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1. ABSTRACT

Humans now strongly influence every major aquatic ecosystem by their unpleasant activities which has resulted in alterations in the normal characteristics and the self-purification ability of water. The excess load of nutrients into the water bodies has resulted in various adverse effects of which eutrophication remains the most prominent of all. It has even lead to various diseases in human beings as the freshwater ecosystems are also getting affected by the wrath of eutrophication. People consume the water and infected organisms of those water bodies which results in various dreadful diseases.

This report examines the water quality parameters of **2** of the most prominent water bodies of the capital city of Jharkhand, namely **The Ranchi Lake** and **The Kanke Dam**. Study of the physico-chemical characteristics of these water bodies were done for a certain period of time from November 2018 to March 2019. The parameters discussed in this report are – **pH, Conductivity, Total Dissolved Solids (TDS), Dissolved Oxygen and Biochemical Oxygen Demand (BOD)**. The analysis of the parameters done in this report are the most recent ones. Most of the parameters were not found in the desirable range for drinking water and hence appropriate measures were suggested to improve the water quality.

Eutrophication causes a tremendous increase in the algal growth on the surface of the water body, which has been reported world-wide, especially for freshwater ecosystems. The excessive algal growth does not allow photosynthesis to take place properly and thus a Hypoxic zone gets created underneath the mat which proves to be lethal for the aquatic community.

This report also contains a brief description of the types of eutrophication, the factors getting disturbed due to eutrophication and the management and control measures to be taken for controlling the adverse impacts of eutrophication.

2. INTRODUCTION

Throughout the history Man has settled near the freshwater lakes and rivers because of his divers needs for water. In the beginning, when the populations were sparse, waters were able to take their own care due to their self-purification capacity, but the ever increasing human pressure on the water bodies because of exponential population growth, modern technology and agriculture, has led to several water pollution problems. One of the most severe and commonest water pollution problems is due to the enrichment of waters by plant nutrients that increases the biological growth and renders the water bodies unfit for diverse uses.

The process of excessive nutrient enrichment of waters that typically results in problems associated with macrophytes, algal or cyanobacterial growth is known as *Eutrophication.*

The eutrophication is basically a natural phenomenon which gets accelerated by increased nutrient supply through human activities. The process of eutrophication starts soon as the lakes are formed, because of the entry of nutrients by natural means, but the rate of eutrophication remains quite low under natural conditions. The present concern for eutrophication relates to the rapidly increasing quantities of nitrogen and phosphorous which are present fairly at low concentration in unmodified natural waters to limit the algal growth.

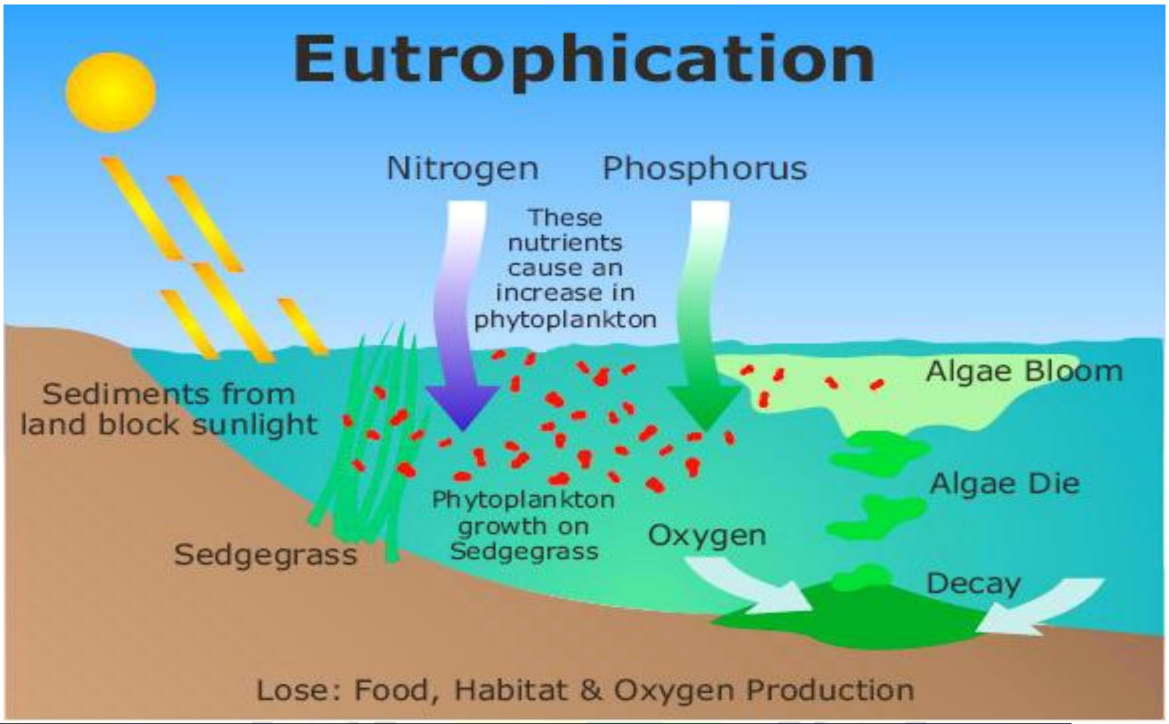


Fig: Pictorial representation of eutrophication.

