Air pollution

- Plume
- ozone depletion.
- Halo carbon numbering
- GHE
- CO_2 causes Global warming but No

  doesn't, why?

  CO_2- absorption spectrum is wide

- Effect of Global warming on sea, land
- Fish, forestial, agriculture
- BOD.
- ecology

4.15 INDUSTRIAL AIR QUALITY

There are big industrial estates, small and cottage industries that generate hazardous and toxic chemicals. The fertilizer plants, textile industry, glass industry, steel plants contribute SO_2, NO_x, smoke volatile organic compounds, chlorine gas, particulate matter, ammonia, CO, CO_2, phenol, cyanide to the atmosphere.

4.16 CONTROL OF PARTICULATE/FLUE GAS EMISSIONS

The most effective method of controlling air pollution is definitely to prevent the formation of air pollutants or to reduce their emission at the source itself. This can be achieved by using pure grade materials, modifying the process of formation, as well as the technologies. Even if all measures are taken, emissions of pollutants cannot be controlled fully and pollution controlled devices should, therefore be used. Some of the different devices for particulate emissions are:

(i) Baghouse

(ii) Cyclone separator

(iii) Scrubber

(iv) Catalytic converter

(v) Electrostatic precipitator

For controlling gaseous pollutants, the flue gases are flame combusted to have CO_2 and water vapour (almost full oxidation), for example, in a catalytic converter or if the flue gas contains enough SO_2, it is removed by its absorption or adsorption as in the scrubber.

(i) **Baghouse:** Such devices are used for collecting very small particles (~ 1 μm) through fabric filtration. A large chamber with several compartments containing fabric filter bags is called baghouse. The bags are distributed in the compartments so that when one compartment is under operation the other can be cleaned. Dust containing gases are passed through the bags and the dust particles are trapped (particle size ≥ 1 μm), after a certain time the particles adhered to the bags disallow particles of more smaller size (~0.01 μm). The efficiency of removal is as high as 100 per cent.

Air Pollution and Control

Baghouses, however, have many disadvantages:
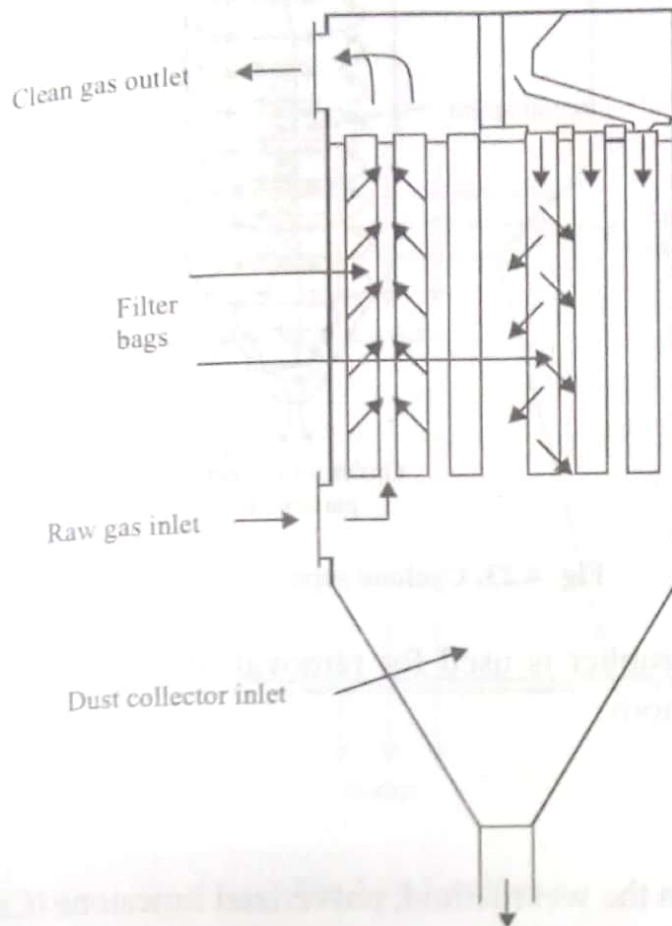(1) expensive (2) attacked by corrosive chemicals (3) cannot operate under moist conditions.

Fig. 4.22. Baghouse filter

Clean gas outlet

Filter bags

Raw gas inlet

Dust collector inlet

(ii) **Cyclone separator:** For relatively large particles (5 – 20 µm), the control device used is cyclone separator. Gaseous emissions containing suspended particles enter tangentially near the top of the cyclone. As the gas spins, the centrifugal force causes dust particles to collide with the outer walls and then gravity causes them to fall down into the collector. The cleaned gas now escapes from the top. Whereas for particles larger than 5µm the efficiency of cyclone separator is about 90 per cent, for smaller particles it is less efficient. However, it is not expensive and is maintenance free.
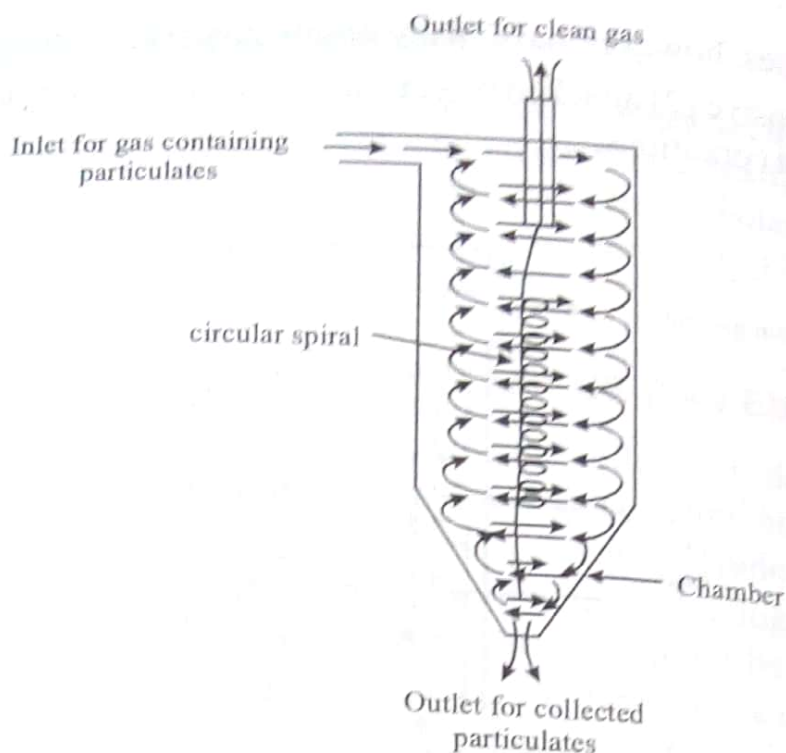
Outlet for clean gas

Inlet for gas containing particulates

circular spiral

Chamber

Outlet for collected particulates

Fig. 4.23. Cyclone separator

(*iii*) **Scrubber:** Scrubber is used for removal of SO_2 from flue gas. There are two methods:

   (*a*) Wet method

   (*b*) Dry method

(*a*) **Wet method:** In the wet method, pulverized limestone ($CaCO_3$) is mixed with water, slurry is made and sprayed into flue gases. Chemical reactions produce calcium sulphite ($CaSO_3 . 2H_2O$) and precipitate it out. The precipitate is removed as a sludge, which is later used in the construction industry.

$$CaCO_3 + SO_2 + 2H_2O \rightarrow CaSO_3 . 2H_2O + CO_2$$
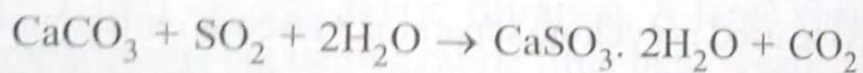
It is a highly efficient (~ 90 per cent) method for removal of SO_2.

