Disposal of The Sewage Effluents

Environment Engineering –II

Syllabus

- Sewage Disposal Discharge of raw and treated sewage on land and water, standards for disposal, raw and treated sewage on land and water, limit of dilution, self –purification of streams, oxygen economy, sewage farming

Disposal of the Treated Sewage or Sewage Effluent

- **The disposal of sewage effluent is the last stage of getting rid of sewage after subjecting it to various steps of processes (i.e.) treatment of transforming the sewage into the harmless liquid which fulfils the minimum standard of health and sanitation**. The main object of controlling disposal of sewage are

1) To render the sewage inoffensive

2) To save the aquatic life in streams

- To eliminate the **danger of contamination of water supplies**
- The **amount or degree of treatment that should be given to the sewage depends upon the source of its disposal as well** as its capacity to assimilate the impurities present in the sewage without itself getting polluted or less useful. So before designing the treatment plant first the source of disposal has to be selected.
- The best method of disposal is always difficult to decide. The methods of disposal are classified into main groups as:

Natural Methods

- **Natural methods**- by which the treated on untreated sewage is disposed off by:
- (i) dilution or disposal into water i.e. into sea, lakes or rivers
- (ii) Disposal on land or land treatment i.e. sewage farming and irrigation.

Natural Methods

Artificial Methods

- **Artificial methods** by which the sewage is disposed off only after subjecting it to various treatments (primary and secondary) such as:
- Screening and detritus removal
- Sedimentation with or without chemicals
- Biological treatment (trickling filter, oxidation pond or activated sludge process)
- Now a days the actual practice is to use both the methods, the sewage is first given the treatment and then it is disposed off by any of the natural method. If full treatment is not given at least the primary treatment is given before disposal.

Artificial Methods

Disposal By Dilution

- **Dilution is a predominant natural method of disposal. Disposal by dilution is the process whereby the raw or treated (most treated) sewage is discharged into water bodies such as rivers, lakes, sea etc..** The discharge sewage, in due course of time, is purified by the self purification process of the natural waters. The sewage is mainly purified due to oxidation of organic matter by bacteria using the DO present in the water bodies. **The degree of the treatment given to the raw sewage before disposing it in to any river will depend not only upon thee quality of raw sewage but also on the self purification capacity of river and the intended use of its water at the down stream side**.
- This method can be used only for the town or city which are located near the river or sea or have a large lake which can be used as a source of disposal.

Disposal By Dilution

Condition Favoring Disposal by Dilution

- **The Dilution method for disposing of the sewage can favorable by adopted under the following conditions:**
- When the sewage is comparatively fresh i.e. it is discharged within 3-4 hours of its collection.
- When the floating matter and settlable solids have been removed by primary treatment.
- When the diluting water has high DO content, so that not only the BOD is satisfied, but sufficient DO remains available for the aquatic life.

Condition Favoring Disposal by Dilution

- **Where the dilution waters are not used for the purpose of navigation or water supply for at-least some reasonable distance on the downstream from the point of sewage disposal.**
- Where flow current of the diluting waters are favorable, causing no deposition or destruction to aquatic life. Its means that swift forward currents are helpful, as they easily carry away the sewage to the point of unlimited dilution. On the other hand, slow back currents tend to cause sedimentation, resulting in large sludge deposits.
- **Where the wastewater does not contain industrial wastewater having toxic substances.**
- **When the outfall sewer of the city or the treatment plant is situated near some natural waters.**

Standards Of Dilution For Discharge Of Wastewater Into Rivers

- The bureau of Indian standards has therefore laid down its guiding standards for sewage effluents, vide **4764-1973 and for industrial effluents vide IS 2490 - 1974**
- These standards are the national guide lines for each state pollution control board, using which they prescribed their legally enforceable standards depending upon the water quality and dilution available in their respective surface water sources.
- **When the industrial waste water are disposed of in to public sewers, their quality should be control by using the standards IS 3306-1974**

Standard of Dilution

Table 3.15 Standards of Dilution Based on Royal Commission Report

Dilution factor	Standards of purification required
Above 500	No treatment is required. Raw sewage can be directly discharged into the volume of dilution water.
Between 300 to 500	Primary treatment such as plain sedimentation should be given to sewage, and the effluents should not contain suspended solids more than 150 ppm.
Between 150 to 300	Treatments such as sedimentation, screening and essentially chemical precipitation are required. The sewage effluent should not contain suspended solids more than 60 ppm.
Less than 150	Complete thorough treatment should be given to sewage. The sewage effluent should not contain suspended solids more than 30 ppm., and its 5 days B.O.D. at 18.3°C should not exceed 20 ppm.

Table 3.16 BIS (ISI) Standards for Discharge of Sewage and Industria' Effluents in Surface Water Sources* and Public Sewers

Sr. No. (1)	Characteristic of the Effluent (2)	Tolerance limit for Sewage Effluent discharged into Surface Water Sources, as per IS 4764–1973 (3)	Tolerance Limit for Industrial effluents discharged into	
			Inland surface waters, as per IS 1490–1974 (4)	Public sewers as per IS 3306–1974 (5)
1.	BOD_5	20 mg/l	30 mg/l	500** mg/l
2.	COD	–	250 mg/l	–
3.	pH value	–	5.5 to 9.0	5.5 to 9.0
4.	Total Suspended Solids (TSS)	30 mg/l	100 mg/l	600 mg/l
5.	Temperature	–	40°C	45°C
6.	Oil and grease	–	10 mg/l	100 mg/l
7.	Phenolic compounds (as Phenol)	–	1 mg/l	5 mg/l
8.	Cyanides (as CN)	–	0.2 mg/l	2 mg/l
9.	Sulphides (as S)	–	2 mg/l	–
10.	Fluorides (as F)	–	2 mg/l	–
11.	Total residual chlorine	–	1 mg/l	–
12.	Insecticides	–	Zero	–
13.	Arsenic (as As)	–	0.2 mg/l	–
14.	Cadmium (as Cd)	–	2 mg/l	–
15.	Chromium, hexavalent (as Cr)	–	0.1 mg/l	2 mg/l
16.	Copper	–	3 mg/l	3 mg/l
17.	Lead	–	0.1 mg/l	1 mg/l
18.	Mercury	–	0.01 mg/l	–
19.	Nickel	–	3 mg/l	2 mg/l
20.	Selenium	–	0.05 mg/l	–
21.	Zinc	–	5 mg/l	15 mg/l
22.	Chlorides (as Cl)	–	–	600 mg/l
23.	Sodium	–	–	60%
24.	Ammoniacal nitrogen (as N)	–	50 mg/l	50 mg/l
25.	Radioactive meterials	–		
	(i) α–emitters		10^{-7} μC/ml (micro curie/ml)	–
	(ii) β–emitters		10^{-6} μC/ml	–

Types Of Receiving Waters For Dilution

- The following are the types of receiving waters into which wastewater or effluent can be discharged for dilution:
- **Perennial rivers and streams**
- **Lakes**
- **Oceans or Sea**
- **Estuaries**
- **Creeks**
- Perennial rivers or streams are probably the best type of receiving waters, since the water is in continuous motion. Also in the natural streams there is balance between plant and animal life, with considerable interaction among the various life forms. **However the discharge flowing during summer and during winter varies. During summer, there may be minimum flow in the stream, so the dilution factor may be low, and also high temperature of water may result in low solubility of oxygen, necessitating proper treatment before dilution.**

Types Of Receiving Waters For Dilution

- **Sometimes, especially when the perennial streams are not available lakes may be used for dilution**. Various characteristics of lakes, such as its size, shape, volume of fresh water flowing into it etc.. should be critically examined before deciding the self purifying capacity.
- **Ocean has abundant water so that the dilution factor is unlimited**. However, sea water has about 20 % less DO than river or stream. The water is turbid due to dissolved impurities and penetration of sun rays is less. Due to this proper care has to be taken in dilution by sea otherwise anaerobic conditions would occur resulting in forming of sludge banks and emission of foul odour.

Types Of Receiving Waters For Dilution

- **A creek is in the form of an inlet on sea coast, which may not have dry weather flow during some part of the year**. Due to this, great care should be taken in disposal of effluent in to it.
- **Estuary is wide lower tidal part of the river**. Hence dilution in an estuary is affected both by ocean water as well as river water. However, the process of dilution is generally satisfactory in estuaries.

Types Of Receiving Waters For Dilution

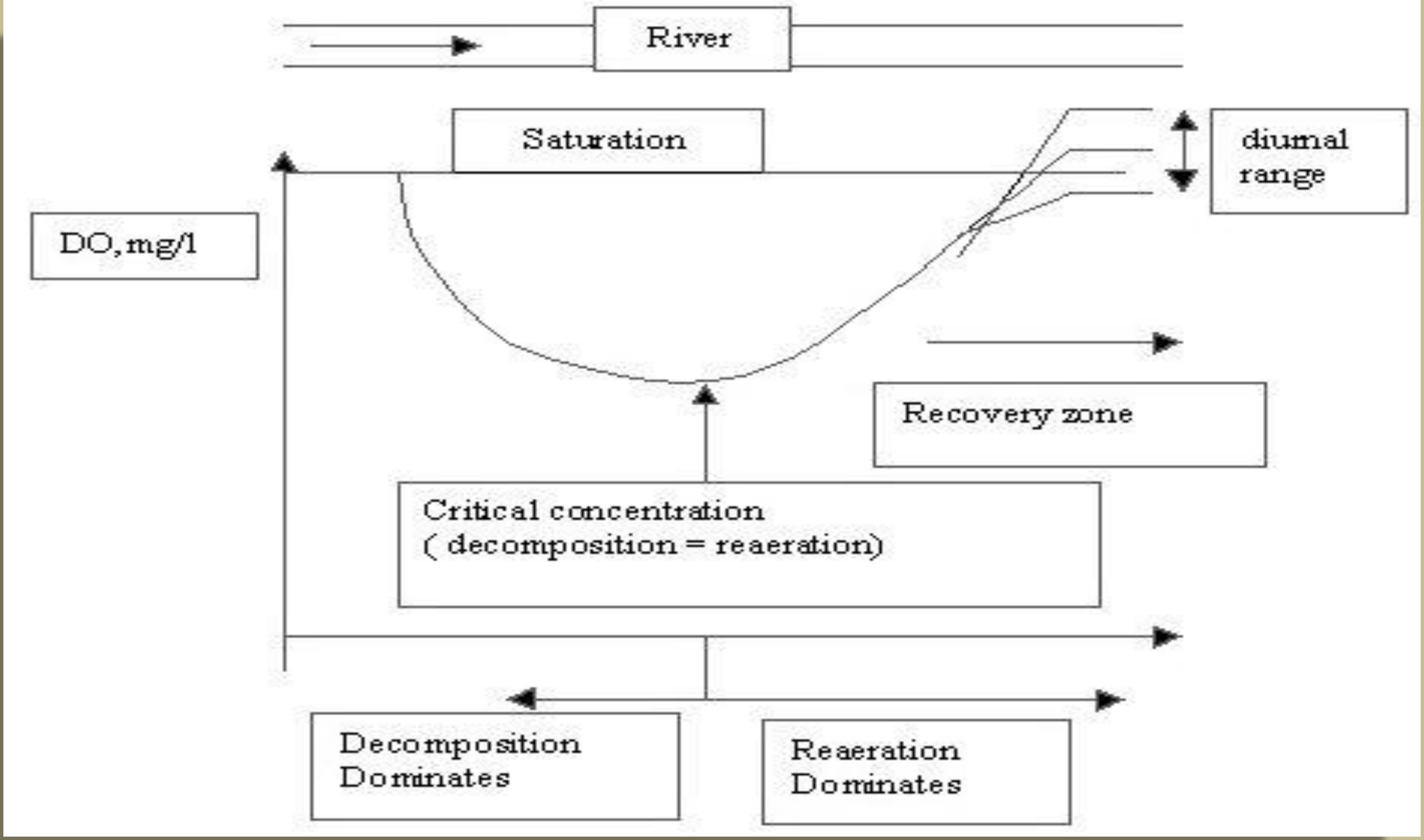
Self Purification of Natural Streams

- When the wastewater or effluents is discharged into natural body of water, the receiving waters gets polluted due to the waste products, present in the sewage effluent. But the conditions do not remain so for ever, because the natural forces of purification, such as dilution, sedimentation, oxidation, reductions etc.. go on acting upon the pollutants and bring back the water into original condition. **This automatic purification of polluted water, in due course of time is called the self purification. The organic matter present in the sewage is broken down by bacteria (present in the stream water to ammonia, nitrate, sulphates, carbon dioxide etc..**