The word '**eutrophic**' comes from the **Greek** word ***eutrophos*** meaning **enrichment of nutrients**. **Weber (1907)**, while studying the evolution of North German peat bogs, found that the upper layers have more nutrients in comparison to the lower layers as the original lakes received much higher nutrients supply prior to their transformation into bogs. He used the terms "eutrophic" (rich in nutrients) and "oligotrophic" (poor in nutrients) to distinguish between these two layers. The trophy of waters indicates the intensity and kind of its organic matter supply. The trophy of water refers to the rate of organic matter supply per unit area per unit time, and cannot be equated with nutrient levels (Findenegg, 1955). The trophy of waters may be through either of the two ways:-

a. Autotrophic (own production)

b. Allotrophic (from surrounding)

It was accepted by all, that for eutrophication, the supply of food should be autotrophic means, and where the main supply of organic matter is by **allochthonous** means, the lakes were called **'*dystrophic*'** having often low primary productivity. However, the lakes with dystrophic conditions but having higher productivity, were called **'Mixotrophic' (Jarnefelt,1925).**

The few points that are important aspects of the present day eutrophication concept are as follows:-

1. Enrichment with nutrients increases the phytoplankton growth in waters, but it cannot be considered as a only factor for eutrophication, as it is possible that the growth may be limited by other conditions like temperature, light, and some other growth factors.

2. Trophy of waters cannot be defined by only algal density and biomass as it also incorporates production, though both are related.

3. The most important criterion for eutrophication is the increase in phytoplankton productivity.

4. The eutrophication term should be applied only to autotrophic production, while for the allotrophic lakes, it is called dystrophy.

3. MECHANISM OF EUTROPHICATION

Eutrophication arises from the oversupply of nutrients, which leads to overgrowth of plants and algae. After such organisms die, the bacterial degradation of their biomass consumes the oxygen in the water, thereby creating the state of **Hypoxia.**

The primary limiting factor of eutrophication is Phosphate. The availability of phosphorous generally promotes excessive plant growth and decay, favouring simple algae and plankton over the other more complicated plants, and cause a severe reduction in water quality.

Phosphorous is a necessary nutrient for plants to live, and is the limiting factor for plant growth in many freshwater ecosystem. Phosphate adheres tightly to soil, so it is mainly transported by erosion. Once translocated to lakes, the extraction of phosphate into water is slow, hence the difficulty of reversing the effects of eutrophication.

The sources of these excess phosphates are phosphates in detergents, industrial or domestic run-offs have emerged as the dominant contributors to eutrophication. However, numerous literature reports that Nitrogen is the primary limiting nutrient for the accumulation of algal biomass. Sodium triphosphate is one of the components of many detergents, which is a major contributor to eutrophication.

The process of eutrophication takes place in the following steps:-

1. Excess nutrients are applied to the soil.
2. Some nutrients leach into the soil where they can remain for years.
3. Eventually, they get drained into water body.
4. The excess nutrients cause an **algal bloom**.
5. The algal bloom blocks the light of the sun from reaching the bottom of water body.
6. The plants beneath the algal bloom die because they cannot get sunlight to photosynthesis.
7. Eventually, the algal bloom dies and sinks to the bottom of the lake. Bacteria begins to decompose the remains, using up oxygen for respiration.

4. TYPES OF EUTROPHICATION

The idea that over thousands of years a natural development ontogeny of lakes occurs from deep and oligotrophic to shallow and eutrophic, then to a wetland and then a terrestrial meadow has been present in the ecological literature for decades. Eutrophication or nutrient pollution, is a major environmental concern for lakes, tributaries, rivers, estuaries and coastal water.

There are two types of eutrophication:-

a. Cultural Eutrophication

b. Natural Eutrophication

4.a Cultural Eutrophication

Cultural eutrophication also known as **Anthropogenic** or **Accelerated** Eutrophication, is the process that speeds up natural eutrophication because of human activity. Due to clearing of land and building of towns and cities, land runoff is accelerated and more nutrients such as phosphates and nitrate are supplied to lakes and rivers, and then to coastal estuaries and bays. Extra nutrients are also supplied by treatment plants, golf courses, fertilizers, farms, as well as untreated sewage.
When algae die, they decompose and the nutrients contained in that oganic matter are converted into inorganic form by microorganisms. This decomposition process consumes oxygen, which reduces the concentration of dissolved oxygen. The depleted oxygen levels in turn may lead to fish kills and a range of other effects reducing biodiversity. Nutrients may become concentrated in an **anoxic zone** and may only be made available again during autumn turn-over or in conditions of turbulent flow.