(*b*) **Dry method:** In this process, lime (CaO) is used for removal of SO_2.

$$CaO + SO_2 + 2H_2O \rightarrow CaSO_3 . 2H_2O$$
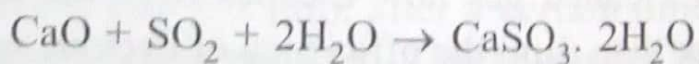
Although, the efficiency of removal in dry method is nearly 95 per cent, it is expensive due to the use of lime.

Flue gas

Spraying
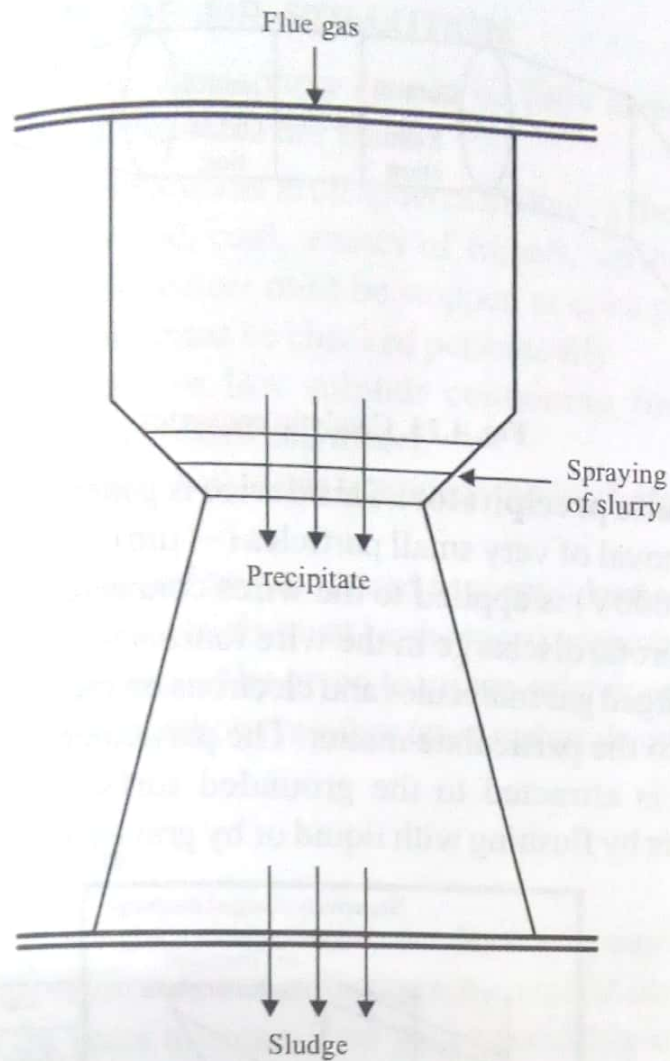of slurry

Precipitate

Sludge

Fig. 4.24. Scrubber

(*iv*) **Catalytic converter:** Catalytic converter is used in the automobile engine for controlling emissions very effectively. Three-way catalytic converter is now available in the market. Three way means, removal of three pollutants such as CO, hydrocarbons and NO_x. In this type of catalytic converter, CO and hydrocarbon are oxidized to CO_2 and NO_x is reduced to N_2 in the same catalytic bed.

The catalytic converters not only control emissions but also allow engines to operate at near stoichiometric conditions. The efficiency of catalytic converter however, gets reduced drastically when leaded petrol is used.
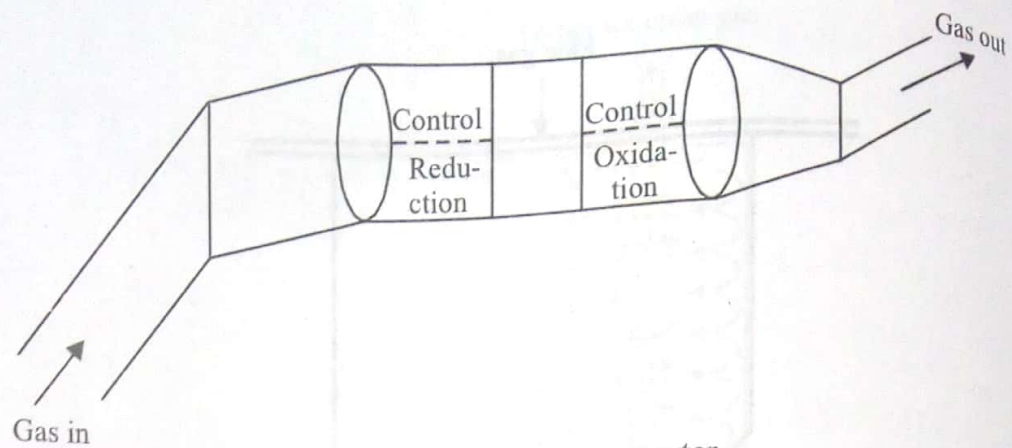
Fig. 4.25. Catalytic converter

(v) Electrostatic precipitator: This device is generally used in power plants for removal of very small particles (~1 μm). In this process, high voltage (100,000V) is applied to the wires connected to the grounded plates. The corona discharge in the wire ionizes the incoming gas, the positively charged gas molecules and electrons on their way to grounded plate adhere to the particulate matter. The particulate matter becomes charged and is attracted to the grounded surface, where they are removed either by flushing with liquid or by gravitational force.
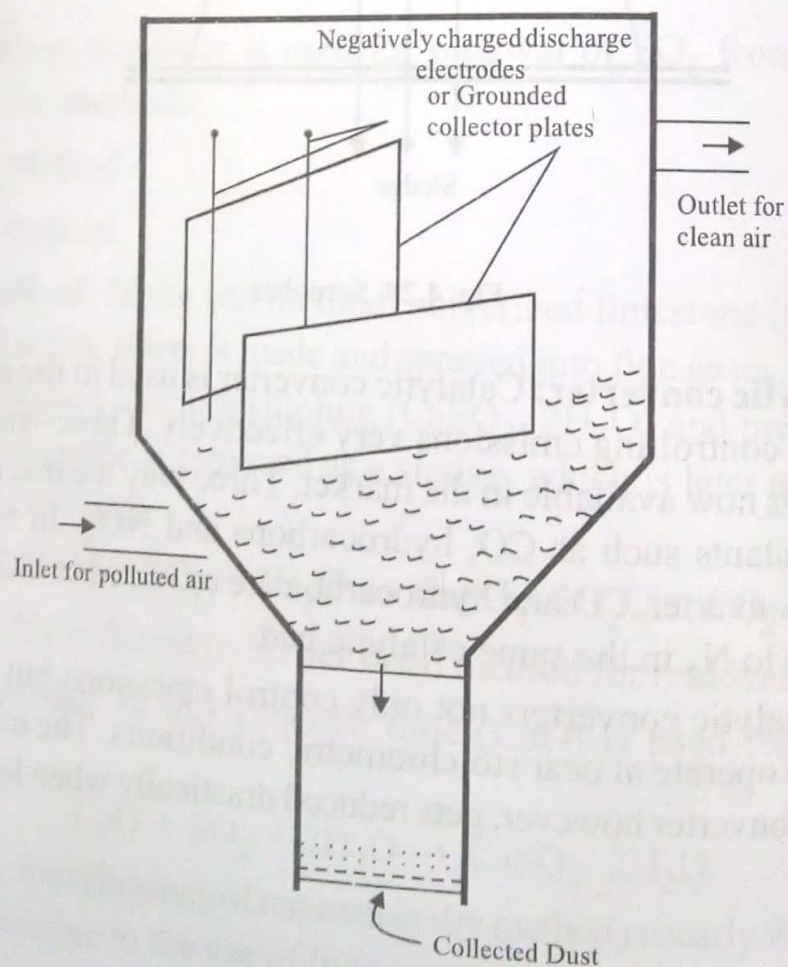

Fig. 4.26. Electrostatic precipitator

4.17 CONTROL OF AIR POLLUTION

Pollution of air in the atmosphere cannot be fully abated but can be controlled if certain measures are taken.