Self Purification of Natural Streams

- **In this process the Dissolved Oxygen (DO) content of the natural water decreases and a deficiency of DO is created. The DO is replenished by the diffusion form the atmosphere (re-aeration).** The stable by product of oxidation mentioned above are utilized by the plants and algae forms the food for protozoa, rotifers, and crustaceans. They in turn becomes food for minnows and tiny fish which become food for man. The man discharges his waste back to stream. **Thus the natural cycle of self purification continues and the rivers water regains its original quality. The complete self purification is only possible if the concentration of pollutants is less than the assimilative capacity of the river, it becomes polluted and aquatic life gets affected as some minimum DO is required for survival of fish.**

Self Purification of Natural Streams



The various forces of purification which help in effecting self-purification process are summarized below:

Physical forces which includes

(i) Dilution

(ii) Dispersion

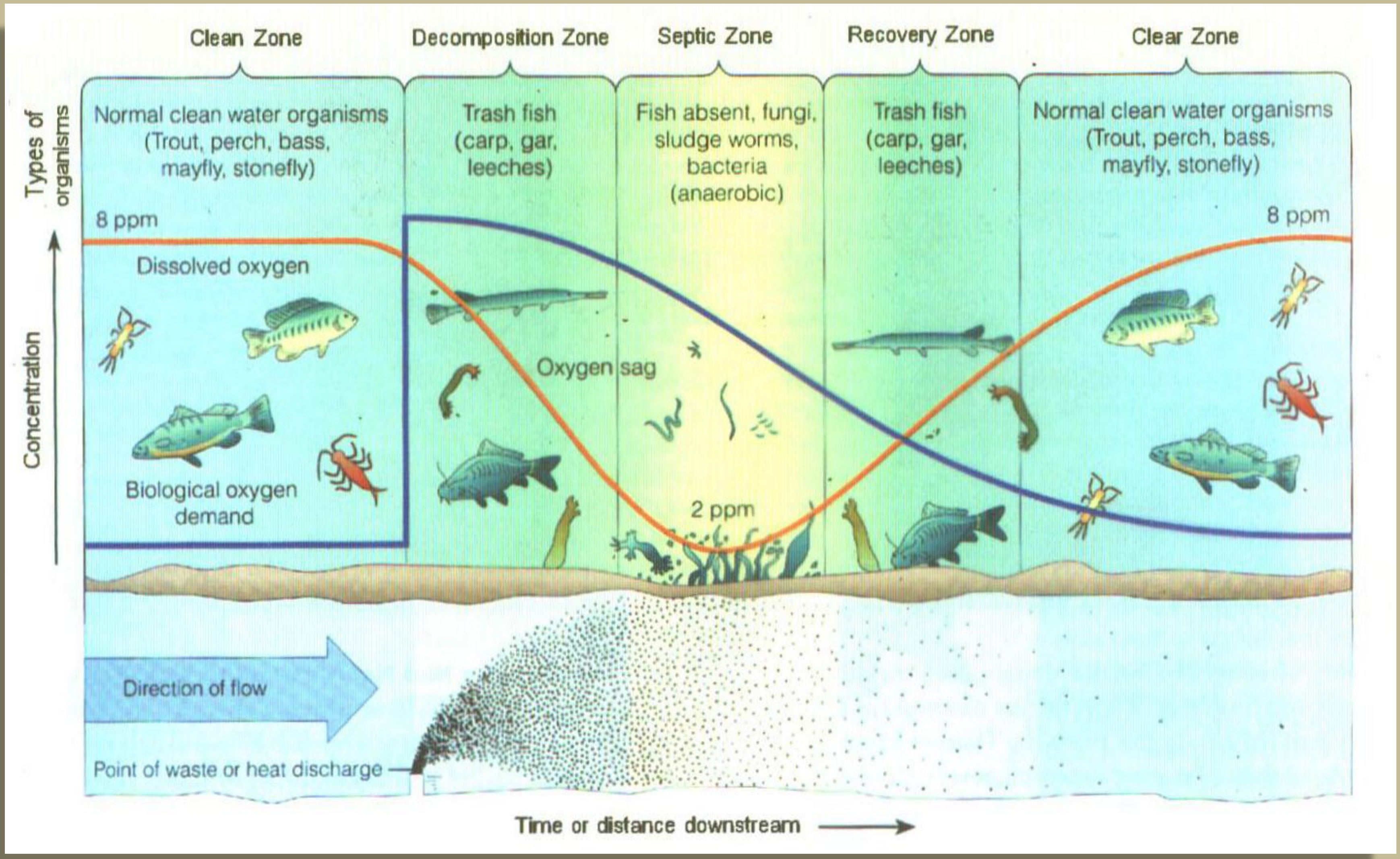
(iii) Sunlight (acts through bio-chemical reactions)

Chemical forces aided by biological forces (called bio chemical forces) which includes

(i) Oxidation (Bio Oxidation)

(ii) Reduction

The various forces of purification which help in effecting self-purification process are summarized below:



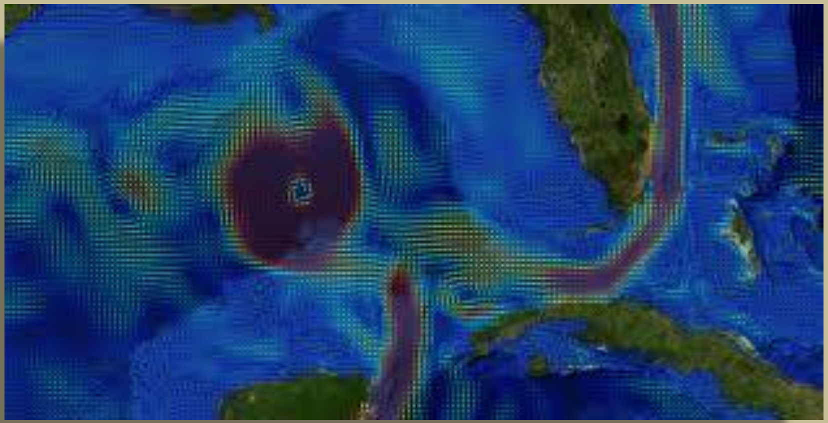
These forces are described below:

- **(i) Dilution:**
- When the wastewater is discharged into large volume of water contained in the river or stream, its gets diluted, due to which the concentration of organic matter is reduced and thus the potential nuisance of sewage is also reduced.
- If Cs and Cr are the concentrations of any impurities such as organic content, BOD, suspended solids, dissolved oxygen in the sewage and river having discharge Qs and Qr respectively, the resulting concentration C of the mixture is given by
- $C_s Q_s + C_r Q_r = C (Q_s + Q_r)$

$$C = \frac{C_s Q_s + C_r Q_r}{(Q_s + Q_r)}$$

Dispersion due to currents

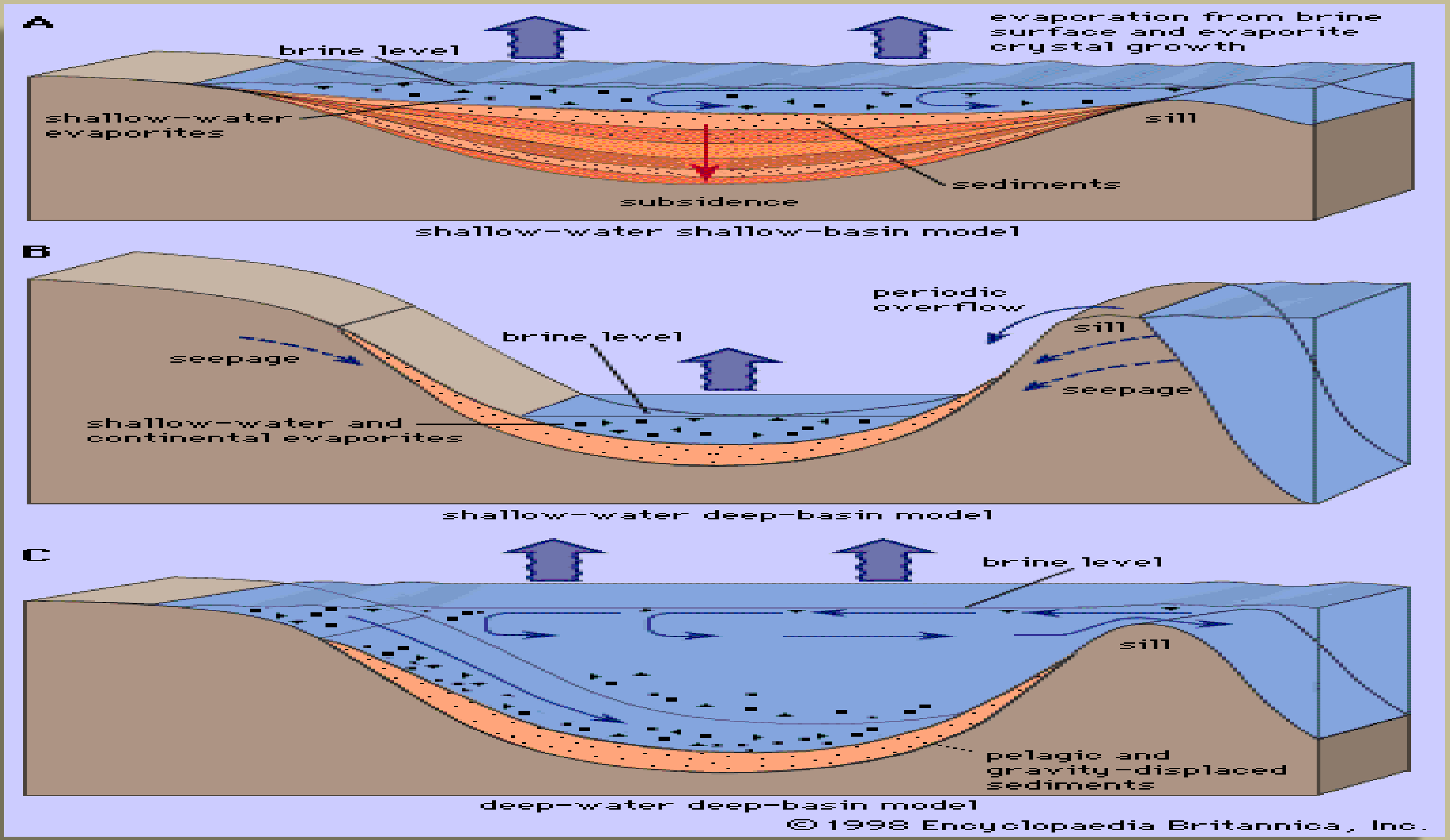
- Self purification of stream largely depends upon currents which will readily disperse the wastewater in the stream, preventing local high concentration of pollutants. High velocity also increases the re-aeration which reduces the time of recovery, through length of the stream affected by wastewater is increased.