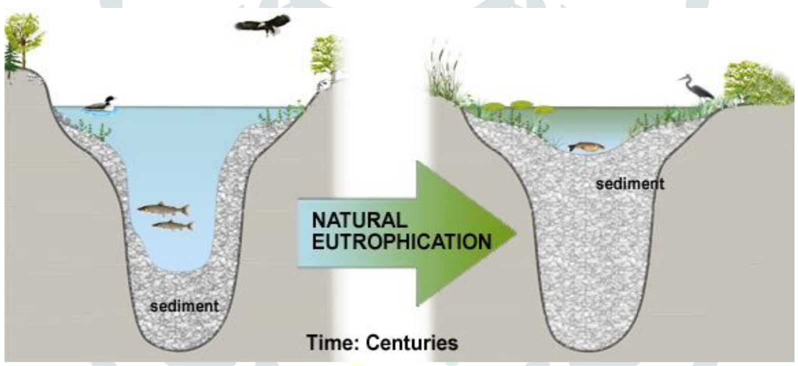
Enhanced growth of aquatic vegetation or phytoplankton and algal blooms disrupts normal functioning of the ecosystem, causing a variety of problems such as a lack of oxygen needed for fish and shellfish to survive. The water becomes cloudy, typically coloured a shade of green, yellow, brown, or red. Eutrophication also decreases the value of rivers, lakes and aesthetic enjoyment. Health problems can occur where eutrophic conditions interfere with drinking water treatment.
Human activities can accelerate the rate at which nutrients enter ecosystem. Runoff from agriculture and development, pollution from septic systems and sewers, sewage sludge spreading, and other human-related activities increases the flow of both inorganic nutrients and organic substances into ecosystems.
Phosphorous is often regarded as the main culprit in cases of eutrophication in lakes subjected to **"point source"** pollution from sewage pipes. The concentration of algae and the trophic state of lakes correspond well to phosphorous levels in water.

4.b Natural Eutrophication

Although eutrophication is commonly caused by human activities, it can also be a natural process, particularly in lakes. **Eutrophy** occurs in many lakes like in temperate grasslands.

The lakes generally originate as oligotrophic and have limited quantities of nutrients depending upon the mode of their formation and composition of original sediments. These nutrients are however, insufficient to produce any significant algal growth. At this stage the lakes have only autochthonous nutrients, which usually recycle completely in the absence of any outside supply. All the biological production is completely decomposed after death. As the allochthonous nutrients start entering the lake, the process of eutrophication sets in. the principal natural sources of nutrients are the natural runoff, fall of leaves and twigs from the surrounding vegetation, periodical submergence of the nearby terrestrial vegetation, rain fall and bird droppings, etc.

The buildup of nutrients through this slow mode of entry gradually starts increasing the growth of algae. When the algae die and decompose, the locked nutrients are again made available to the fresh algal growth. During each cycle, the nutrients are progressively increased in the water body. With the advancement of eutrophication, the cycling of nutrients is unable to maintain an equilibrium between production and decomposition with the result that an ever-increasing organic matter is introduced in the lakes which ultimately gets deposited at the bottom. Slowly, the thickness of the bottom sediments increases with time, leading to the formation of swamps, bogs, marshes, and finally to the extinction of the water body in the long run.



The process of eutrophication in lake passes from oligotrophic to eutrophic condition through some arbitrary intermediate stages called **oligo-mesotrophic**, **mesotrophic** and **meso-eutrophic**. It is also evident that with the progress of eutrophication, an increasing quantity of nutrients come in circulation, and cycles become unable to complete. The speed of eutrophication does not depend only on the rate of nutrient supply, but other factors like climate and morphometric features also become important. The tropical or hot climate usually supports a higher rate of eutrophication as it favors higher nutrient utilization and algal growth in comparison to cold and temperature climates.

5. CLASSIFICATION OF TROPHIC STATE OF AN AQUATIC BODY

The **Trophic State** is a classification system designed to be defined as the total weight of biomass in a given aquatic system at the time of measurement. This is based on the amount of oxygen present in the Hypolimnion during the summer.

Certain types of phytoplankton and zooplankton are found in typically high-nutrient lakes and others in nutrient-poor lakes. Rhode (1970) gave an approximate range of phytoplankton production in oligotrophic and eutrophic lakes which was used for trophic categorization of lakes.

Table 5.A*: Approximate ranges of phytoplankton primary production in oligotrophic and eutrophic lakes.*

Lakes	Mean rates in growing season (mg C.m-2 .d-1)	Annual rates (g cm-2 yr-1)
Oligotrophic	30-100	7-25
Eutrophic (i)Natural (ii)Polluted	 300-100 1500-3000	 75-250 350-700

Classification of trophic state of aquatic bodies are important because they allow us to compare productivity of ecosystems within and among ecoregions and provide an initial approach to determine the extent of Cultural Eutrophication. An **Ecoregion** or ecological region is an ecologically and geographically defined area containing distinct assemblages of natural communities and species. The biodiversity of flora and fauna is distinct for every ecoregion.

Trophic State Index (TSI) is a classification system designed to rate bodies of water based on the amount of biological activity they sustain. Although the term "trophic index" is commonly applied to lakes, any surface body of water may be indexed. The quantities of nitrogen, phosphorus, and other biologically useful nutrients are the primary determinants of TSI of a water body. Nutrients such as nitrogen and phosphorus tend to be limiting resources in standing water bodies, so increased concentrations tend to result in increased plant growth, followed by subsequent increase in the trophic levels. **Wetzel (1975)** classified water bodies based on the concentration of Nitrogen and Phosphorus.

