neutrons.

Isotopes of any particular element contain the same number of protons, but different numbers of neutrons.
Most of the isotopes which occur naturally are stable. A few naturally occurring isotopes and all of the man-made isotopes are unstable. Unstable isotopes can become stable by releasing different types of particles. This process is called radioactive decay and the elements which undergo this process are called radioisotopes.

**Radioactive Decay**

Radioactive decay results in the emission of either:
- An alpha particle (\(\alpha\))
- A beta particle (\(\beta\))
- A positive beta particle (positron) (\(\beta^+\))
- Or gamma ray (\(\gamma\))

In a nuclear reaction the mass and atomic number must be the same on both sides of the equations.

**Alpha Decay**

An alpha particle is identical to that of a helium nucleus. It contains two protons and two neutrons.
**Beta Emission**

A beta particle is a fast moving electron which is emitted from the nucleus of an atom undergoing radioactive decay.

Beta emission occurs when a **neutron changes into a proton and an electron**.

\[
\begin{array}{c}
\text{A} \\
\text{X} \\
\text{Z} \\
\rightarrow \\
\text{A} \\
\text{Y} \\
\text{Z} + 1 \\
\downarrow \\
\text{proton stays} \\
in \text{nucleus} \\
\end{array} + \begin{array}{c}
\text{0} \\
\text{e} \\
-1 \\
\end{array}
\]

Neutron splits emitting negative particle leaving a proton.
- Atomic # increases by 1
- Mass # stays the same
  (electrons have no mass)

Beta emission of Carbon-14;

\[
\begin{array}{c}
\text{14} \\
\text{C} \\
\rightarrow \\
\text{7} \\
\text{N} \\
\end{array} + \begin{array}{c}
\text{0} \\
\text{e} \\
-1 \\
\end{array}
\]
**Positron Emission**

A positron is like an electron but it has a positive charge.

During positron emission a **proton changes into a neutron** and the excess positive charge is emitted.

\[
\begin{align*}
\text{proton} & \rightarrow \text{neutron} \\
A_X^Z & \rightarrow A_Y^{Z-1} + ^0_+\text{e} \\
\text{mass stays in nucleus} & \\
\text{Proton splits emitting positive particle} & \\
\text{leaving a neutron.} & \\
\cdot \text{ Atomic # decreases by 1} & \\
\cdot \text{Mass # stays the same} & \\
\text{ (positrons, like electrons, have no mass)}
\end{align*}
\]

Positron emission of Oxygen-16;

\[
\begin{align*}
^16_8\text{O} & \rightarrow ^{16}_7\text{N} + ^0_+\text{e} \\
\end{align*}
\]

**Gamma Decay**

When atoms decay by emitting \(\alpha\) or \(\beta\) particles to form a new atom, the nuclei of the new atom formed may still have too much energy to be completely stable. These atoms will emit gamma rays to release that energy. Gamma rays are high energy radiation. Gamma rays are not charged particles like \(\alpha\) and \(\beta\) particles. There is no change in mass or atomic number.

\[
\begin{align*}
^A_ZX & \rightarrow ^A_ZX + ^0_0\gamma
\end{align*}
\]
Radiation Exposure

Nuclear radiation can transfer the energy from nuclear decay to the electrons of atoms or molecules and cause ionization. The roentgen (R) is a unit used to measure nuclear radiation exposure; it is equal to the amount of gamma and X ray radiation that produces $2 \times 10^9$ ion pairs when it passes through 1 cm$^3$ of dry air. A rem is a unit used to measure the dose of any type of ionizing radiation that factors in the effect that the radiation has on human tissue. Radiation units are presented in the table given below:
Radiation Effects on Body

**Radiation Penetration in Tissues**

- **Alpha Particle**: Easily Stopped, Least Penetrating
- **Beta Particle**: Very Much Smaller, More Penetrating
- **Gamma Ray and X-Rays**: Pure Energy, with No Mass, Most Penetrating