1. Develop people's awareness in all spheres including the governments.
2. Free burning of wood, coal, wastes of forests, agricultural wastes and many other solid matters must be stopped at open places.
3. Vehicular emissions must be checked periodically.
4. Use of natural gas or low sulphur containing fuels should be encouraged in place of petrol and diesel.
5. Industries must adopt waste gas treatment facility before releasing it to air.
6. Lead free petrol should be introduced to control lead pollution.
7. All sorts of waste materials must be disposed properly.
8. Large importance should be given to utilize solar energy.
9. Use of chlorofluorocarbons or other toxic materials must be reduced or substituted.

Industrial Accidents

Many industrial accidents have led to the death of many people as well as created great environmental pollution which might not be possible to overcome in the years to come. Two major accidents are cited here.

Bhopal MIC Gas Tragedy: On the night of December 3, 1984 people of Bhopal, MP, India suffered the tragic incidence of methyl isocyanate gas (MIC, CH_3NCO) leakage from the Union Carbide Company's chemical plant. MIC gas is accompanied by about 2 per cent of phosgene gas ($COCl_2$). The threshold limit values of MIC and $COCl_2$ is 0.02 ppm and 0.1 ppm respectively. $COCl_2$ enhances the toxic effect of MIC. The most dangerous effect of MIC is that once it enters the human blood it undergoes several complicated processes and forms cyanides and becomes fatal to human begins. In the tragic incidence more than 2000 people died, approximately 11000 people lost their eyesight and about 2500 pregnancies got aborted.

The antidote of MIC is not known, although sodium thio sulfate can be used as antidote for neutralisation of MIC in body.

Chernobyl Disaster: The disaster at the Chernobyl nuclear power plant in Ukraine, formerly USSR, was in April 1986 due to flawed Soviet

Biochemical Effects of Heavy Metals

Cadmium (Cd)

Sources of Cadmium:

1. Industrial effluent
2. Cadmium nickel batteries
3. Nuclear fission plants
4. Water pipes

Cadmium occurs in nature in association with zinc minerals. Plants take up zinc (Zn^{2+}) and along with trace amounts of associated Cd (Cd^{2+}) are also acquired. The Cd^{2+} thus absorbed, replace Zn^{2+} as they have same charge and almost similar size and get attached to the active site of enzymes which leads to cadmium toxicity inhibiting its essential enzymes function. Cd^{2+} ion has greater affinity for sulphur containing ligands, e.g., SH in cysteine amino acids and SCH_3 in methionine.

$$\text{Enzyme} \begin{matrix} \text{SH} \\ \text{SH} \end{matrix} + Zn^{2+} \longrightarrow \text{Enzyme} \begin{matrix} \text{S} \\ \text{S} \end{matrix} Zn + 2H^+$$

$$\Big\downarrow Cd^{2+}$$

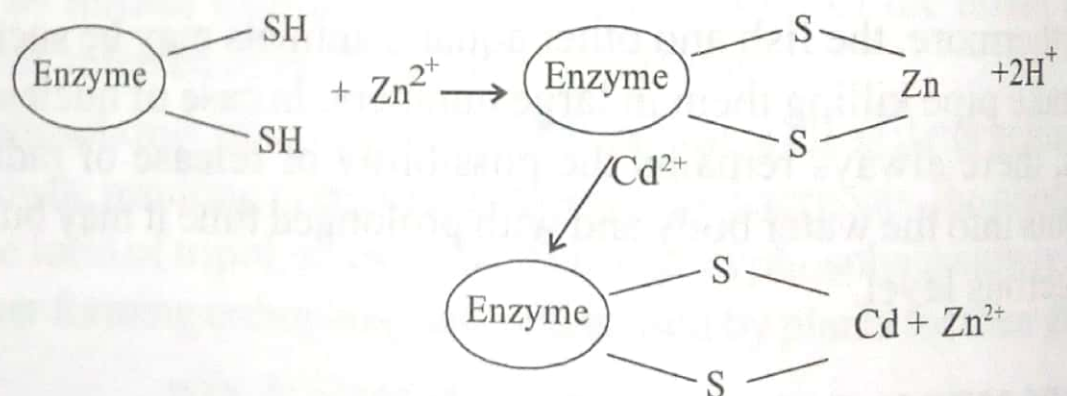$$\text{Enzyme} \begin{matrix} \text{S} \\ \text{S} \end{matrix} Cd + Zn^{2+}$$

Fig. 5.2. Enzyme-cadmium interaction

The enzymes inhibited by Cd^{2+} include: (1) adenosine triphosphate (2) alkaline phosphate (3) carbonic anhydrase, etc.

Effects of Cadmium:

1. Kidney damage
2. Disorder of liver and brain
3. Bone marrow disorder
4. Gastric and intestinal disorder

The outbreak of Cd poisoning occurred in Japan in the form of 'Itai-Itai' or 'Ouch-Ouch' disease. Many people got affected by this disease which rendered their bones fragile.

Mercury (Hg)

Sources of Mercury:

1. Mining and refining of Hg

2. Agricultural industry producing organic mercury as pesticides and fungicides

3. Paper industry using Hg as cathode

4. Chlorine and sodium hydroxide producing industry using Hg electrode

5. Laboratories using Hg

Importance of mercury as toxic metal came into limelight after the incidence of Minamata disease in Japan (1953-1960). At Minamata Bay in Japan many people lost their lives, many were permanently crippled and babies born to mothers consuming the mercury contaminated fish were genetically defective. The source of mercury was the effluent discharged into the bay from a vinyl chloride plant, Minamata Chemical Company. The fish in the bay were found to contain 25 to 100 ppm mercury in the form of methyl mercury.

The Minamata incidence was followed by a tragic incidence in Iraq, where many people died consuming wheat contaminated with organic mercury used as fungicides for seed dressings (methyl mercury nitrite, methyl mercury chloride, etc.).

It is to be noted that all the forms of Hg are not toxic. Elemental Hg is relatively inert and non-toxic. However, due to its high vapour pressure, when inhaled it causes severe damage to the central nervous system. Inorganic Hg is highly insoluble and also non-toxic. Mercurous ion (Hg_2^{2+}) is low toxic but not mercuric ion (Hg^{2+}). The toxicity of Hg^{2+} is due to its high affinity for sulphur atoms, by attaching itself to sulphur containing amino acids of protein, it forms bonds with hemoglobin and serum albumin containing sulphydryl groups.

The most toxic species are, however, organic mercury, especially CH_3Hg^+ as it is soluble in fat, lipid of membranes and brain tissue. The covalent Hg-C bond cannot be disrupted easily and thus, remains for a long time in the cells. This, in turn, prohibits active transport of sugars,

but allows passage of K to the membrane, resulting in energy deficienc in cells and disorder of central nervous system.

Mercury in Food Chain

It is very interesting to note that the mercury which was discharge from the vinyl chloride plant of Minamata Chemical Company wa relatively non-toxic elemental HgO or inorganic salt, the fish howeve contained highly toxic CH_3Hg^+. The prolonged research on this subje led to the revelation of how the conversion took place. The conversic stages are as given below:

(i) Hg and its salts convert to methyl mercury by anaerobic bacter such as 'clostridium cochluarium' in water. The conversion is suppose to be facilitated by Co (III), containing vitamin B_{12} coenzyme.