Table 5.B: ***Trophic classification of water bodies on the basis of concentration of Nitrogen and Phosphorus*.**

Trophic Category	*Inorganic Nitrogen (in mg/m)*	*Total Phosphorus (in mg/cubic metre)*
Ultra-oligotrophic	<200	<5
Oligo-mesotrophic	200-400	5-10
Meso-eutrophic	300-650	10-30
Eutrophic	500-1500	30-100
Hyper-eutrophic	>1500	>100

Shanon and Breznonic (1972) developed TSI in the form of a score ranging from 0 to 10 and divided the clear and coloured water bodies into 5 categories.

Table 5.C: ***TSI score on which lakes can be categorized.***

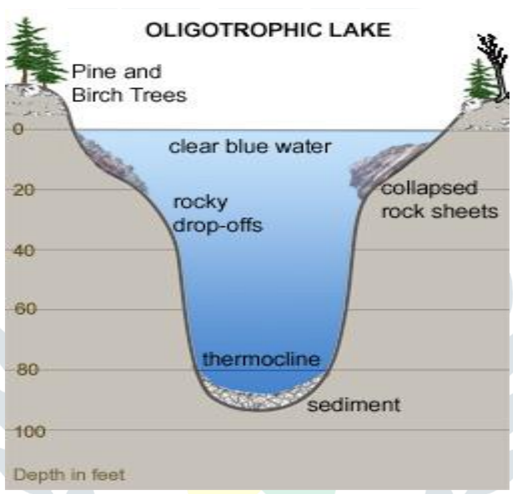
Trophic category	*TSI score*
Hyper-eutrophic	>10
Eutrophic	7-10

Meso-trophic	3-7
Oligo-trophic	2-3
Ultra-oligotrophic	<2

On the basis of the nutrient content and fertility, any aquatic body, especially freshwater body can be classified into the categories mentioned below.

5.1 Oligotrophic

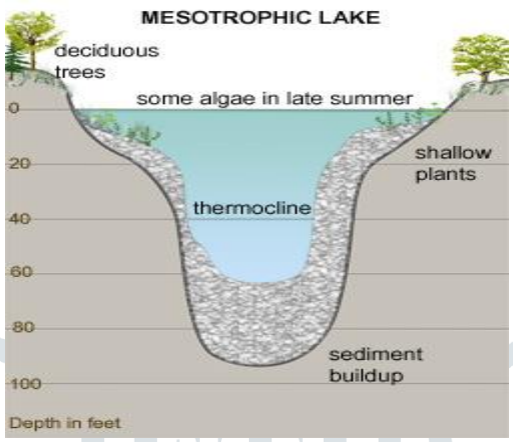
'Oligo' means **'few'** and **'trophos'** means **'nutrition'**. An oligotrophic lake is a lake with low primary productivity, as a result of low nutrient content. These lakes have low algal production, and consequently, often have very clear waters, with high drinking-water quality. They are very deep nearly 18 metres with little vegetation around the margin. They have rich oxygen content in the Hypolimnion. The bottom contour is **V-shaped** and is very low in fertility. The volume of Epilimnion is less than that of the Hypolimnion.



Common physical characteristics of oligotrophic lake communities include blue or green highly transparent water, Secchi disk depths ranging from 4 to 8 metres, low dissolved nutrients, especially nitrogen and calcium, low primary productivity and sediments with low levels of organic matter. In the case of oligotrophy the vertical oxygen distribution is essentially uniform.

5.2 Mesotrophic

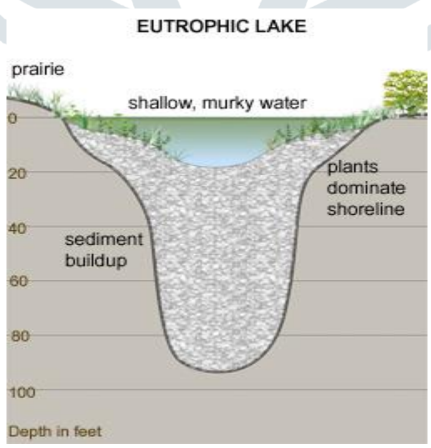
"Meso" means **'medium'** and "trophos" means 'nutrition'. It is an intermediate stage between Oligotrophic and Eutrophic lakes. They contain medium amount of nutrients and are usually found with algal blooms in late summers.



The top layer of the water surface becomes warm from the Sun rays and contain algae. Since oxygen is the byproduct of photosynthesis so its concentration remains high on the surface. The bottom layers become coloured and become **anoxic** in mid summers.

5.3 Eutrophic

'Eutrophos' means **'well-nourished'** or **'nutrient-rich'**. They are usually less than 18 metres deep. The bottom contour becomes **U-shaped** and water colour varies from green to yellow or brownish-green. They are large areas of shallow waters and more marshy vegetation. The fertility of this kind of lake is quite high as the bottom region is rich in Humus content. The oxygen content of the Hypolimnion is greatly reduced during summers. The volume of Epilimnion is usually greater than the Hypolimnion. Plankton are abundant and consist of various different kinds of species in contrast to Oligotrophic lakes.