Sedimentation

- The settle able solids, if present in sewage effluents, will settle down into bed of river, near the outfall of sewage, thus helping in the self purification process as the concentration of sewage may get reduced.

Sedimentation



Sunlight

- Sunlight acts as disinfectants and stimulates the growth of algae (they produce their own food by the process of photosynthesis) which produce oxygen during daylight but utilizes oxygen at night. **Hence wherever there is algal growth, the water may be saturated with DO during day light hours, through anaerobic conditions exist in night.**

Sunlight

Oxidation

- **The oxidation of organic matter present in the sewage effluents will start as soon as the sewage is discharged into the river. The anaerobic bacteria will oxidize the organic matter utilizing the dissolved oxygen of the stream**. The deficiency of oxygen so created, will be filled up by the atmospheric oxygen. **The process of oxidation, will continue till the organic matter has been completely oxidized.** This is the most important action responsible for effecting the self purification of the rivers.

Oxidation

Reduction

- Reduction occurs due to hydrolysis of organic matter settled at the bottom either chemically or biologically. Anaerobic bacteria will help in splitting the complex organic constituents of sewage into liquids and gases, thus paving the way for their ultimate stabilization by oxidation.

Factors affecting self purification capacity of the river or stream.

Self purification capacity of a river or a stream depends on following factors

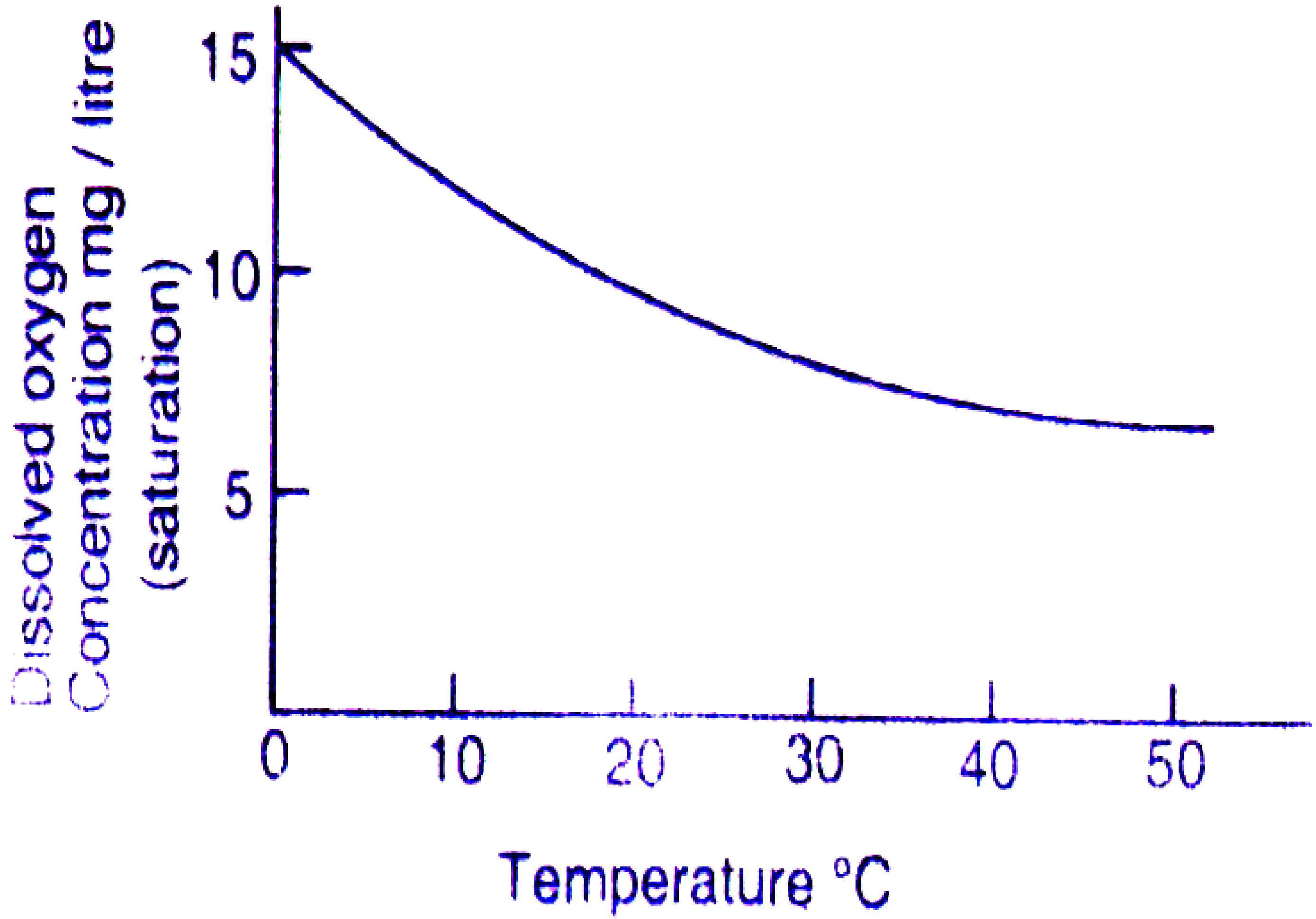
- Temperature
- Hydrographic factors such as the velocity and surface expanse of the river or stream
- Rate of re-aeration
- Amount and type of organic matter
- Available initial DO
- Types of microorganisms present.

Factors affecting self purification capacity of the river or stream

Temperature

- **The rate of biological activity increases with increase in temperature and decreases with decrease in temperature**, hence the rate of oxygen demand also increases with increase in temperature and decrease in temperature.
- **The dissolved oxygen content of water, which is very essential for maintaining aquatic life and aerobic conditions, is also influence by the temperature**. The solubility of oxygen decreases with increase in temperature. The solubility of oxygen decreases with increase in temperature. **So at higher temperature the rate of biological activities is high and the DO concentration is low, causing rapid depletion of DO. This can results in a development of anaerobic conditions and subsequent nuisance.**

Temperature



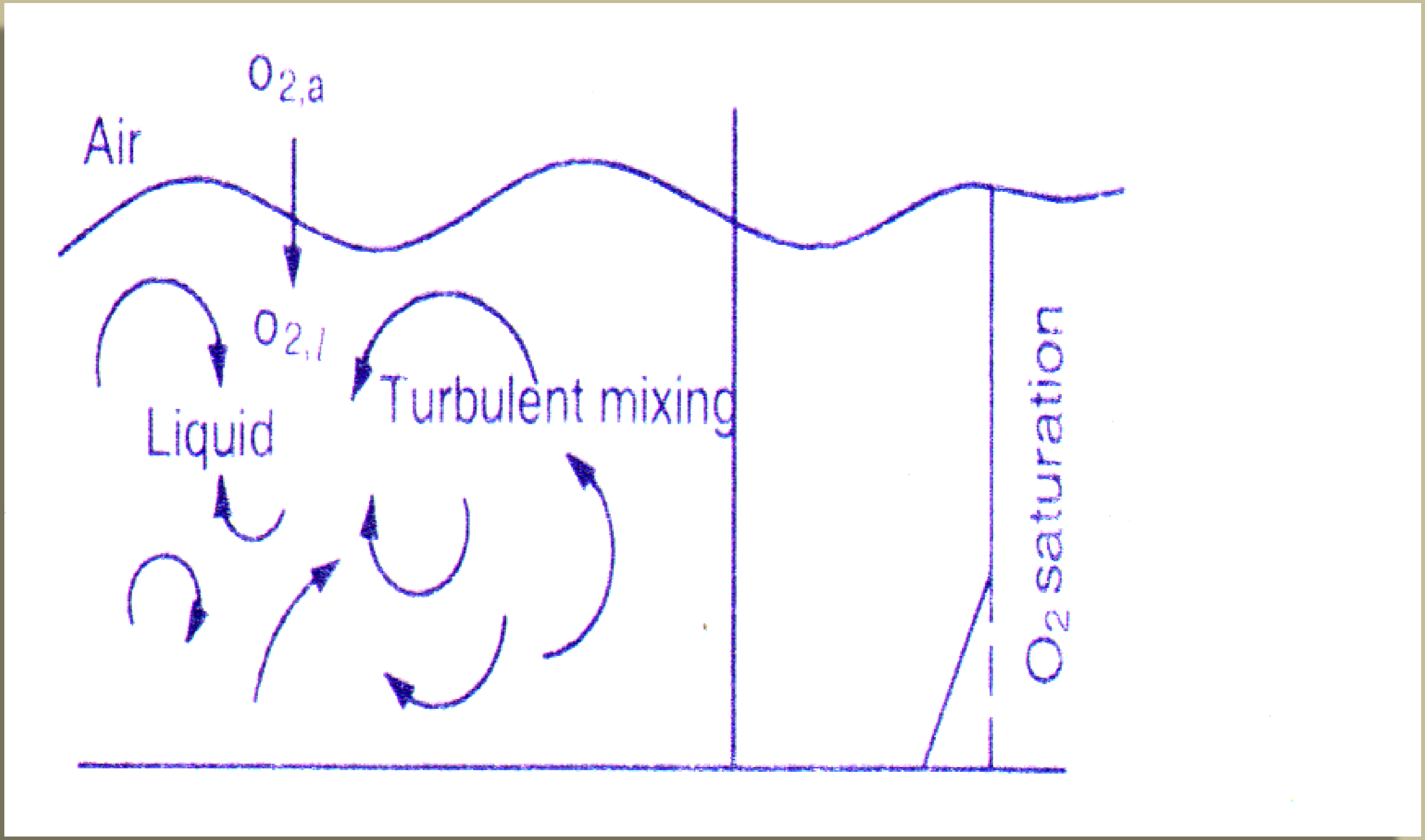
Hydrographic factors like velocity and surface expanse of the river:

- **In a swiftly moving stream i.e. with high velocity the oxygen is replenished quite rapidly**. The water surface at the air liquid interface is being continuously replaced by the turbulence of the stream movement. **The oxygen saturated layer is overturned and replaced by an oxygen deficit layer. In this way the oxygen-saturated liquid is rapidly mixed throughout the stream to supply the microorganisms with sufficient oxygen. Too high velocity is also not preferable because it will created lot of turbulence which would scour the bottom sediments, increase turbidity and retard algal growth.**
- **In a slow moving stream, the surface water is not being turned over. The stream tends to flow in distinct layers**. At the air liquid interface the water is saturated with oxygen which can mix with the oxygen deficit layers only by slow diffusion. The failure to replace the oxygen being used in the lower regions of the stream allows anaerobic conditions to developed.

Hydrographic factors like velocity and surface expanse of the river:

- Rivers having large surface expense will also have better reaeration as large surface area is open to atmospheric diffusion of oxygen.
- **Rate of re-aeration:**
- The rate at which the DO deficiency is replenished, will considerably govern the self purification process. The greater is this rate, the quickere is the self purification. As discuss earlier re-aeration is related to temperature and hydrographic characteristics of river.