(ii) The CH_3 group, bonded to Co (III) in coenzyme is transferred methyl cobalamin to Hg^{2+}, forming CH_3Hg^+ or $(CH_3)_2Hg$.

$$\overset{CH_3}{\underset{|}{>Co<}} (III) + Hg^{2+} \xrightarrow{\text{Methylcobalamin}} >Co< (III) + CH_3Hg+ \text{ or } (CH_3)_2HG$$
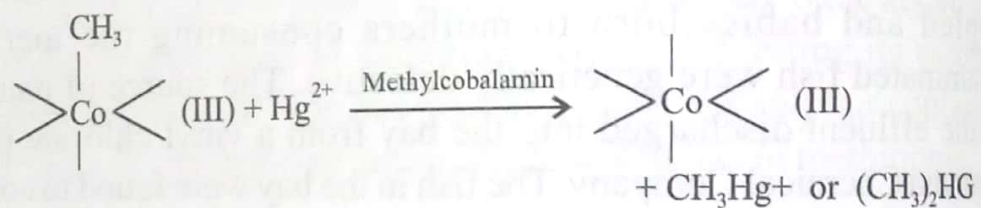
Fig. 5.3. Biological methylation of mercury

(iii) This CH_3Hg^+ undergoes translocation in plants and animals a finds its way into the food chain.

$$Hg^{2+} \downarrow \text{Anaerobic bacteria}$$
$$CH_3Hg^+ \downarrow$$
Phytoplankton

Insects — Small fish
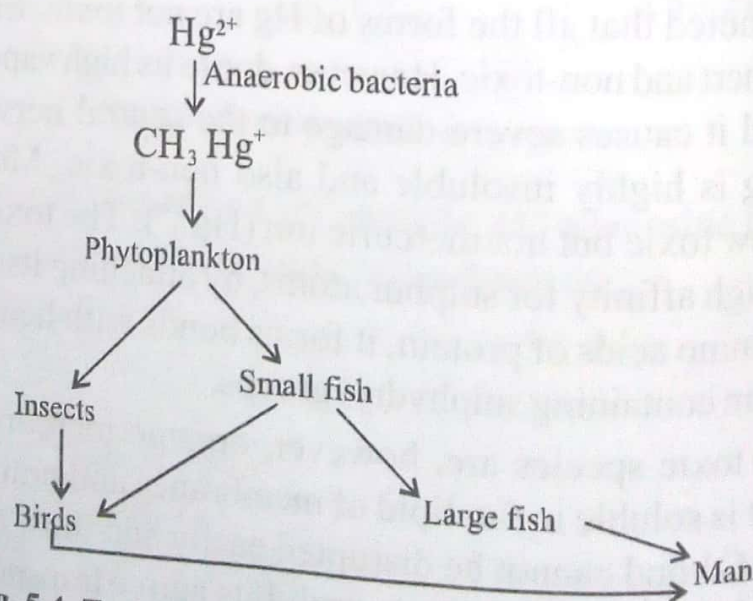
Birds — Large fish — Man

Fig. 5.4. Translocation of mercury into various trophic levels

The soluble methyl mercury through food chain (as shown above) gets magnified in every stage of consumption and finally gets deposited in fish tissue or insects, exceeding the permissible level. Man eating fish or bird thus, accumulate the mercury.

Effects of Mercury:

1. Numbness of limbs, tongue and lips
2. Blurred vision, deafness and mental disorder
3. Kidney damage

Lead (Pb)

Sources of Lead:

1. Mining and refining
2. Automobile emission (tetraethyl lead used as anti-knocking agent)
3. Electrical storage battery industry
4. Ceramic industry
5. Agricultural industry (preparation of insecticides, e.g., lead arsenate)
6. Paints, pigments, varnishes
7. Hair dyes, eye paints, canned foods, sea food, painted toys, etc.

Pb exerts its activity through sulphydryl inhibition. Pb has affinity for sulphur and it also reacts with carbonyl and phosphoryl groups. The main biochemical effect of lead is due to its interference with hemesynthesis, leading to hematological damage. It prohibits utilization of O_2 and glucose for the life sustaining energy production, *i.e.*, interferes with normal metabolic function. When the blood lead level reaches 0.8 ppm, symptoms of anemia occur with high degree kidney infection and brain damage.

One of the most harmful effects of Pb is that it can replace Ca in the bones, accumulate there and subsequently remobilize to soft tissue along with phosphates from the bones and cause severe toxic effects while transporting. Chronic exposure leads to weight loss, loss of teeth, etc.

Organic lead, like tetraethyl lead has been proved more poisonous than inorganic lead. Organic lead can penetrate the skin, can get absorbed in the body tissue faster as compared to the inorganic lead. Organic lead compounds being lipophilic, are selectively localized in central

nervous system causing high degree of toxicity. Organic lead might cause genetic modification also. The tolerance limit of lead is 7 mg/kg body weight of an adult.

Effects of Lead:

1. Lever and kidney damage

2. Mental retardation

3. Genetic modification

It is now believed that the fall of Roman Empire (30 BC to AD 220), was due to lead poisoning. Lead was an expensive metal during the era of Roman Empire. Roman aristocracy used lead containers for storing wine and for cooking. The leaching of lead ultimately caused chronic lead poisoning and caused mental imbalance, degenerated behaviour and collapse of Empire.

Arsenic (As)

Sources of Arsenic:

1. Natural rocks and soils

2. Agricultural industry (chemicals like As_2O_3, lead arsenate, etc.)

3. Fungicides, pesticides and herbicides

4. Mining and extraction

5. Glass industry

In the earth's crust, the level of arsenic is 2 ppm (the main ore being sulphide). The main sources of arsenic pollution are agricultural chemicals. Arsenic can exist in two forms—trivalent and pentavalent. Trivalent arsenic is the most toxic one. The toxic action of arsenic is due to its affinity towards sulphur. It thus, attacks the sulphydryl (–SH) group of an enzyme, inhibiting its enzyme activity essential for the generation of cellular energy in the citric acid cycle.
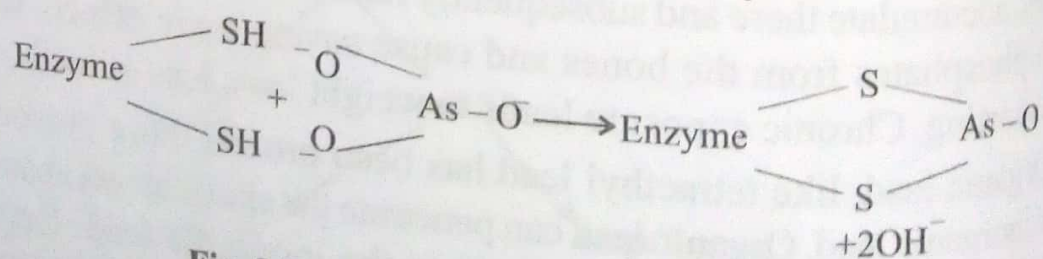
Fig. 5.5. Complexation of arsenic with enzyme

Thus, pyruvate-oxidase system becomes less effective in generation of main energy source, *i.e.*, adenosine triphosphate (ATP) due to its complexation with arsenic. Some biochemical processes involving phosphorous are also hampered due to the interference of arsenic because of its chemical similarity to phosphorous, preventing ATP generation. Arsenic (III) compounds coagulate protein at higher concentration levels.

One of the major contributions of arsenic pollution is contamination of ground water. Contamination of ground water has become a global phenomenon. If arsenic polluted water is used for drinking and cooking purposes for a prolonged time, a person may suffer from anaemia, melanosis, keratosis and conjunctivitis.