Under eutrophic conditions, oxygen values decrease with depth, and the vertical distribution. This is called **Clinograde**. As eutrophic conditions develop, bottom sediments become enriched in organic material, and bottom plants spread throughout the littoral zone eventually converting it into a marshy zone.

5.4 Dystrophic

They are generally **bog-type**, very rich in marginal vegetation and organic content. Oxygen is likely to be scarce or deficit at this depth. The colour of the water changes from yellow to brown and may be acidic due to organic acid and incompletely oxidized decomposition products. Plankton, bottom organisms and fish are usually scarce and **blue-green algae** are often found in abundance on the surface of these kind of lakes. The littoral zone of these kind of lakes become marshy and the lake eventually converts into pond and then it finally gets transformed into a forest cover after a certain succession period.

Qualitatively, we can say that Oligotrophic lakes are low in nutrients, support small algal populations, have low primary production and high transparency with greater mean depths. On the other hand, Eutrophic lakes have high quantities of nutrients, high densities and biomass of algal populations with high primary production, low transparency and usually shallow. But no precise and universally accepted quantification of these data has been made that reflect the true picture of the level of Eutrophication.

6. SOURCES OF EUTROPHICATION

Nutrient pollution released to freshwater or coastal areas come from many diverse sources indulging agriculture, aquaculture, sewage disposal, runoff, and many others. Sources can be broadly classified into two types viz., **Point Sources** and **Non-Point Sources**.

Point Sources are single identifiable sources of pollution. In point sources, the nutrient waste travels directly from the source to the water bodies. They are relatively easy to regulate. Pollutants from Industrial Sources, Power Plants, Sewage Treatment Plants, etc. are regarded as the Point Sources.

Non-Point Sources are those pollutants which come from diffused or ill-defined sources. They are difficult to regulate and usually vary spatially and temporarily with season, precipitation and other irregular events. Pollutants from Urban Sources, Agricultural Sources, Fossil Fuel Sources, etc. are regarded as the Non-Point Sources.

Nutrients enter aquatic medium either by air, surface water or ground water. From region to region, there are significant variations in the relative importance of nutrient sources. The basic broad sources of nutrient enrichment of water bodied are:-

6.1 Agricultural sources

Agricultural nutrient sources include fertilizer leaching and runoff from agricultural fields, wastes from aquaculture operations and left overs of manures.

6.1a) Chemical Fertilizers (Phosphates and Nitrates):- Fertilizers are applied in the fields in the greed of getting excess yield. These fertilizers then get washed away with water and get dumped into the nearby water body increasing the nutrient content of the water body. The fertilizers, which contain nitrogen and phosphorous, are lost through volatilization, surface runoff and leaching to the groundwater. A portion of the volatilized ammonia is re-deposited in the water through atmospheric deposition phosphorous, which binds to the soil, is generally lost through soil erosion from agricultural fields.

6.1b) Manure:- The rapidly changing nature in the rise of livestocks has also resulted in the addition of nutrients into the water body. The large quantity of wastes produced by the livestock is used as a manure and is applied to land as fertilizers to decrease the expenditure on costly chemical fertilizers, stacked in the feedlot or stored in lagoons. An oversupply of manure to the fields means that the excess amount of manure will ultimately be washed off or added into the water body, thus decreasing the nutrient content.

6.1c) Aquaculture (fish farming):- Aquaculture is another growing source of nutrient pollution. Marine fish and shrimp farming often occurs in nets or cages situated in enclosed bays. These farms generate concentrated amounts of nitrogen and phosphorous from their excreta, uneaten food, and other organic wastes. If improperly managed, aquaculture operations can have severe impacts on the aquatic system. For every ton of fish, aquaculture operations produce **42 to 66 kg** of nitrogen waste and **7.2 to 10.5 kg** of phosphorous waste (Strain and Hargrave, 2005).

Annual aquaculture production worldwide increased by 600% in 20 years, from 8 million tons in 1985 to 48.2 million tons in 2005. Today nearly 43% of all aquaculture production is within marine or brackish environment. One of the largest brackish water environment for aquaculture is **Chilka Lake** in **Odisha** which has also started deteriorating day by day due to intensive aquaculture.

6.2 Urban and Industrial sources

Municipal wastewater treatment plants and industrial wastewater discharges, nitrogen leaching from below-ground septic tanks, storm water runoff are some of the urban and industrial sources of nutrient pollution. Municipal sources is often considered as “point source” of nutrient pollution because they discharge nutrients directly to surface water or groundwater via pipe or other discrete conveyance.

Table 6.2.a: ***Average characteristics and nutrient loading of Urban run-off water (based on Weibel et al., 1964)***

Parameters	*Concentration (mg/L)*	*Mass Discharge (kg/acre/yr)*
BOD	18	15
Suspended solids	77	331
Total Nitrogen	1.2	4.1
Total Phosphorus	0.3	1.1

The most prevalent urban source of nutrient pollution is human sewage because in most of the countries when sewage is treated, it is typically aimed at remaining solid wastes and not nutrients. For industrial sources of nutrient pollution, certain industries are larger sources than other. Paper and pulp mills, food and meat processing industries, agro-industries and direct discharge of sewage from maritime vessels are some of the larger sources of industrial nutrient pollution.