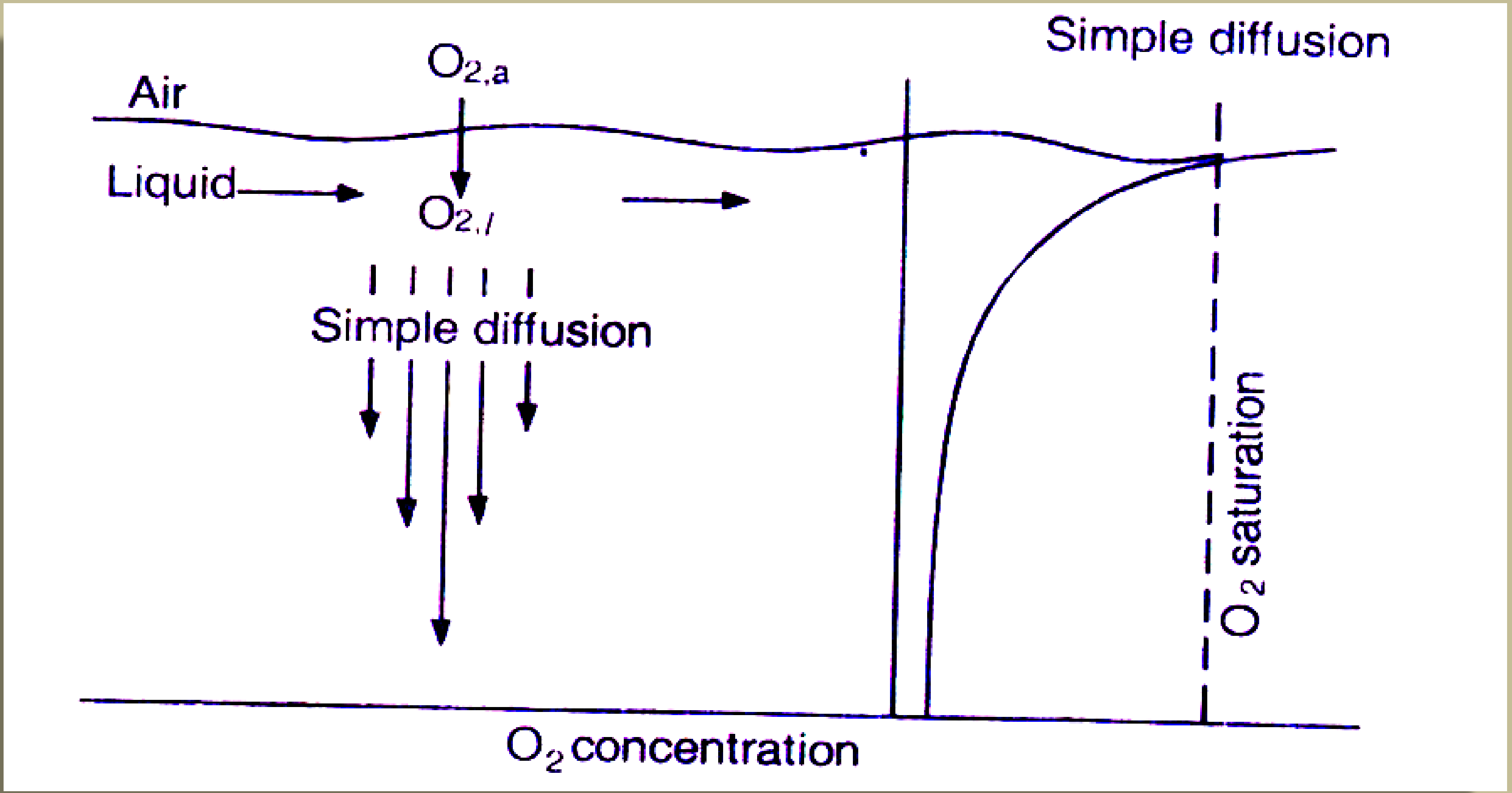
Hydrographic factors like velocity and surface expanse of the river



Amount and type of organic matter

- **If the Waste contains large amount of biodegradable matter its oxygen demand would be very high**. So the DO of the stream depletes faster than the rate of re-aeration and anaerobic conditions are developed. Thus the self purification capacity of the stream is affected.

Amount and type of organic matter



Available Initial DO

- Greater the concentration of DO at the time of sewage discharge, the better and earlier the self purification will occur.

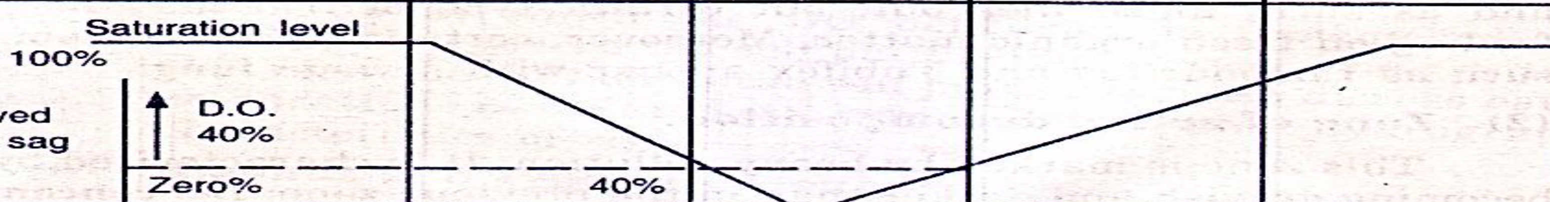
Types of microorganisms present:

- **If algae are present along with the bacteria re-aeration would increase as algae carbon dioxide and gives out oxygen**. So oxygen gets added by algae as well from the atmosphere, thus increasing the DO concentration and thereby increasing the self purification capacity of the river.

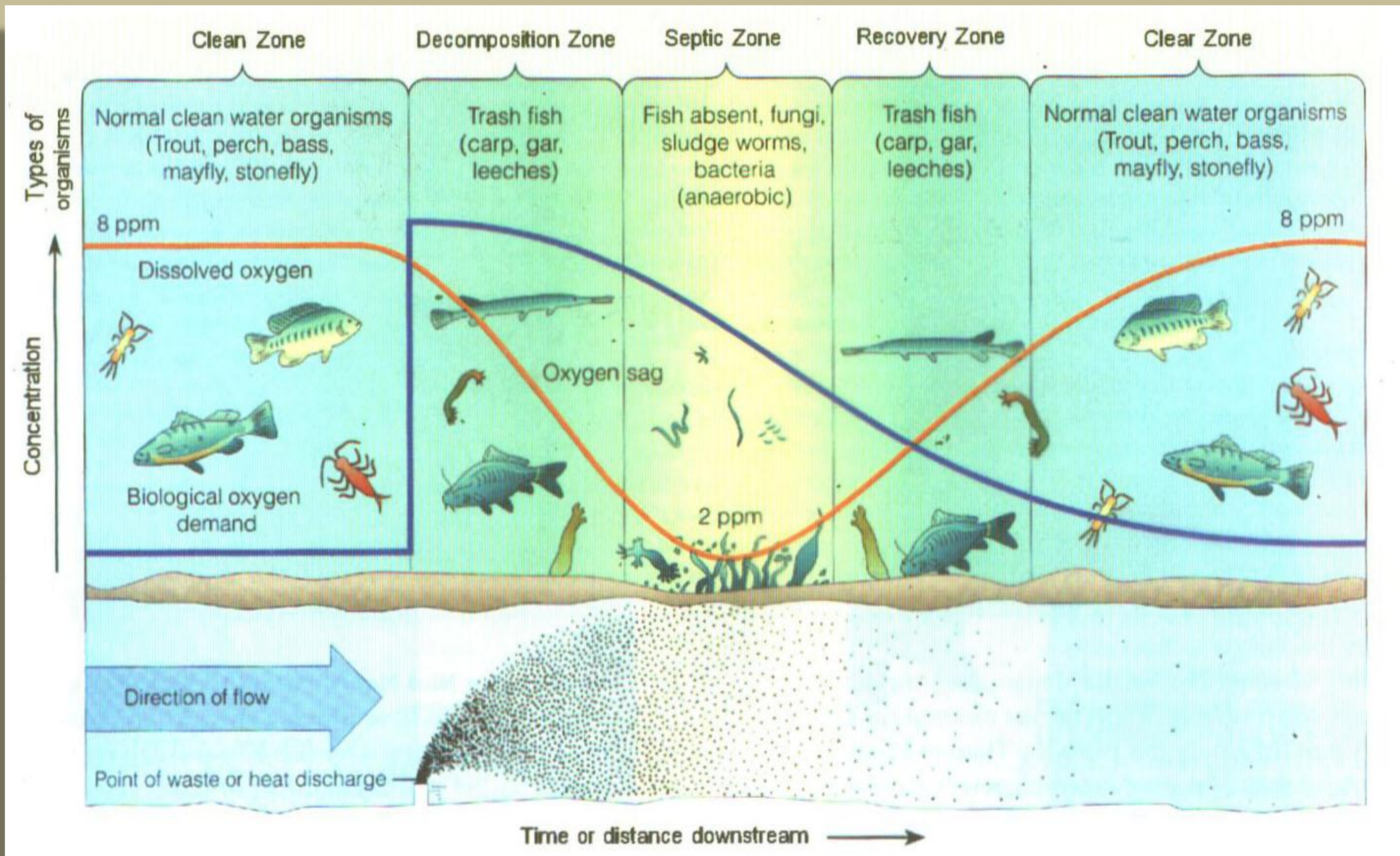
Zones of pollution in a river or Stream

- A polluted stream undergoing self-purification can be divided into following four zones
- **Zone of degradation**
- **Zone of active decomposition**
- **Zone of recovery**
- **Zone of clearer water**
- These zones are explained below:

Zones of pollution in a river or Stream

	← Zones of pollution →				
	Clear water	Zone of degrdation	Zone of active decomposition	Zone of recovery	Zone of clearer water
Dissolved oxygen sag curve					
Physical Indices	Clear water, no bottom sludge, no colour	Floating solids; bottom sludge present, colour getting turbid	Darker and greyish colour, evolution of gases like $CH_4CO_2H_2S$ etc. lot of sludge coming to the surface forming an ugly scum layer at top	Turbid with bottom sludge	Clear water with no bottom sludge
Fish presence	Ordinary fish like game, pan, food & for age etc. present	Tolerant fishes like carps, buffalo, gary, etc. present	No fish present	Tolerant fish like carp, buff alo, etc. are present	Ordinary fish like game, pan, food, and forage, etc. present
Bottom Animals					
Algae & Protozoa etc. called plankton					

Zones of pollution in a river or Stream



Zone of Degradation

- This zone is found for a certain length just ahead of the point where sewage is discharged into the river. **This Zone is characterized by water becoming dark and turbid with formation of sludge deposits at the bottom**. Bacteria will start oxidation of the organic matter the DO is reduced to about 40 % of the saturation valve 9 at 30 0C it is 7.6 mg/l and at 20 0C it is 9.17 mg/l). There is an increase in carbon dioxide content. Oxygenation occurs but is slower than deoxygenating.
- These conditions are unfavorable to the development of aquatic life; and as such, algae dies out, but certain type of fish may be present feeding on fresh organic matter. Moreover, certain typical bottom worms such as limondrilus and Tubifex appear with sewage fungi.

Zone of Active Decomposition

- **This zone is marked by heavy pollution. It is characterized by water becoming grayish and darker than in the previous zone. DO concentration falls down to zero**, an anaerobic conditions may set in with the evolution of gases like methane, carbon dioxide, hydrogen sulphide, etc.. bubbling to the surface, with masses of sludge forming ugly scum layer at the surface. As the organic decomposition slackens due to stabilization of organic matter, rate of deoxygenating becomes lesser than the re-aeration rate and DO again rises to the original level (i.e. above 40 %)
- **In this region, the bacteria flora will flourish. At the upper end, anaerobic bacteria will replace aerobic bacteria, while at the lower end, the position will replace aerobic bacteria, while at the lower end the position will be reversed. Protozoa and fungi first disappear then reappear**. Fish life will be absent. Algae and tubifex will also be absent. Maggots and Psychoda (Sewage fly) larvae will, however, be present in all but the most septic sewage.