<table>
<thead>
<tr>
<th>Dose (rem)</th>
<th>Probable effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–25</td>
<td>no observable effect</td>
</tr>
<tr>
<td>25–50</td>
<td>slight decrease in white blood cell count</td>
</tr>
<tr>
<td>50–100</td>
<td>marked decrease in white blood cell count</td>
</tr>
<tr>
<td>100–200</td>
<td>nausea, loss of hair</td>
</tr>
<tr>
<td>200–500</td>
<td>ulcers, internal bleeding</td>
</tr>
<tr>
<td>&gt; 500</td>
<td>death</td>
</tr>
</tbody>
</table>
Application of Nuclear Radiation

Radioactive dating is the process by which the approximate age of an object is determined based on the amount of certain radioactive nuclides present. Age is estimated by measuring either the accumulation of a daughter nuclide or the disappearance of the parent nuclide. Carbon-14 is used to estimate the age of organic material up to about 50,000 years old. In medicine, radioactive nuclides are used to destroy certain types of cancer cells (Cobalt-60). Radioactive tracers are radioactive atoms that are incorporated into substances so that movement of the substances can be followed by radiation detectors. Radioactive tracers can be used to diagnose diseases. Radioactive tracers in fertilizers are used to determine the effectiveness of the fertilizer. Nuclear radiation is also used to prolong the shelf life of food.

Radioactive Wastes

Radioactive decays produce the remaining isotopes known as radioactive wastes. Radioactive wastes can be classified into three categories. The classification of the radioactive waste is made according to quantity, half time, radioactivity, concentration, type of waste and type of radiation emitted.

<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>RADIOACTIVE WASTE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LOW-LEVEL WASTE</td>
</tr>
<tr>
<td></td>
<td>INTERMEDIATE-LEVEL WASTE</td>
</tr>
<tr>
<td></td>
<td>HIGH-LEVEL WASTE</td>
</tr>
<tr>
<td>SOURCE</td>
<td>Hospitals, laboratories, industries, and nuclear power stations.</td>
</tr>
<tr>
<td></td>
<td>Laboratories, industries, and nuclear power stations.</td>
</tr>
<tr>
<td></td>
<td>Nuclear power stations.</td>
</tr>
<tr>
<td>WASTE VOLUME</td>
<td>90% (1% of the radioactivity)</td>
</tr>
<tr>
<td></td>
<td>7% (6% of the radioactivity)</td>
</tr>
<tr>
<td></td>
<td>3% (9% of the radioactivity)</td>
</tr>
<tr>
<td>EXAMPLES</td>
<td>Paper, rags, glass, shoes, clothing, tools, filters, etc.</td>
</tr>
<tr>
<td></td>
<td>Reactor components, chemical sludge, and contaminated materials from reactor.</td>
</tr>
<tr>
<td></td>
<td>Fuel rods, liquid waste, high-radioactive fissile products, and some heavy elements.</td>
</tr>
<tr>
<td>HALF-LIFE</td>
<td>Short</td>
</tr>
<tr>
<td></td>
<td>Long</td>
</tr>
<tr>
<td>RADIOACTIVITY LEVEL</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>High</td>
</tr>
<tr>
<td>MANAGEMENTS</td>
<td>Solid wastes stored in special drums and then buried in shallow landfill areas. Compost can reduce its volume and incinerated in a closed container before disposal.</td>
</tr>
<tr>
<td></td>
<td>Solidified in concrete or bitumens for disposal. Short-lived waste [mainly from reactors] is buried at isolated sites that are geologically stable. Long-lived waste [from processing nuclear fuel] is buried deep underground.</td>
</tr>
<tr>
<td></td>
<td>Solidified by incorporating it into borosilicate glass which is sealed in a stainless steel canister is buried deep underground (600).</td>
</tr>
</tbody>
</table>

Nuclear Wastes

Fission is the primary process powering nuclear reactors. The products of the fission include the nuclei as well as the nucleons formed from the fragments’ radioactive decay. Both fission and fusion produce nuclear waste. Fission produces more waste than fusion.


Containment of Nuclear Waste: Nuclear waste needs to be contained so that living organisms can be shielded from radioactivity. There are two main types of containment: on-site storage and off-site disposal.

Storage of Nuclear Waste: The most common form of nuclear waste is spent fuel rods from nuclear power plants. Fuel rods can be contained temporarily above the ground in water pools or in dry casks.