Storm water runoff is another significant source of nutrients from urban areas. Rainfall events flush nutrients from residential lawns and impervious surfaces into nearby rivers and streams causing nutrient enrichment.

Table 6.2b*: Average Nitrogen and Phosphorus in Rural runoff (after Fruh, 1968)*

Origin of runoff	*Total Nitrogen (kg/acre/yr)*	*Total phosphorus (kg/acre/yr)*
Forest runoff	0.6-1.4	0.13-0.36
Surface irrigation return flow	1.1-10.8	0.42-1.76
Sub-surface irrigation return flow	17.2-75.3	1.1-7.3

These sources play a major role in enrichment of the water bodies as the greatest amount of nutrients are discharged from these sources, especially from the Municipal Sewage which contains a good amount of phosphates and nitrates, which are the main reasons of Eutrophication.

6.3 Fossil fuel sources

When fossil fuels are burnt, they release nitrogen oxides (NOx) into the atmosphere. NOx contributes to the formation of smog (smoke+fog) and acid rain. NOx is redeposited to land and water through rain and snow, known as Wet deposition or can settle out in the air in a process known as Dry deposition. Coal-fired power plants and exhaust from cars, buses and trucks are the primary sources of NOx.

6.4 Natural events

Natural events such as floods and the natural flow of rivers and streams can also wash excess nutrients off the land into water system thus causing excessive growth of algal blooms.

Also, as lakes grow old, they naturally accumulate sediments as well as phosphorous and nitrogen nutrients which contribute to the explosive growth of phytoplankton and cyanobacterial blooms.

6.5 Rainfall and Atmospheric Deposition

Rainwater may contain varying amounts of nutrients depending upon the local atmospheric pollution experimental data indicate that rain water, on an average, contains 0.16 to 1.06mg per liter of nitrate, nitrogen, 0.04 to 1.78mg per litre of ammonia nitrogen and from traces to 0.1mg per litre of phosphorous(Carrol, 1962).

6.6 Ground water

Ground water in some cases may act as a source of nitrogen to the surface water. It is, however, not a recognised source at all places but may be an important factor in certain areas. It has been estimated that about 42% of nitrogen in Wisconsin surface water comes from ground water (Hasler, 1968).

6.7 Domestic sewage

Sewage is the commonest source of nutrients and organic matter, and undoubtedly the greatest contributor towards eutrophication of lakes. Large quantities of nitrogen and phosphorous are excreted by humans and animals which get their way into sewage.

According to an estimate average 2gm of PO4-P per day is released through urine and faeces by an average person. Phosphatic detergents in sewage are also important contributor of phosphorous. Conventionally treated sewage (without tertiary treatment) may contain 15 to 35mg per liter of total nitrogen and 6 to 12 mg per litre of phosphorous (Hume and Gunnerson, 1962). Untreated sewage, besides nutrients also adds largest quantities of nitrogenous organic matter.

Besides the above factors, the land use pattern and human activities in the catchment or watershed area also influence the enrichment of water bodies. Removal of vegetational cover may have two-folds. It permits more erosion of soil to increase the sediments and thus decreasing the volume of lakes. Phosphorous, generally remains tightly bound to the soil particles, difficult to be leached out by the runoff, but may be transported to the water bodies along with the mass of eroded soil.

7. DISTURBANCES IN BASIC PHYSICO-CHEMICAL CHARACTERISTICS OF A WATER BODY

Pollution can be considered as a departure from the balance between photosynthesis and respiration. A eutrophic water body is one where photosynthesis exceeds the respiration activity. It is characterized by a progressive accumulation of algae which ultimately leads to an organic overloading.

Physico-chemical characteristics are basically the physical and chemical properties of a water body. It includes factors like Temperature, Alkalinity, pH, etc. The frequent rise and fall of these factors affects the fauna and flora of a water body, altering their numbers and diversity. Some of the most important characteristics which are greatly affected by nutrient enrichment are listed below.

7.1 TEMPERATURE

Water has a high specific heat capacity which is a significant property in stabilizing the aquatic environment. The excessive amount of nutrients in water body along with higher temperature favors the growth of algal communities and aquatic weeds. The rate of Eutrophication is usually higher in tropical waters than in the waters of temperate or colder regions. Nutrients vary with season and are also affected by the overturning of the water which brings the decomposing benthic materials to the photosynthetic zone, restricting proper photosynthesis.

7.2 TRANSPARENCY

Transparency determines the **photic** conditions of a water body. Light is an important factor which limits the photosynthesis in water. The light penetration in water can be related to the presence of turbidity and colour that restricts the depth of photic zone. Summers are known to show the minimum transparency. This means that during summers the water is more turbid, not clear enough to watch the activities going on inside the water body. The winters are said to have maximum transparency. Turbid water means nutrient enrichment has started which will slowly lead to the degradation of the water quality.