Zone of Recovery

- **In this zone, the river stream tries to recover from its degraded condition to its former appearance. The water becomes clearer, and so the algae reappears while fungi decreases.** BOD decreases and DO content rises above 40 % of the saturation value; Protozoa, Rotifers, Crustaceans and large plants like sponges, Bryozoans, etc.. The organic material will be mineralised to form nitrate, phosphate, carbonates, etc..

Zone of Clearer Water

- **In this zone, the river attains its original condition with DO rising up to the saturation value.** Water becomes attractive in appearance, fish (which requires at least 4 to 5 mg /l of DO) and usual aquatic life prevails. Some pathogenic organisms may still, however survive and remain present, which confirms the fact that " once the river water has been polluted, it will not be safe for drinking, unless it is properly treated.

Indices of Self Purification

- The stage of self purification process can be determined by the physical, chemical, and biological analysis of water.
- **Physical Indices**: Colour and turbidity
- **Chemical Indices**: DO, BOD, and suspended solids.
- **Biological indices**: Different types of micro and macro organisms (Growth and presence of different types of organism gives the idea of the self purification process and zone of pollution).

The Oxygen Sag or Oxygen Deficit of a Polluted River.

- The oxygen deficit D at any time in a polluted river is the difference between the actual D.O. Content at the water temperature
- **Oxygen Deficit (D)= Saturation DO- Actual DO**
- In order to maintain clean conditions in a river, the oxygen deficit must be nil, and this can be found out by knowing the rates of de-oxygenation and re-oxygenation.

The Oxygen Sag or Oxygen Deficit of a Polluted River

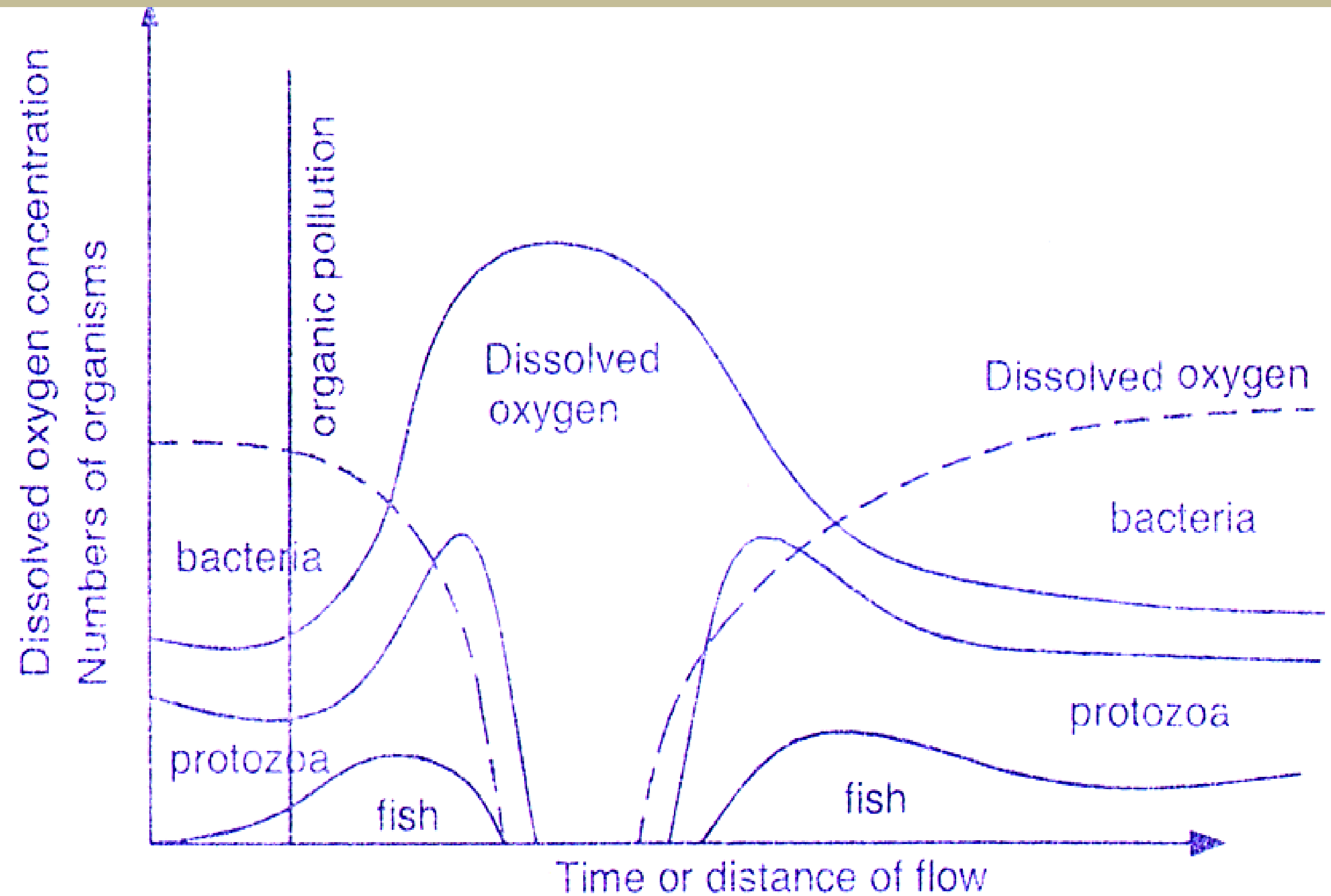


Fig. 3.9 Effect of pollution on biological life in a stream

De- Oxygenation Curve:

- In a polluted steam, the DO content goes on reducing due to decomposition of volatile organic matter. The rate of de-oxygenation depends upon the amount of the organic matter remaining to be oxidized at the given time (L_t) as well as the temperature of reaction (T). Hence, at a given temperature, the curve showing depletion of DO with time which is called de-oxygenation curve is similar to the first stage BOD Curve described earlier. It can also be mathematically expressed by the first stage BOD equation $\frac{Lt}{L} = (10^{-kD.t})$

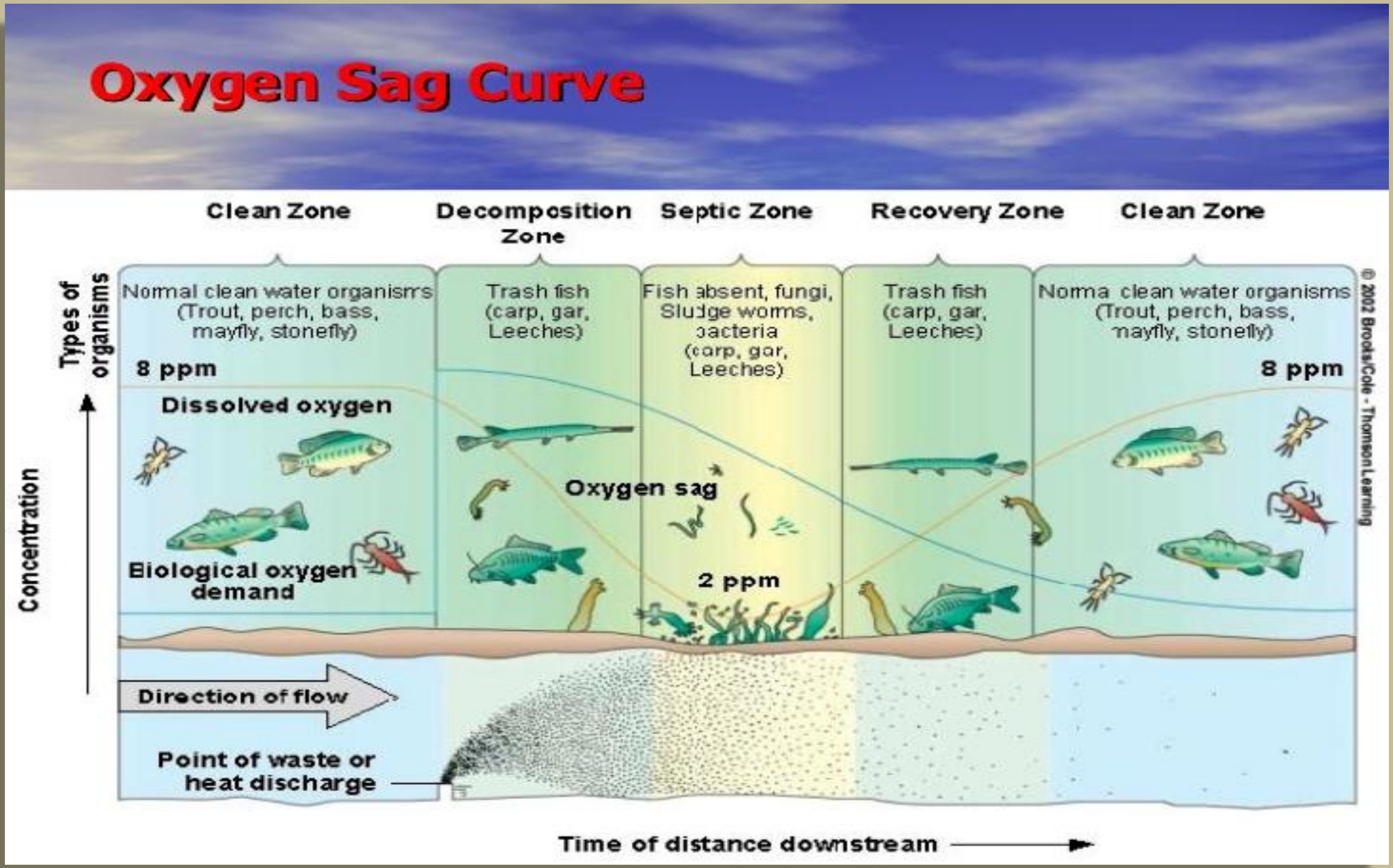
Re-Oxygenation Curve

- Oxygen which is consumed by the bacteria in oxidation of organic matter is replenished from the atmosphere, this process is called re-oxygenation. **The rate at which the oxygen is supplied by the atmosphere to the polluted water depends upon:**
- *Velocity of the stream and the resulting turbulence created, more the velocity more is the rate.*
- *The depth of the receiving water, lesser is depth more is the rate.*
- *Temperature of water, rate decreases with increase in temperature.*
- *The saturation deficit or the oxygen deficit below the saturation valve.*
- *Depending upon these factors, the rate of de-oxygenation can be expressed mathematically and plotted in the form of a curve called re-oxygenation curve.*