Major Effects of Arsenic:

1. Affects liver
2. Causes central necrosis and cirrhosis
3. Damages bone marrow and cellular elements of the blood
4. May lead to skin cancer

Differences between BOD and COD methods

BOD Method	COD Method
1. This method determines the amount of oxygen required to degrade the waste in water by the micro-organisms, i.e., biologically.	1. This method determines the amount of oxygen required to degrade the waste in water by oxidizing agent, i.e., chemically.
2. Demand oxygen is supplied by dissolved oxygen (DO) in the water sample.	2. Demand oxygen is supplied by oxidizing agent, such as $K_2Cr_2O_7$.
3. Amount of oxygen required for biodegradable substance is determined.	3. Amount of oxygen required for both biodegradable and non-biodegradable substances is determined.
4. The value of BOD is always less than COD.	4. The value of COD is always greater than BOD.
5. As it involves microorganisms, the duration of BOD test is very high.	5. It does not involve microorganisms instead an oxidizing agent is used, so it requires very little time.
6. BOD method is less scientific than COD method.	6. COD method is more scientific than BOD method.

Q. 6. A BOD test is run using 50 ml of waste water mixed with 100 ml of pure water. The initial DO of the mixture is 6.0 mg/l and after 5 days it becomes 2.0 mg/l. After a long time, the DO remains fixed at 1.0 mg/l.

(a) What is BOD_5 of waste water?

(b) What is the ultimate BOD (BOD_u)?

(c) What is the remaining BOD after 5 days?

(d) What is the reaction rate constant measured at 20°C?

(e) What would be the reaction rate if measured at 35°C?

Ans. (a) $BOD_5 = \dfrac{6-2}{50/100}$ mg/l $= \dfrac{4}{1/3}$ mg/l $= 12$ mg/l.

(b) If DO is fixed, then it can be assumed that all the oxygen is consumed and hence, this is the ultimate BOD (BOD_u).

$$BOD_u = \frac{6-1}{50/150} \text{ mg/l} = \frac{5}{1/3} \text{ mg/l} = 15 \text{ mg/l}$$

(c) The remaining BOD after 5 days would be: $(15-12)$ mg/l
= 3 mg/l (As BOD_u is the DO_i)

(d) We know that

$$BOD_t = c_0(1-e^{-kt})$$

Hence, $$BOD_5 = c_0(1-e^{-5k})$$

or $$12 = 15(1-e^{-5k})$$

or $$e^{-5k} = 1 - \frac{12}{15} = \frac{3}{15} = \frac{1}{5} = 0.2$$

or $$ln(e^{-5k}) = ln(0.2) \quad \text{or} \quad -5k = -1.61 \quad \text{or} \quad k = 0.322$$

The BOD reaction rate constant is 0.322/day.

(e) We know that,

$$k_T = k_{20}\theta^{(T-20)}$$

Hence, $$k_T = 0.322 \times 1.047^{(35-20)}$$

$$= 0.322 \times 1.047^{15}$$

$$= 0.644$$

The BOD reaction rate constant is 0.644/day at 35°C.

Q. 7. A waste water sample of 25 ml is diluted by adding 275 ml seeded dilution water. The initial demand oxygen (DO_i) is found to be 9.0 mg/l and after 5 days the final demand oxygen (DO_f) is 3.0 mg/l. If the seeded dilution water has initial (B_i) of 10.0 mg/l and final (B_f) 8.0 mg/l, then find the BOD_5 of the waste.

Ans. The dilution factor $$(P) = \frac{25}{25+275} = \frac{25}{300} = 0.083$$

$DO_i = 9$ mg/l; $\qquad B_i = 10$ mg/l
$DO_f = 3$ mg/l; $\qquad B_f = 8$ mg/l

We know, $$BOD_5 = \frac{(DO_i - DO_f) - (B_i - B_f)(1-P)}{P}$$

$$= \frac{(9-3)-(10-8)(1-0.083)}{0.083}$$

$$= \frac{6-2(0.017)}{0.083} = \frac{6-0.034}{0.083} = \frac{5.966}{0.083} = 7.19 \text{ mg/l.}$$

Q. 8. What will be the ratio of BOD_5 at 20°C, to that of $BOD_{2.5}$ at 35°C?

Ans. We know, $BOD_t = c_0(1-e^{-kt})$

c_0 is the total amount of oxygen needed to decompose the waste.

k is the rate constant for decomposition.

t is the time of measurement.

Hence, $BOD_5 = c_0(1-e^{k_{20} \times 5})$ ... (1)

Now, $k_T = k_{20}\theta^{(T-20)}$

where, k_T is the rate constant at temperature $T°C$ and k_{20} is the rate constant at temperature 20°C. θ is a constant equal to 1.047.

So, $K_{35} = K_{20}(1.047)^{35-20} = K_{20} \times 2$

Thus, $BOD_{2.5} = c_0(1-e^{-2 \times K_{20} \times 2.5})$ ...(2)

Now dividing equation (2) by (1), we have

$$\frac{BOD_{2.5}}{BOD_5} = 1$$

Q. 9. The BOD_5 of a sample of waste water is found to be 325 mg/l. The initial DO (DO_i) of diluted waste water is 20 mg/l and the test requires a decrease in DO of at least 4 mg/l, with at least 3 mg/l of DO remaining at the end of five days. Now, find out the range of dilution factor (P), required to produce acceptable results.

Ans. We know, $BOD = \dfrac{DO_i - DO_f}{P}$

Thus, $BOD_5 = 325 = \dfrac{20-3}{P}$

or $325 = \dfrac{17}{P}$ or, $P = \dfrac{17}{325} = 0.052$

Now again, $325 = \dfrac{4}{P_1}$ or $P_1 = \dfrac{4}{325} = 0.0123$

The desired range of dilution factor is 0.0123 to 0.052.

Q. 10. In a five-day test, the DO level drops by 1.0 mg/l of seeded dilution water. A 300 ml BOD bottle filled with 21ml waste water and the rest seeded dilution water, shows a drop of 6 mg/l in the same period (five days). What would be the BOD_5 of the waste?

Ans. The dilution factor (P) $= \dfrac{21}{300} = 0.07$

For waste water diluted by seeded dilution water,

$$BOD_5 = \frac{(DO_i - DO_f) - (B_i - B_f)(1 - P)}{P}$$

Here, drop of DO of waste water $= DO_i - DO_f = 6$ mg/l

Drop of DO of seeded dilution water $= B_2 - B_f = 1$ mg/l

Hence, $BOD_5 = \dfrac{6 - 1.0(1 - 0.07)}{0.07} = \dfrac{6 - 1.0(0.03)}{0.07} = \dfrac{5.97}{0.07} = 85.3\,mg/l$

Q. 11. The BOD rate reaction constant is 0.30/day. Calculate the expected BOD_5 if the two day BOD in 150 mg/l. (Suppose temp. is constant).

Ans. We know, $BOD_t = c_0 (1 - e^{-kt})$

$\therefore \qquad BOD_2 = c_0(1 - e^{-2k}) = c_0 (1 - e^{-2 \times 0.30})$

or $\qquad 150 = c_0 (1 - e^{-2 \times 0.30})$

or $\qquad c_0 = \dfrac{150}{1 - e^{-0.6}} = 333$ mg/l

The ultimate carbonaceous BOD $= 333$ mg/l

Hence, $BOD_5 = \dfrac{150}{1 - e^{-0.6}}(1 - e^{-0.30 \times 5}) = 333(1 - e^{-1.5}) = 258$ mg/l

Thus, the five day BOD is 258 mg/l.

Q. 12. A waste water sample has a BOD at 20°C equal to 200 mg/l and ultimate BOD of 400 mg/l. Find the BOD_5 at 35°C.

Ans. We know,

$$BOD_t = c_0 (1 - e^{-kt})$$

or

$$BOD_5 = c_0 (1 - e^{-5k})$$

or

$$200 = 400 (1 - 1^{-5k})$$

or

$$1 - e^{-5k} = 0.5$$

or

$$e^{-5k} = 0.5$$

or

$$k = 0.138$$

Thus, at 20°C BOD reaction rate constant $K_{20} = 0.138$ /day.