Disposal of Nuclear Waste: Disposal of nuclear waste is done with the intention of never retrieving the materials. For example, there are 77 disposal sites around the United States. A new site called Yucca Mountain is being developed for the permanent disposal of much of the nuclear waste.

Radiation Health Effects

When the human body bathes in the radiation voluminously, the function to make the cell newly is destroyed. It becomes impossible for the skin to produce new cells in a word. It comes for the skin to peel off fast when the cell that composes the skin has died and not to fall. When the genetic code is damaged, it is thought to make it to cancer afterwards enough.

Effect of Nonionizing Radiation

It is an electromagnetic radiation without the sufficient energy though the atom and the molecule are ionized. The electric charge ion is not generated even if the object is passed, and it has the energy only of the movement of the electron to a higher semiplace.
However, it is confirmed that various biological consequences are in each nonionizing radiation.

**Effect of Ionizing Radiation**

This is dangerous. The alpha or the beta particle discharged from X rays, gamma rays, and the radionuclide such as those collapses is contained as this example of the kind of the radiation.

**Effect of Nuclear Bomb/Plant**

A nuclear bomb generates two types of the radiation that has the lethal property.
1. It kills directly and deterioration leaves other injuries to suffer from the explosion.
2. Irradiating it near the site generates X rays and gamma rays with fatal of the radiation or fatal dose near it.

The nuclear plant is not a luminescence gamma and X-ray irradiation. Most of the radioactivity is a form of a radioactive cesium and a radioactive iodine that is the by-product of the nuclear fission of the uranium in the fuel rod.

**Effect of Cesium and Iodine**

Cesium-137 and Iodine-131 are dangerous. Iodine-131 is absorbed to the possibility thyroid that it causes the tumor by priority. Because it possesses the half-life of the eighth, and damages the cell that is rapidly divided of it, it is the most dangerous for children. The problem can be improved by taking the tablet of a usual iodine to unite with a substantial thyroid, and to prevent a radioactive iodine from uniting.

8. **Soil Pollution**

Soil pollution is defined as the build-up in soils of persistent toxic compounds, chemicals, salts, radioactive materials, or disease causing agents, which have adverse effects on plant growth and animal health. Soil is the thin layer of organic and inorganic materials that covers the Earth's rocky surface. The organic portion, which is derived from the decayed remains of plants and animals, is concentrated in the dark uppermost topsoil. The inorganic portion made up of rock fragments, was formed over thousands of years by physical and chemical weathering of bedrock. Productive soils are necessary for agriculture to supply the world with sufficient food. There are many different ways that soil can become polluted, such as:

- Seepage from a landfill
- Discharge of industrial waste into the soil
- Percolation of contaminated water into the soil
- Rupture of underground storage tanks
- Excess application of pesticides, herbicides or fertilizer
• Solid waste seepage

The most common chemicals involved in causing soil pollution are:
• Petroleum hydrocarbons
• Heavy metals
• Pesticides
• Solvents

Types of Soil Pollution

• Agricultural Soil Pollution
• Soil pollution by industrial effluents and solid wastes
• Pollution due to urban activities

Causes of Soil Pollution

_Indiscriminate use of fertilizers_

Soil nutrients are important for plant growth and development. Plants obtain carbon, hydrogen and oxygen from air and water. But other necessary nutrients like nitrogen, phosphorus, potassium, calcium, magnesium, sulfur and more must be obtained from the soil. Farmers generally use fertilizers to correct soil deficiencies. Fertilizers contaminate the soil with impurities, which come from the raw materials used for their manufacture. Mixed fertilizers often contain ammonium nitrate (NH₄NO₃), phosphorus as P₂O₅, and potassium as K₂O. For instance, As, Pb and Cd present in traces in rock phosphate mineral get transferred to super phosphate fertilizer. Since the metals are not degradable, their accumulation in the soil above their toxic levels due to excessive use of phosphate fertilizers, becomes an indestructible poison for crops.