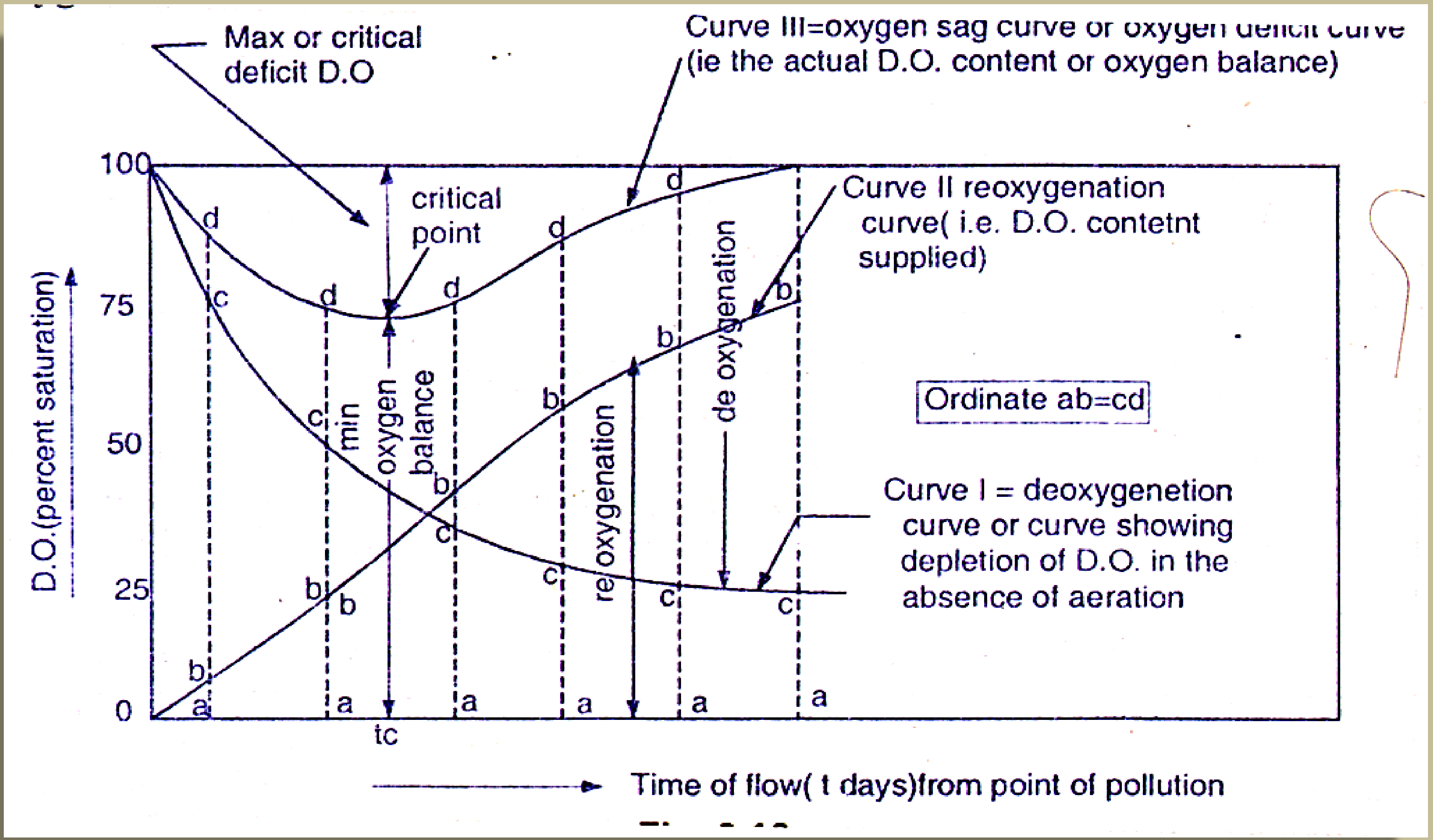
Oxygen Sag Curve or Oxygen Deficit Curve

- In running polluted stream exposed to atmosphere, the deoxygenation and re-oxygenation process occurs simultaneously. If the de-oxygenation is more rapid than the re-oxygenation, an oxygen deficit occurs.
- The amount of the resultant oxygen deficit can be obtained by algebraically adding the de-oxygenation and re-oxygenation curve. The resultant curve so obtained is called the oxygen sag curve or oxygen deficit curve. From the curve, the oxygen deficit D and oxygenation balance (100-D)% in a stream after a certain lapse of time can be found out.
- It can be seen that when de-oxygenation rate exceeds the reoxygenation rate, the oxygen sag curve shows increasing deficit of oxygen; but when both rates become equal, the critical point is reached, and finally when the rate of de-oxygenation falls below that of re-oxygenation, the oxygen deficit goes on decreasing till becoming zero.

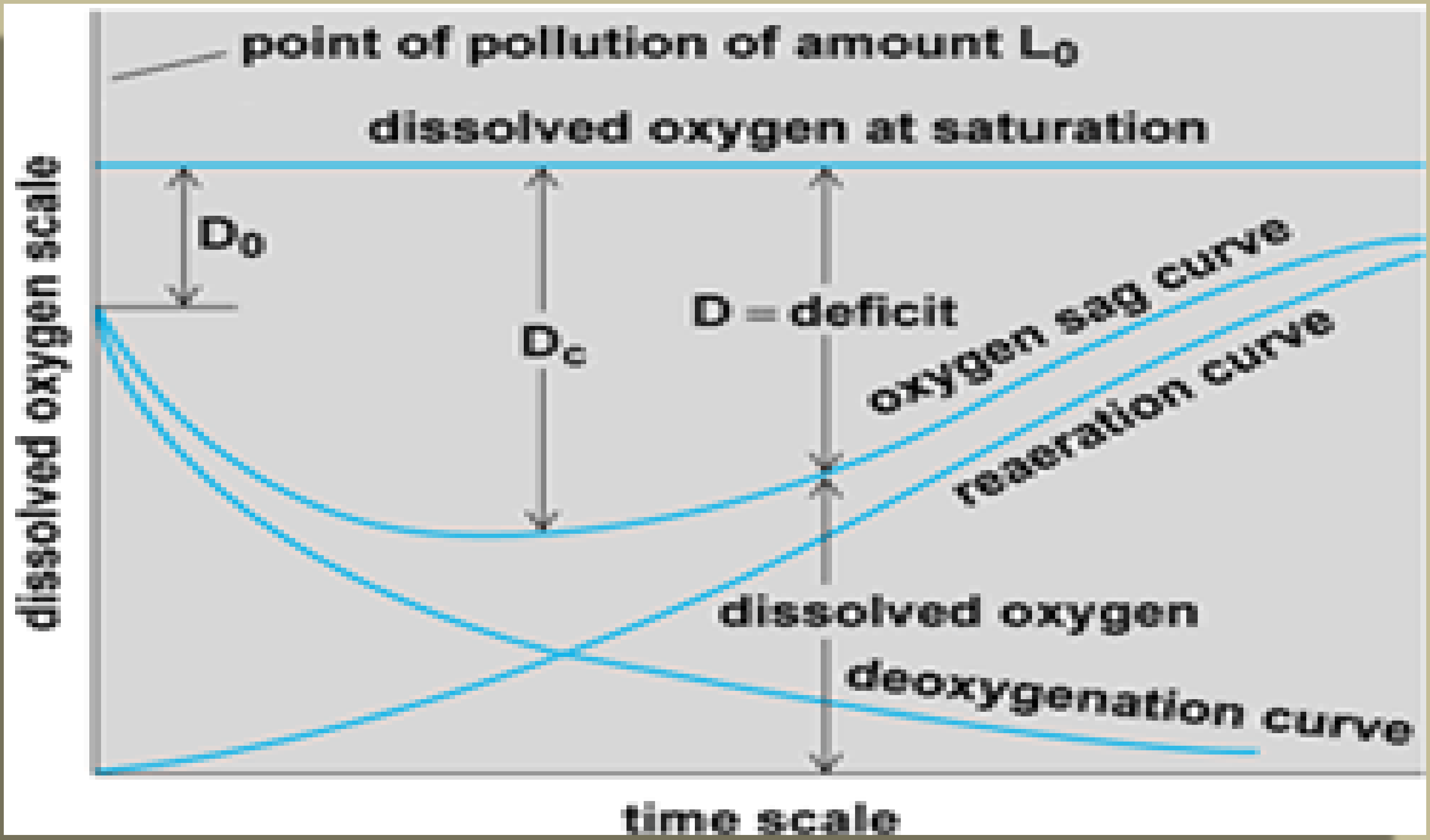
Oxygen Sag Curve or Oxygen Deficit Curve



Oxygen Sag Curve or Oxygen Deficit Curve



Oxygen Sag Curve or Oxygen Deficit Curve



The entire analysis of super–imposing the rates of deoxygenation and re-oxygenation have been carried out mathematically and the results obtained can be expressed in the form of famous streeter-phelps equation, i.e.

$$D_t = \frac{k_D \cdot L}{k_R - k_D}\left[(10)^{-k_D \cdot t} - (10)^{-k_R \cdot t}\right] + \left[D_o \times (10)^{-k_R \cdot t}\right] \qquad ...3.8$$

where D_t = the D.O. deficit in mg/lit after t days

L = ultimate first stage B.O.D. of the mix at the point of waste discharge in mg/lit

D_O = Initial oxygen deficit of the mix at the mixing point in mg/lit

k_D = De–oxygenation coefficient for wastewater, which can be considered as equal to the BOD rate constant determined is the laboratory, through BOD tests performed at different times on BOD bottles.

Also k_D varies with temperature as per equation gives below

$$k_{D(T)} = k_{D(20)}\ (1.017)^{T-20}$$

The typical values of $k_{D(20)}$ vary between 0.1 to 0.2 and generally taken as 0.1.

k_R = Re–oxygenation coefficient for the stream. It can be determined by the field test by using equations

$$k_{D(20^\circ)} = \frac{3.9\sqrt{v}}{y^{1.5}} \qquad ...3.9$$

where v = Avg. stream velocity is m/sec

y = Avg. stream depth in m.

k_R varies with temperature as per the equation

$$k_{R(T)} = k_{R(20^\circ)}\ (1.016)^{T-20^\circ} \qquad ...3.10$$

where $k_{R(T)}$ is the k_R value at T°C and $k_{R(20)}$ is the k_R value at 20°C. Typical values of $k_{R(20)}$ are gives is table 3.17.

Table 3.17 values of reoxygenation coefficient (k_R) at 20°C

Sr. No.	Type of water body	Value of $k_{R(20)}$ per day
1.	Small ponds and back waters	005 to 0.10
2.	Sluggish streams, large lakes and impounding reserviors	0.10 to 0.15
3.	Large streams of low velocity	0.15 to 0.20
4.	Large streams of normal velocity	0.20 to 0.30
5.	Swift streams	0.30 to 0.50
6.	Rapids and waterfalls	over 0.5

Streeter–Phelps Equation

$$D_t = \frac{k_D \cdot L}{k_R - k_D}\left[(10)^{-k_D \cdot t} - (10)^{-k_R \cdot t}\right] + \left[Do \times (10)^{-k_R \cdot t}\right] \quad \ldots 3.8$$

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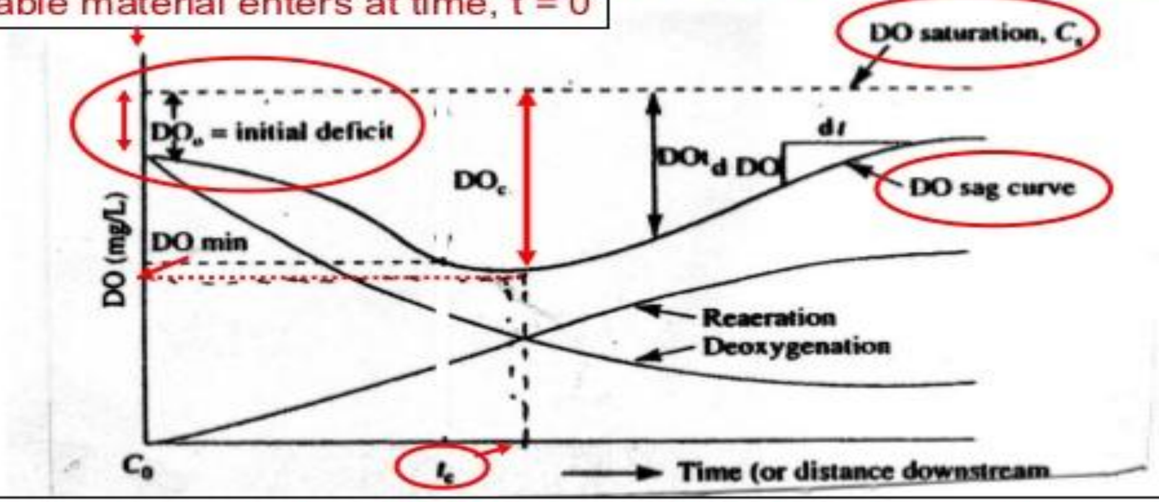
Streeter-Phelps Equation

BOD and Dissolved Oxygen in Aquatic Environments – Streeter-Phelps Equation

Biodegradable material enters at time, t = 0



The Streeter-Phelps Equation predicts the dissolved oxygen changes (DO sag) in water over time after introduction of a biodegradable substance into an aquatic environment.