Now we know,

$$K_T = K_{20} \theta^{(T-20)}$$

or

$$K_{35} = K_{20} \theta^{(T-20)}$$

or

$$K_{35} = 0.138 (1.047)^{35-20} = 0.138 (1.047)^{15} = 0.276/\text{day}.$$

Hence, BOD_5 at 35°C is

$$BOD_5 = c_0 (1 - e^{-0.276 \times 5}) = 400(1 - e^{-0.276 \times 5}) = 300 \text{ mg/l}$$

Therefore, at 35°C, BOD_5 of waste water is 300 mg/l.

Q. 13. A test bottle, (300 ml capacity) with 10.0 ml sample is mixed with enough water to fill the container. The initial DO is 10 mg/l. For accurate measurement, it is desirable to have at least a 3.0 mg/l drop in DO during the five day run and the final DO should be at least 3.0 mg/l. For what range of BOD, would the dilution produce the desired results?

Ans. The dilution fraction $P = 10/300$. To get at least a 3.0 mg/l drop in DO, the minimum BOD required is given by

$$BOD_5 \geq \frac{DO_i - DO_f}{P} = \frac{3}{10/300} = 90 \text{ mg/l}$$

To assure at least 3.0 mg/l of DO remaining after five days,

$$BOD_5 \leq \frac{(10-3)}{10/300} \text{ mg/l} = 210 \text{ mg/l}$$

Hence, this dilution will be satisfactory for BOD_5 values between 9 and 210 mg/l.

Q. 14. The dilution factor for an unseeded mixture of waste and water is 0.050. The DO of the mixture is initially 8.0 mg/l and after five days it drops to 2.0 mg/l. The reaction rate constant is estimated to be 0.22 day^{-1}. Find out the following:

(a) What is the five-day BOD of the waste?

(b) What would be the ultimate carbonaceous BOD?

(c) What would be the remaining oxygen demand after five days?

Ans. (a) $BOD_5 = \dfrac{DO_i - DO_f}{P} = \dfrac{8-2}{0.050} = 120 \text{ mg/l}$

(b) We know $BOD_5 = c_0 (1 - e^{-kt})$

or $c_0 = \dfrac{BOD_5}{(1 - e^{-kt})} = \dfrac{BOD_5}{(1 - e^{-0.22 \times 5})} = \dfrac{120}{(1 - e^{-0.22 \times 5})} = 180 \text{ mg/l}$

(c) After five days, 120 mg/l of oxygen demand, out of the total (c_0) 180 mg/l would have already been used. The remaining oxygen demand, would therefore, be $(180 - 120)$ mg/l $= 60$ mg/l.

Q.15. A waste sample contains 50 mg/l of Ca^{2+}, 36.5 mg/l of Mg^{2+} and 10 mg/l of Na^+. What is the total hardness in (a) meq/l and (b) mg/l as $CaCO_3$?

Ans. (a) The equivalent weight of Ca^{2+}

$$= 40/2 = 20 \text{ mg / meq,}$$

and that of $Mg^{2+} = 24.3/2 = 12.15 \text{ mg/l}$

$$50 \text{ mg/l } Ca^{2+} = \dfrac{50 \text{ mg/l}}{20 \text{ mg/meq}} = 2.5 \text{ meq/l}$$

and $36.5 \text{ mg/l } Mg^{2+} = \dfrac{36.5 \text{ mg/l}}{12.15 \text{ mg/meq}} = 3 \text{ meq/l}$

$$= 3 \text{ meq/l}$$

Hence, total hardness $= (2.5 + 3.0)$ meq/l

$$= 5.5 \text{ meq/l.}$$

(Na^+ has no contribution to hardness.)

Total hardness in mg/l as $CaCO_3$

$=$ Total hardness in meq/l $\times$ equivalent weight of $CaCO_3$

Total hardness in mg/l as $CaCO_3$

$$= (5.5 \text{ meq/l}) \times 100/2 \text{ mg/l} = 275 \text{ mg/l as } CaCO_3.$$

(d) Noise in an area is measured as 95 dBA for 1 hour, 90 dBA for 3 hours, 100 dBA for 30 minutes and 75 dBA for 3 hours. The permissible noise exposure duration of 100 dBA is 1 hour, 95 dBA is 2 hours, 90 dBA is 4 hours and 75 dBA is any time. Find out whether the permissible limit has exceeded or not and also state if the condition is good for the health of a worker or not.

Solution.

Noise level dBA:	100	95	90	75
Measured hours:	½	1	3	3
Permissible hours:	1	2	4	∞

We know noise threshold limit value $= \dfrac{C_1}{T_1} + \dfrac{C_2}{T_2} + \ldots\ldots$

where, C = actual hours exposed to a particular noise level.

T = permissible hours of exposure to that noise level.

The noise threshold limit value $= \dfrac{\frac{1}{2}}{1} + \dfrac{1}{2} + \dfrac{3}{4} + \dfrac{3}{\infty} = 1\dfrac{3}{4}$

As the noise threshold limit value crosses the permissible limit, *i.e.,* 1, therefore, the existing working environment is not good for the worker.

Plants utilize CO_2 from the atmosphere in the process of photosynthesis and eventually carbon compounds are formed.

$$6\,CO_2 + 6H_2O \underset{\substack{Dark\\Chlorophyll}}{\overset{Light\,(uv)}{\rightleftarrows}} C_6H_{12}O_6 + 6O_2$$
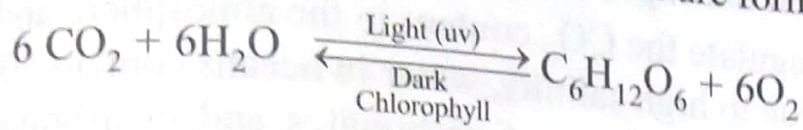
At night in absence of light, some of these carbon compounds again get oxidized during respiration and in the process CO_2 and energy again get released.