_Indiscriminate use of pesticides, insecticides and herbicides_

Plants on which we depend for food are under attack from insects, fungi, bacteria, viruses and other animals, and must compete with weeds for nutrients. To kill unwanted populations living in or on their crops, farmers use pesticides. The first widespread insecticide use began at the end of World War II and included DDT (dichlorodiphenyltrichloroethane). Insects soon became resistant to DDT and as the chemical did not decompose readily, it persisted in the environment. Since it was soluble in fat rather than water, it biomagnified up the food chain and disrupted calcium metabolism in birds, causing eggshells to be thin and fragile. As a result, large birds of prey such as the brown pelican, ospreys, falcons and eagles became endangered. DDT has been now been banned in most western countries.

_Dumping of large quantities of solid waste_

In general, solid waste includes garbage, domestic refuse and discarded solid materials such as those from commercial, industrial and agricultural operations. They contain increasing amounts of paper, cardboards, plastics, glass, old construction material,
packaging material and toxic or otherwise hazardous substances. Since a significant amount of urban solid waste tends to be paper and food waste, the majority is recyclable or biodegradable in landfills. Similarly, most agricultural waste is recycled and mining waste is left on site. The portion of solid waste that is hazardous such as oils, battery metals, heavy metals from smelting industries and organic solvents are the ones we have to pay particular attention to. These can in the long run, get deposited to the soils of the surrounding area and pollute them by altering their chemical and biological properties. They also contaminate drinking water aquifer sources. More than 90% of hazardous waste is produced by chemical, petroleum and metal-related industries and small businesses such as dry cleaners and gas stations contribute as well.

Deforestation and soil erosion

Soil erosion occurs when the weathered soil particles are dislodged and carried away by wind or water. Deforestation, agricultural development, temperature extremes, precipitation including acid rain, and human activities contribute to this erosion. Humans speed up this process by construction, mining, cutting of timber, over cropping and overgrazing. It results in floods and cause soil erosion. Forests and grasslands are an excellent binding material that keeps the soil intact and healthy. They support many habitats and ecosystems, which provide innumerable feeding pathways or food chains to all species. Their loss would threaten food chains and the survival of many species. During the past few years quite a lot of vast green land has been converted into deserts. The precious rain forest habitats of South America, tropical Asia and Africa are coming under pressure of population growth and development (especially timber, construction and agriculture). Many scientists believe that a wealth of medicinal substances including a cure for cancer and aids, lie in these forests. Deforestation is slowly destroying the most productive flora and fauna areas in the world, which also form vast tracts of a very valuable sink for CO$_2$.

Underground soil in cities is likely to be polluted by
- Chemicals released by industrial wastes and industrial wastes
- Decomposed and partially decomposed materials of sanitary wastes

Many dangerous chemicals like cadmium, chromium, lead, arsenic, selenium products are likely to be deposited in underground soil. Similarly underground soil polluted by sanitary wastes generates many harmful chemicals. These can damage the normal activities and ecological balance in the underground soil.

Environmental Long Term Effects of Soil Pollution

When it comes to the environment itself, the toll of contaminated soil is even more dire. Soil that has been contaminated should no longer be used to grow food, because the chemicals can leech into the food and harm people who eat it. If contaminated soil is used to grow food, the land will usually produce lower yields than it would if it were not contaminated. This, in turn, can cause even more harm because a lack of plants on the soil will cause more erosion, spreading the contaminants onto land that might not have
been tainted before. In addition, the pollutants will change the makeup of the soil and the
types of microorganisms that will live in it. If certain organisms die off in the area, the
larger predator animals will also have to move away or die because they've lost their food
supply. Thus it's possible for soil pollution to change whole ecosystems.

Effects of soil pollution in brief:

- pollution runs off into rivers and kills the fish, plants and other aquatic life
- crops and fodder grown on polluted soil may pass the pollutants on to the
  consumers
- polluted soil may no longer grow crops and fodder
- soil structure is damaged (clay ionic structure impaired)
- corrosion of foundations and pipelines
- impairs soil stability
- may release vapours and hydrocarbon into buildings and cellars
- may create toxic dusts
- may poison children playing in the area

**Soil Pollution Control**

- reducing chemical fertilizer and pesticide use
- reusing of materials
- recycling and recovery of materials
- reforesting
- solid waste treatment