Streeter-Phelps Equation

k_R = Re–oxygenation coefficient for the stream. It can be determined by the field test by using equations

$$k_{D(20°)} = \frac{3.9\sqrt{v}}{y^{1.5}} \quad ...3.9$$

where v = Avg. stream velocity is m/sec

y = Avg. stream depth in m.

k_R varies with temperature as per the equation

$$k_{R(T)} = k_{R(20°)}\,(1.016)^{T-20°} \quad ...3.10$$

where $k_{R(T)}$ is the k_R value at T°C and $k_{R(20)}$ is the k_R value at 20°C. Typical values of $k_{R(20)}$ are gives is table 3.17.

Table 3.17 values of reoxygenation coefficient (k_R) at 20°C

Sr. No.	Type of water body	Value of $k_{R(20)}$ per day
1.	Small ponds and back waters	005 to 0.10
2.	Sluggish streams, large lakes and impounding reserviors	0.10 to 0.15
3.	Large streams of low velocity	0.15 to 0.20
4.	Large streams of normal velocity	0.20 to 0.30
5.	Swift streams	0.30 to 0.50
6.	Rapids and waterfalls	over 0.5

The oxygen deficit curve can be plotted easily with the help of equation 3.8, by using different values of t is days :

The critical time (t_c) after which the minimum dissolved oxygen occurs can be found by differentiating eq. 3.8 and equating it to zero; which on solving gives

$$t_c \left[\frac{1}{k_R - k_D}\right] \log \left[\left\{\frac{k_D \cdot L - k_R D_O + k_O D_O}{k_D \cdot L}\right\} \frac{k_R}{k_D}\right] \quad ...3.11$$

and the critical or max. oxygen deficit is given by

$$D_c = \frac{k_D \cdot L}{k_R} [10]^{-k_D t_c} \quad ...3.12$$

The constant $\frac{k_D}{k_R}$ is sometimes represented by f, called self purification constant, the values of which are given in table 3.18.

Table 3.18 Values of self purification constant f

Sr. No.	Type of water body	Value of f
1.	Small ponds and back waters	0.5 to 1.0
2.	Sluggish streams, large lakes and impounding reserviors	1.0 to 1.5
3.	Large streams of low velocity	1.5 to 2.0
4.	Large streams of normal velocity	2.0 to 3.0
5.	Swift streams	3.0 to 5.0
6.	Rapids and waterfalls	over 5.0

using $\frac{k_D}{k_R}$ as f, eq. 3.11 becomes as

$$t_c = \frac{1}{k_D(f-1)} \log \left[\left\{1 - (f-1)\frac{D_O}{L}\right\} f\right] \quad ...3.13$$

and equation 3.12 becomes

$$D_c = \frac{L}{f} (10)^{-k_D \cdot t_c} \quad ...3.14$$

Solving this equation and substituting the value of t_c from equation 3.13, we get

$$\left(\frac{L}{D_c \cdot f}\right)^{f-1} = f\left[1 - (f-1)\frac{D_O}{L}\right] \quad ...3.15$$

Disposal of Wastewaters in Lake

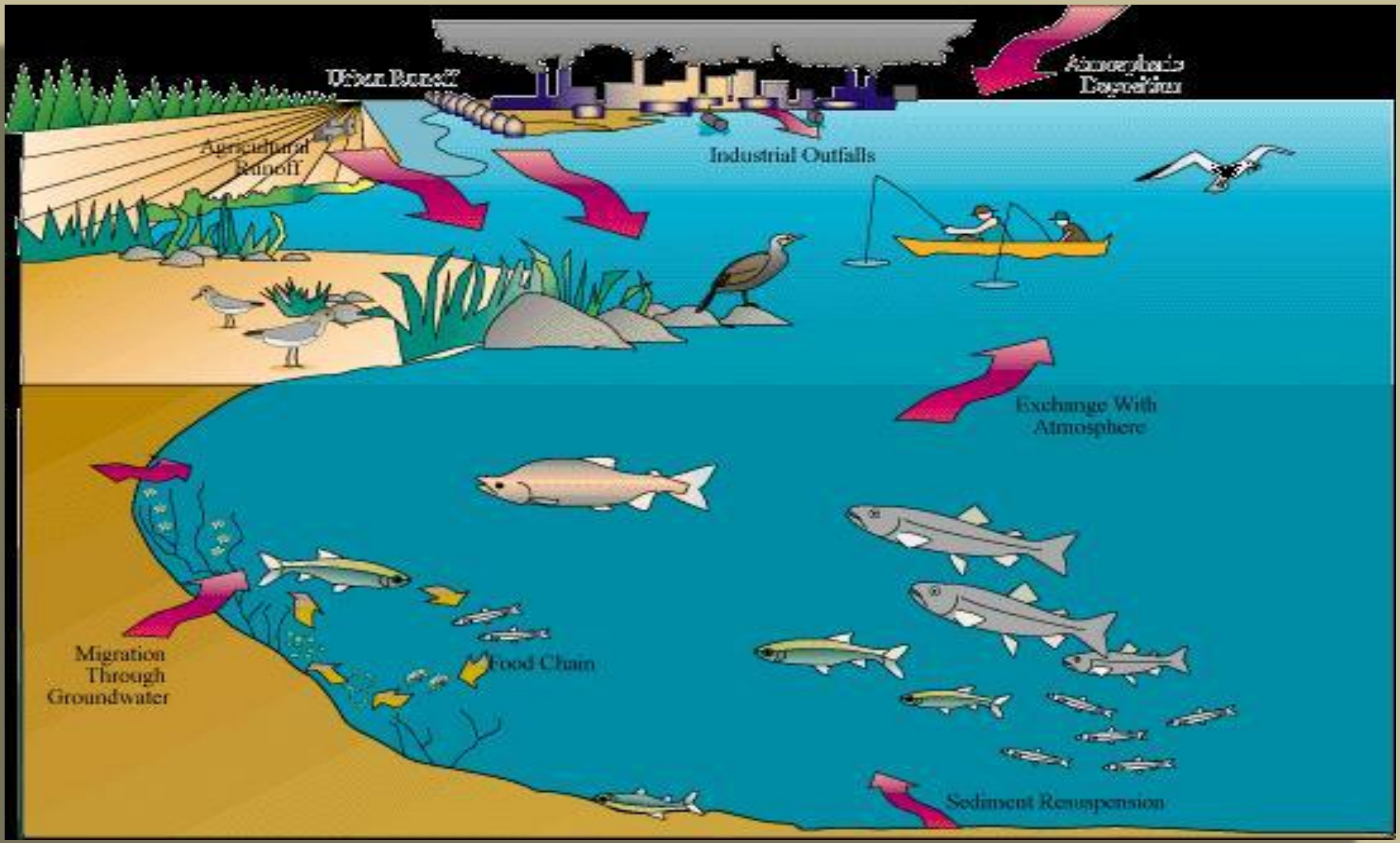
- **Disposal of wastewater in confined in much more harmful than its disposal in flowing streams and rivers**. Water quality management is entirely different from that in rivers. River is a flowing water body while lake has stagnant waters, so in lakes only top surface would become saturated with DO, but the bottom layers would not have enough oxygen. Overturning of layers would not occur frequently, so that DO content would not be uniform through out the depth of lake. Overturning takes place only when there is change in the season due to which there will be temperature difference between water in different layers which cause change in the densities of different layers and overturning occurs.

Disposal of Wastewaters in Lake

Lake Pollutants

- **In Lake the phosphorous a nutrient largely contained in industrial domestic wastewater is seriously affecting the quality of lakes and hence it is considered as the prime lake pollutant**. Oxygen demanding wastes may be the other important lake pollutant. **The toxic chemicals from industrial wastewater can be present.**

Lake Pollutants

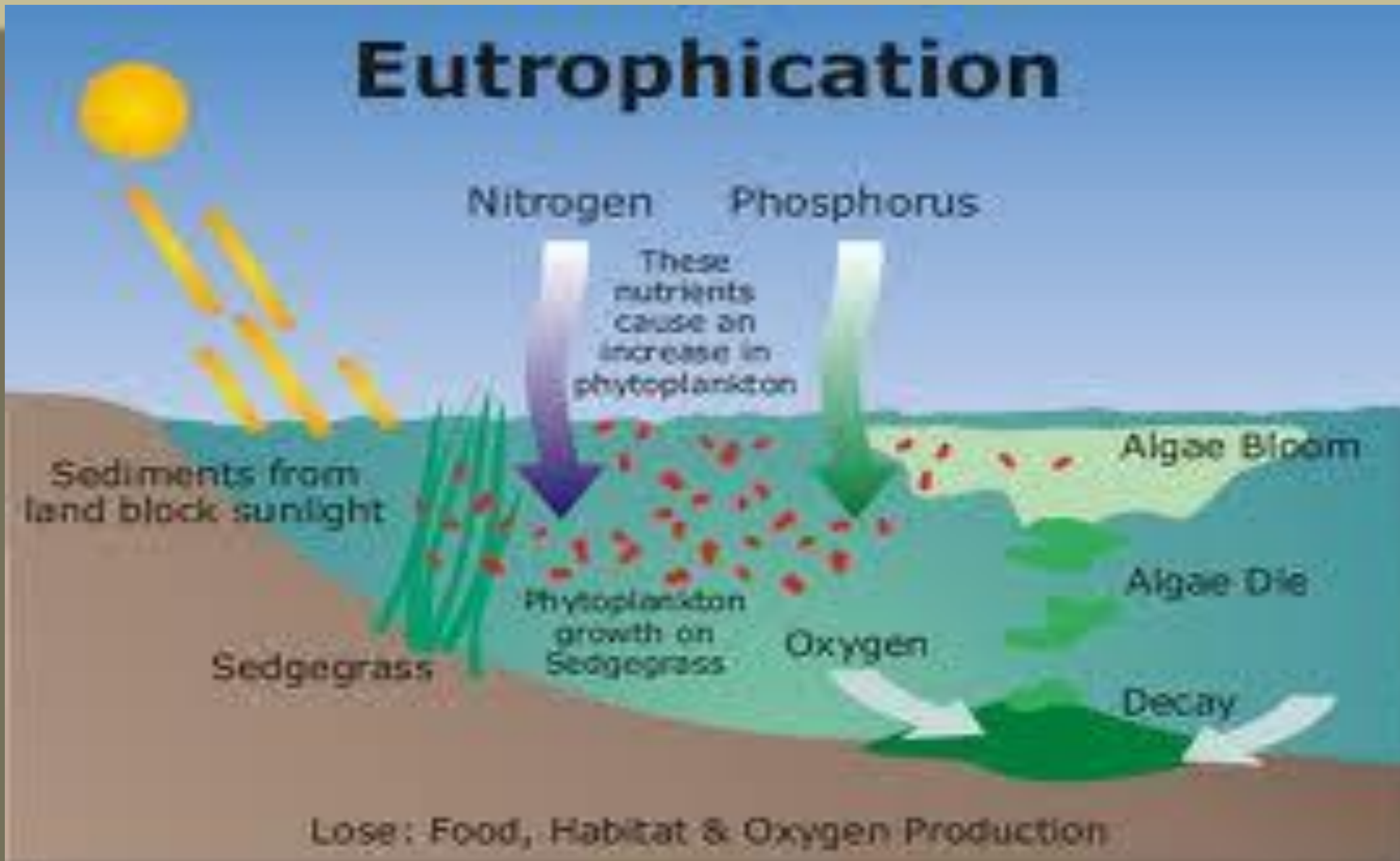


Lake Pollutants

Eutrophication

- **Phosphorous acts as the nutrients for the algal growth. Increase in the phosphorous content would increase the algal growth. Excessive in the phosphorous content would increase the algal growth.** Excessive algal growth (algal Bloom) will create lot of the problems like taste, odour, problems in oxygen diffusion in lower layer. **Ultimately the entire lake can get covered with algae and it may become useless for other organisms**