Animals consume plants and accumulate carbon. When the plants and animals die they are decomposed by some new organisms and CO_2
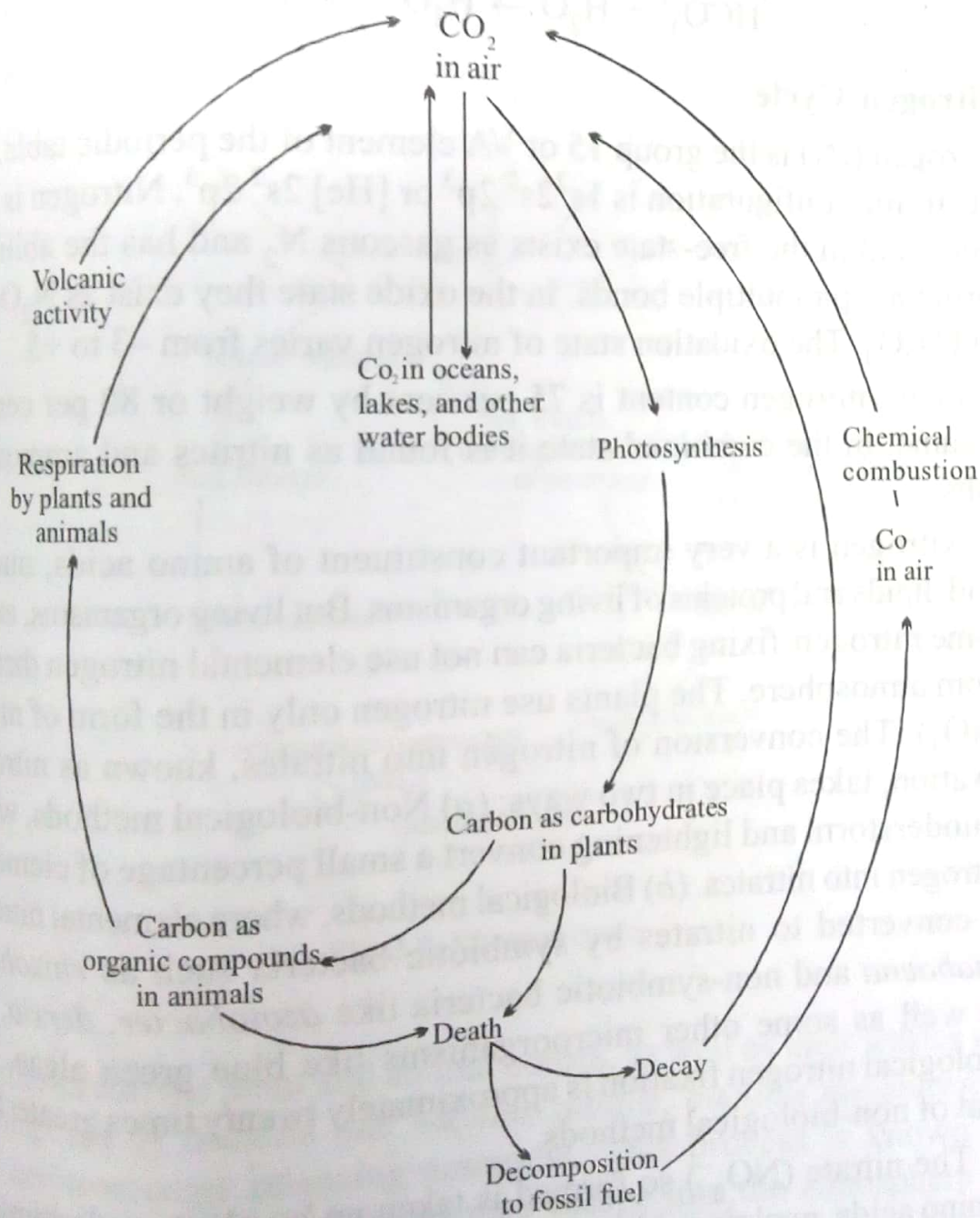

Fig. 3.5. Carbon cycle

tissues. . . . acids and proteins in their

Atmospheric Nitrogen
(N₂)

Nitrogen Fixation
(Electric Discharge)
$N_2 + O_2 \rightarrow NO, NO_2 \rightarrow$ Rain washed

Nitrogen Fixation
(Bacteria in modules)

Denitrifying
bacteria

Fertilizer plants

Soil Nitrate
$(NO_3)^-$

Nitrate bacteria

Plants
(Nitrogen in form
of proteins)

Animals
(Nitrogen in form
of proteins)

Soil Nitrites

Nitrite bacteria

Death

Ammonium compounds
$(NH_4)^+$

Decay and waste

Decomposition

Fig. 3.6. Nitrogen cycle

Sulphur as sulphatic salt in soil (SO_4^{2-})

Aerobic

Chemoautotrophic and photosynthetic bacteria

Sulphur in rocks, metal sulphides, fossil fuels

Anaerobic

Hydrogen sulphide (H_2S)

Plants uptake (Sulphur as organic compounds)

Animals uptake (Sulphur as organic compounds)

Decay and decomposition
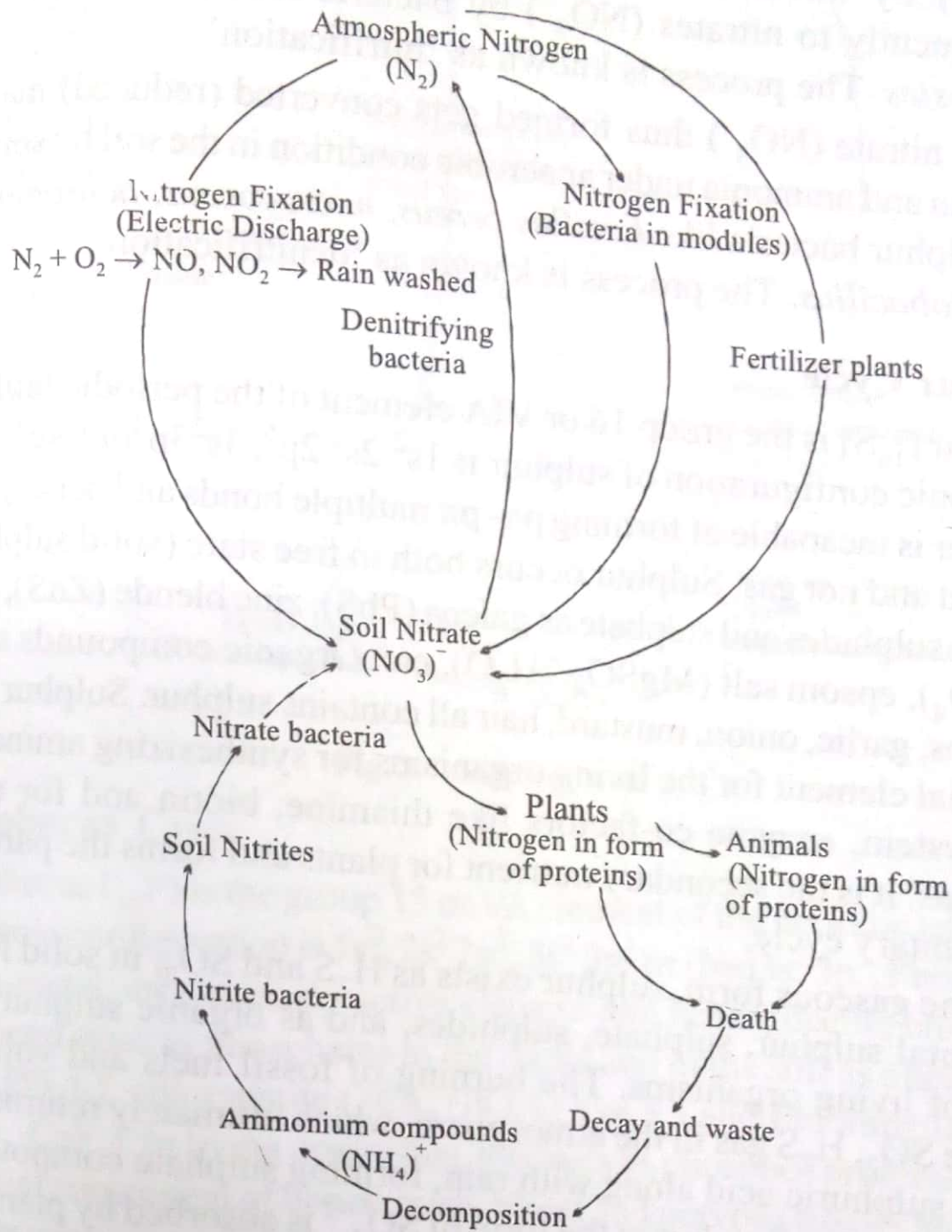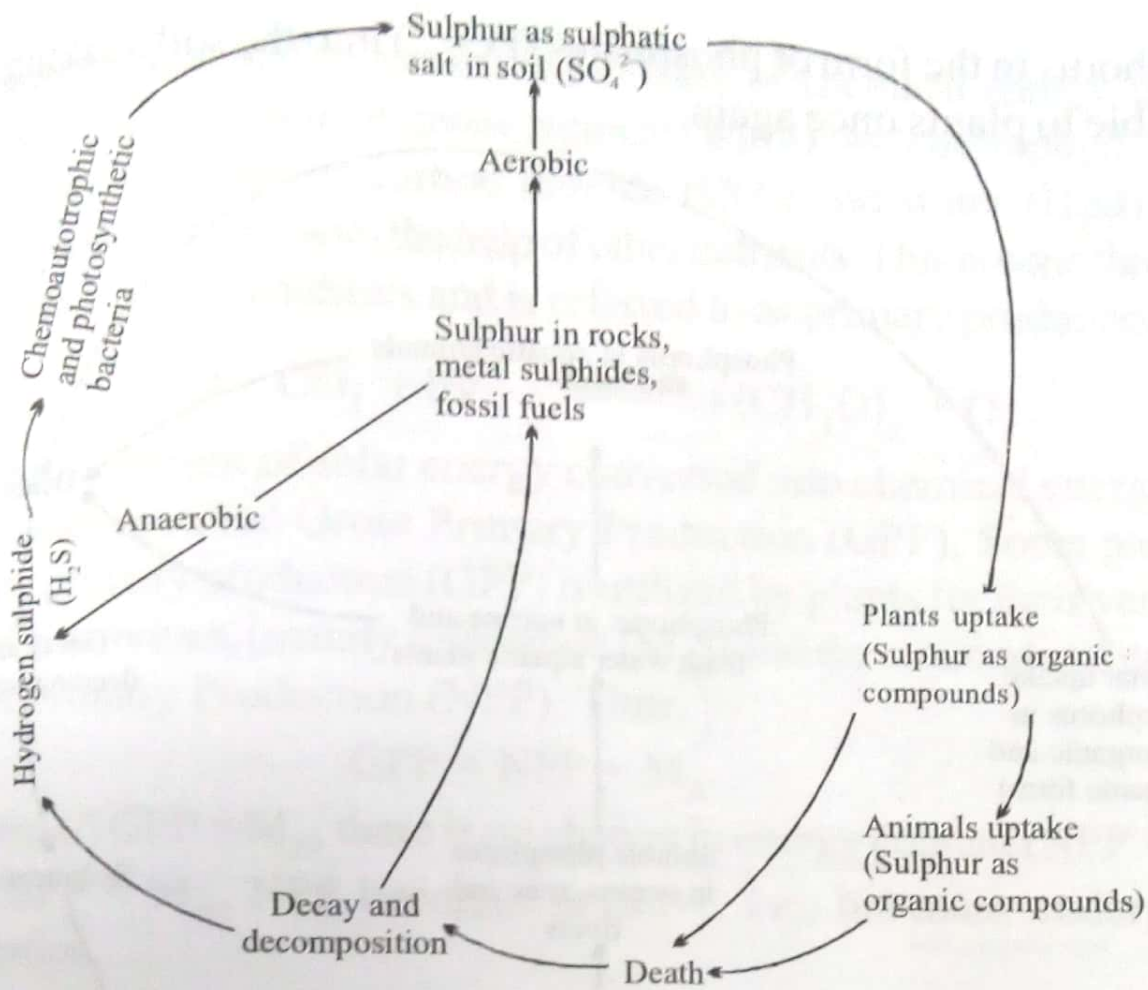
Death