Table 7.2.a: ***Important parameters used for indicating levels of Eutrophication in water bodies.***

Physical	*Chemical*	*Biological*
Transparency (D) Mean depth (D)	Nutrient level (I) Dissolved solids (I) Hypolimnetic oxygen (D) Epilimnetic oxygen (D) Supersaturation (I)	Algal bloom frequency (I) Zooplankton (I) Bottom fauna biomass (I) Littoral vegetation (I) Primary production (I)

(D)= the values decrease (I)= the values increase

7.3 TOTAL DISSOLVED SOLIDS (TDS)

TDS is the measure of the dissolved combined content of all organic and inorganic materials contained in a suspended form in a water body. The separation of Oligotrophic and Eutrophic Lakes is basically done keeping this factor in consent.Oligotrophic lakes have less TDS content as compared to that of **Mesotrophic** and **Eutrophic** lakes. **Oligotrophic** lakes have **less than 100 ppm**(parts per million) and **Eutrophic** lakes have **more than 100 ppm** TDS. So the increasing amount of TDS indicates that Cultural Eutrophication has occurred in the water body.

7.4 TOTAL ALKALINITY

Total alkalinity is a natural separation point between hard and soft water. Hard water does not allow soaps to form lather because of the increased amount of iron and other elements. Thus, high alkalinity of a water body shows that eutrophication has occurred.

7.5 pH

pH is the logarithmic scale used to specify acidity or alkalinity of an aqueous solution. The pH of pure water is 7. Eutrophication increases the photosynthetic rate which leads to the consumption of greater quantities of bicarbonates resulting in the formation of more and more carbonates, raising the pH of water bodies.

During the winter season, when photosynthetic activity subsides, the pH is decreased owing to the excessive accumulation of free carbon dioxide in water. At this time, the previously precipitated carbonates may get re-dissolved.

7.6 DISSOLVED OXYGEN (DO)

Dissolved oxygen refers to the free, non-compound oxygen present in water. A dissolved oxygen level too high or too low can affect the water quality. When respiration exceeds photosynthesis, the dissolved oxygen gets rapidly exhausted, forcing reduction of several oxidized chemical species **like Nitrates, Sulphates and Carbon dioxide** into **Nitrogen, Ammonia, Hydrogen Sulphide** and **Methane**. They are harmful for several aquatic species and are also responsible for the foul odour.

In Oligotrophic water, the concentration of dissolved oxygen and nutrients do not vary much with depth. But in case of a Eutrophic water body, the surface water has higher dissolved oxygen levels and lower nutrients in comparison to the benthic layers. When the microbes start utilizing the maximum spaces in the water body, they start consuming the dissolved oxygen present in water sometimes leading to **Hypoxic conditions**.

Table 7.6.a: ***Minimum Dissolved Oxygen levels required for protection of aquatic life.***

(After USEPA, 1972)

Temperature (in degree centigrade)	*100% Saturated oxygen levels (mg/ L)*	*Minimum level of oxygen required for aquatic life protection*	
		DO (mg/L)	*%Saturation*
1.5	14	6.8	48.6
7.7	12	6.8	56.7
16.0	10	6.5	65.0
21.0	9	6.2	68.9
27.5	8	5.8	72.5
36.0	7	5.8	82.9

7.7 NITRATES AND PHOSPHATES

Nitrates and **Phosphates** are better indicators of Eutrophication. It is now almost a well-accepted fact that in most situations Phosphorus and Nitrogen frequently limit the algal productivity and biomass. But, they play a major role in the formation of various kinds of blooms of different algae. The occurrence of various blooms may lead to the clogging of gills of the fish and also has other toxic effects on the aquatic organisms. Blue-green colouration of the lakes, foul odour and massive production of mosquitoes are also some of the correlated phenomena which can be frequently observed in summers. In summer season the light intensity of the Sun rays are quite high resulting in much more deteriorated water quality along with high degrees of Eutrophication. These nutrients are basically added into the water bodies from the agricultural run-offs. The chemical fertilizers generally contain a huge amount of Nitrates and Phosphates in them.