Eutrophication



Eutrophication

Disposal of Wastewater in Sea or Ocean

- **The saturation concentration of dissolved oxygen in water decreases with increasing salt concentration of DO in sea water is approximately 80 % of that in water. In addition to this deficiency, the temperature of sea water is lower than the sewage temperature, whereas the specific gravity is higher..** Due to this reasons, when the sewage is discharged into the sea water, the lighter and warmer sewage will rise up to the surface, resulting in lighter and warmer sewage will rise up to the surface, resulting in spreading of the sewage at the top surface of sea in a thin film or 'sleek' **Moreover seawater contains a large amount of dissolved matter which chemically reacts with the sewage solids, resulting in the precipitation of some of the sewage solids, giving a milky appearance to the sea water and resulting in formation of sludge banks and thin milky layer formed at the top of sea water produce offensive hydrogen sulphide gas by reacting with sulphate rich sea water.** As such the capacity of seawater to absorb sewage solids is not as high as that of fresh water of a river. Also the DO content is less. **However, since the sea contains large volume of water, most of these deficiencies can be overcome if the sewage is discharged deep into the sea, much away from the coast line, with extreme care.**

Disposal of Wastewater in Sea or Ocean

Table 3.19 BIS (ISI) Standards for Wastewater Effluents to be Discharged into Marine Coasts

S.No.	Constituent Pollutant contained in the Wastewater Effluent	Tolerance Limit
(1)	(2)	(3)
1.	BOD_5	100 mg/l
2.	COD	250 mg/l
3.	pH value	5.5 to 9.0
4.	Total suspended solids	100 mg/l
5.	Oil and grease	20 mg/l
6.	Fluorides (as F)	15 mg/l
7.	Ammoniacal Nitrogen (as N)	50 mg/l

Note : In addition to these major constituents, limits are prescribed for many trace metals and non–metals.

Table 3.20 Comparison between sea water and river/stream water dilution

Item	Sea water	River/stream water
Dissolved oxygen	About 20% less than river	More DO
Specific gravity	High	Low
Quantity of solids in suspension	Large	Small
Penetration of sun rays	Less penetration due to turbid water	More penetration due to clear water
Maximum sewage load	No limits	Depends on stream discharge
Condition of sewage after discharge	Usually anaerobic, formation of sludge banks and giving foul odour.	Mostly remain aerobic
Suitability	For towns situated on sea shore	For towns situated on banks of river

Following points should be kept in mind while discharging sewage into the sea.

- The sewage should be **discharged in deep sea water**.
- In order to mix sewage properly with the seawater, the sewage should be released at a minimum depth of 3 to 5 m **below the water level and taking it sufficiently inside the shore, and thus preventing nuisance to baths and recreation centres on the shore**.
- **To prevent the backing up and spreading of sewage on the sea shore, the sewage should be disposed of only during low tides, large sized tanks may, therefore be constructed to hold the sewage during high tides**. Provision of a large sized sewer, grated with non return valve at the end, is also an alternative to hold the sewage during high tides.

Following points should be kept in mind while discharging sewage into the sea.

- **Before deciding the position of the outfall point, the sea current, wind directions, velocity, etc., should be properly studied. The sea currents, wind direction, velocity, etc..** should be properly studied. The point of disposal should be such that the sewage is taken away from the shore by the winds, and not brought back near the shore by the winds, and not brought back near the shore.
- **The outfall sewer should be placed on a firm rocky foundation, and encased in thick stone masonry, so as to properly protect it from wave action, floating debris, etc..**
- The discharge of Industrial waste waters into sea should however, be controlled in respect of the quality of the effluents, by adhering to the following **Indian standards., prescribed by IS 1968-1976.**

Disposal of Sewage on land

- In this method, the sewage effluent either treated or raw is disposed of by applying it on land. The most common forms of land application are irrigation (Sewage farming) and rapid infiltration.
- When raw or partly treated sewage is applied on the land, a part of it evaporates and remaining portion percolates in the soil. If proper voids are maintained in the soil , the organic sewage solids are oxidized by the bacteria present in the soil under aerobic condition.
- However, if the soil is made of heavy, sticky, and fine grained materials, the void space will soon get clogged resulting in non aeration of these voids which would lead to anaerobic condition and subsequent evolution of foul gases.
- Application of too strong or too hard of sewage will also result in the quick formation of anaerobic conditions. The loads of sewage can be reduced by dilution or pretreatment.

Disposal of Sewage on Land

Disposal of Sewage on Land

Table 3.22 BIS (ISI) standards of wastewater effluents to be discharged on land for irrigation

S. No.	Characteristic/constituent of Effluent wastewater	Tolerance limit as per IS : 3307 – 1965
(1)	(2)	(3)
1.	BOD_5	500 mg/l*
2.	pH value	5.5 to 9.0
3.	Total Dissolved Solids (TDS)	2100 mg/l
4.	Oil and grease	30 mg/l
5.	Chlorides (as Cl)	600 mg/l
6.	Boron	2 mg/l
7.	Sulphates	1000 mg/l
8.	Percentage of Sodium with respect to total content of Sodium, Calcium, Magnesium and Pottasium	60%
9.	Radioactive Materials (i) α–emitters (ii) β–emitters	 10^{-9} μC/ml 10^{-8} μC/ml

Sewage Farming

- In irrigation methods sewage is used for irrigation the crop. This method in addition to disposing the sewage, may help in increasing crop yields as the **sewage generally contains lot of nutrients however the sewage effluent must be made safe before using it for irrigation.**

Sewage Farming

Sewage Farming

Sewage Sickness

- **When the sewage is applied continuously on a piece of land, the soil pores or voids may get filled up and clogged with sewage matter retained in them**. The time taken for such clogging will depend upon the type of the soil and the load present in sewage. But once these voids gets clogged, free circulation of air will be prevented an anaerobic conditions will develop within the pores. **Decomposition of organic matter would take place under anaerobic conditions with evolution of foul gases like H_2S, CO_2 and methane. This phenomenon of soil getting clogged, is known as sewage sickness.**

Methods of Preventing Sewage Sickness

Primary Treatment of Sewage

- **The sewage should be disposed of only after primary treatment**, such as screening, grit removal and sedimentation. This will help in removing settle able solids and reducing the BOD load by 30 % or so and soil will not get clogged frequently

Choice of Land

- **The piece of land used for sewage disposal should normally be sandy or loamy**. Clayey lands should be avoided.

Under drainage of soil

The land, on which the sewage is being disposed of can be drained, if a system of under drains is laid below, to collect the effluents This will also minimize the possibility of sewage sickness.

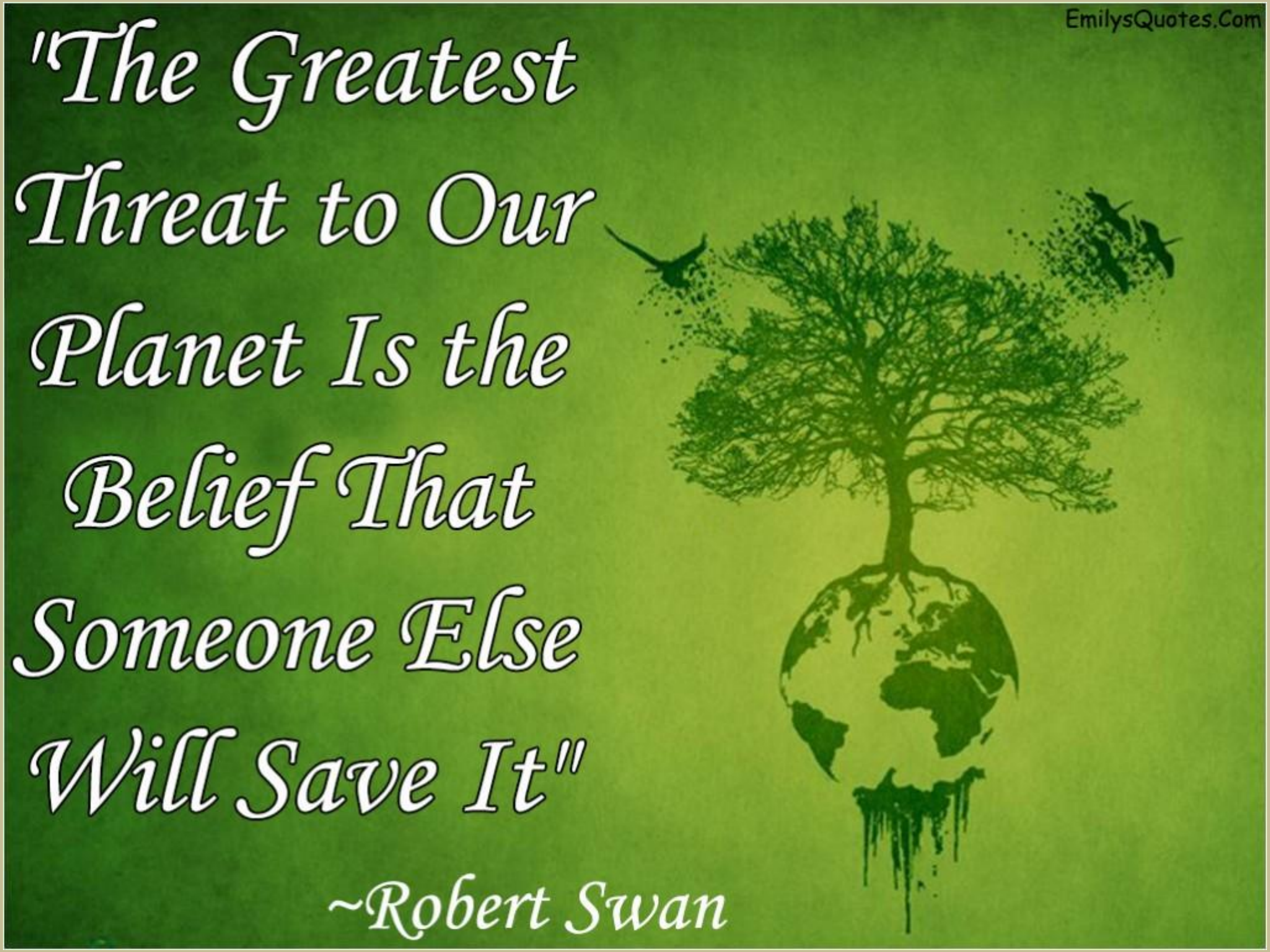
Methods of Preventing Sewage Sickness

Giving rest to the land

- The land being used for disposal should be given rest, periodically by keeping some extra land as reserve and standby for diverting the sewage during the rest period. Moreover, during the rest period, the land should be thoroughly ploughed, so that it gets broken up and aerated.

Rotation of crops

- Sewage sickness can be reduced by planting different crops This will help in utilizing the fertilizing elements of sewage and help in aeration of soil.


"The Greatest Threat to Our Planet Is the Belief That Someone Else Will Save It"
~Robert Swan
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