Fig. 3.7. Sulphur cycle

Phosphorus Cycle

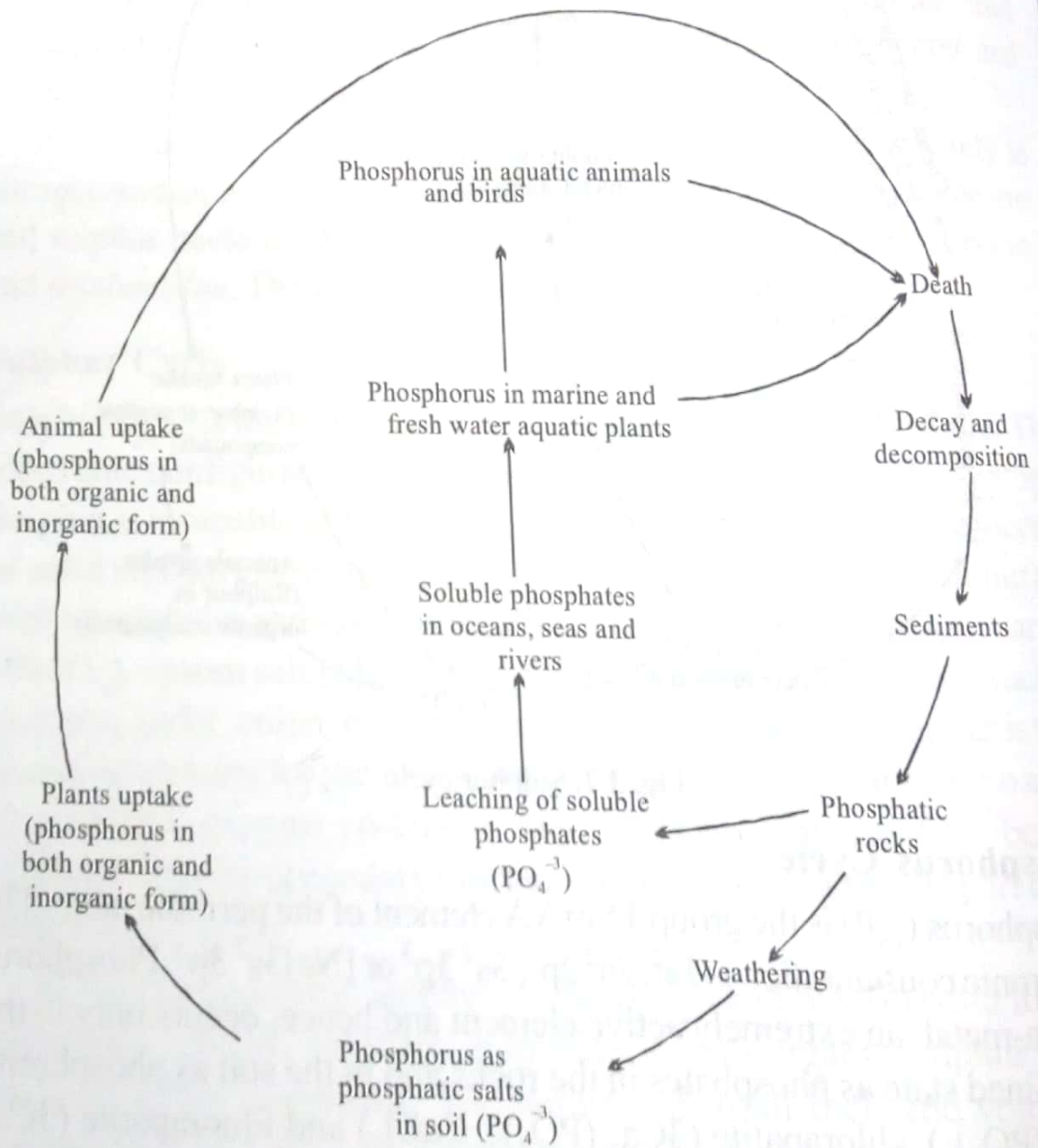phosphorus in the form of phosphates (PO_4^{-3}) into the soil, making them available to plants once again.

Phosphorus in aquatic animals and birds

Death

Animal uptake (phosphorus in both organic and inorganic form)

Phosphorus in marine and fresh water aquatic plants

Decay and decomposition

Soluble phosphates in oceans, seas and rivers

Sediments

Plants uptake (phosphorus in both organic and inorganic form)

Leaching of soluble phosphates (PO_4^{-3})

Phosphatic rocks

Weathering

Phosphorus as phosphatic salts in soil (PO_4^{-3})

Fig. 3.8. Phosphorus cycle

Thus, phosphate cycle starts from (PO_4^{-3}) in the rocks