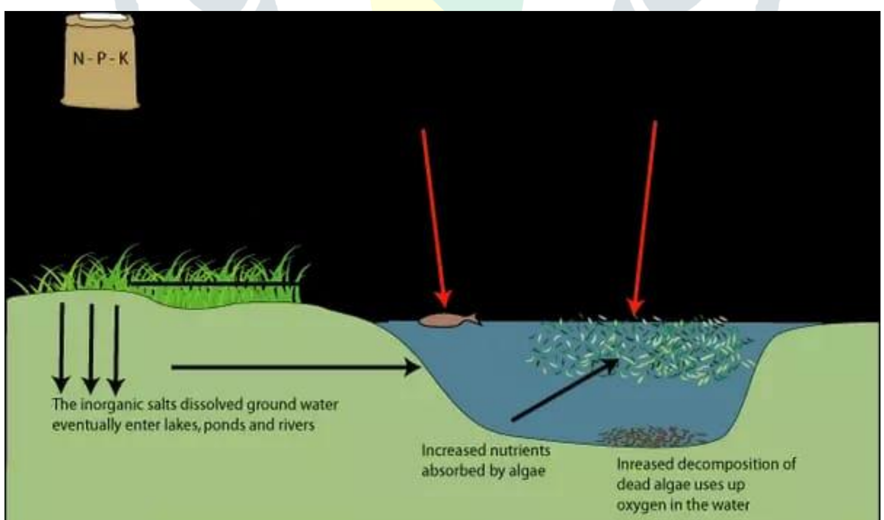


Fig: ***Diagrammatic representation of effects of excess nutrients***

Phosphorus is considered to be most important of all other nutrients in limiting Eutrophication in almost all situations. The importance of **Nitrogen** is **secondary** to the Phosphorus as it can also be fixed by Nitrogen-fixing blue-green algae which can thrive well in Nitrogen deficient water where there is no supplementary source of Phosphorus. The **Nitrogen-fixing algae** can convert **inert Nitrogen** gas into its assimilative **Nitrate** form.

The Nitrate ions get easily **leached out** from the soil but the Phosphate ions are more **tightly bound** to the soil particles and cannot be easily entrained in the run-off water. As a result Nitrogen can enter the water body more frequently through the natural sources than Phosphorus. Nitrogen however can become limiting in the tropical or hot climate due to increased **Denitrification**. **Denitrification** is a microbially facilitated process where **nitrate** is reduced to **molecular Nitrogen** through a series of intermediate gaseous Nitrogen Oxide products. Nitrogen in many cases may also become secondarily limiting for algal growth, especially at the time of plentiful Phosphorus supply.

Water bodies may become enriched with nutrients through both Natural and Anthropogenic sources. Nevertheless, their quantities may greatly differ from source to source. The anthropogenic sources are much more significant contributors of nutrients than the Natural sources.

8. FLUCTUATION IN PLANKTONIC ACTIVITIES AND DEGRADATION IN NUTRIENT STATUS

Almost all physico-chemical changes in water bring about a change in flora and fauna due to **homeostatic** factors which lead to the attainment of new equilibrium. In doing so, many desirable species including fish are replaced by undesirable species. **Homeostasis** is defined as the state of steady internal conditions maintained by living organisms. The **Phytoplankton** communities start growing immensely and rapidly covering the surface layers of the water bodies. There is an algal succession resulting in the dominance of blue-green algae which have very low nutritional values in the food chain and many of them produce the blooms. Some of the important bloom-forming blue-green algae genera include ***Microcystis*** sp., ***Anabaena*** sp., ***Oscillatoria*** sp., etc.

Filamentous green algae such as ***Spirogyra*** sp., ***Cladophora*** sp. and ***Zygnema*** sp. form a dense floating mat or **blanket** when the density of the bloom becomes sufficient to reduce the intensity of Solar Rays below the surface layers of water. Some of the common mat-forming algae found in polluted water are ***Volvox*** sp., ***Ulothrix*** sp., etc. **Cyanobacterial bloom** caused by **Cyanobacteria** are also very common in certain places. These blankets often give shelter to some undesirable insects including mosquitoes. Many algal species have **allelopathic** effects on other algae which frequently results in the formation of typical associations and assemblages of algae in Eutrophic water bodies. **Allelopathy** is a biological phenomenon by which an organism produces one or more biochemicals that influence the germination, growth, survival and reproduction of other organisms.

Nutrient enrichment has very limited direct effects on **Zooplankton** communities but indirect effects may be significant. Among them some of the most common Zooplankton are ***Mesocyclops*** sp., ***Navicula*** sp., ***Daphnia*** sp., ***Cyclops*** sp., etc. The diversity of Zooplankton remain high if the diversity of Phytoplankton is also high as often found in case of Oligotrophic or moderately Eutrophic water bodies.

In Oligotrophic water the size of Phytoplankton is usually smaller than 50 micrometres, but the size of Zooplankton enlarges making the Phytoplankton communities to be controlled by zooplankton grazing. On the contrary, increasing Eutrophication makes the size of Phytoplankton larger while decreasing the size of Zooplankton, as a result of which the Phytoplankton communities can no longer be controlled by the latter.

Table 8.A: ***General characteristics of Oligotrophic and Eutrophic water bodies (based on Mason, 1983).***

PARAMETERS	*OLIGOTROPHIC*	*EUTROPHIC*
Summer oxygen in Hypolimnion	Present	Absent
Algae	High species diversity with low density and productivity, mostly dominated by Chlorophyceae	Low species diversity with high density and productivity, dominated mostly by Cyanophyceae
Algal Bloom	Rare	Frequent
Nutrient enrichment	Low	High
Animal production	Low	High

The Eutrophication also promotes the growth of several submerged floating or even emergent **Macrophytic plants** in water like ***Salvinia molesta, Eichhornia crassipes***, etc., and the overall conditions become quite unaesthetic. As the changes occur in the water bodies due to Eutrophication, the characteristics of sediments also change. There is an accumulation of organic matter which affects the Benthic communities. They become dominated by Chironomids and Polycheates with fewer numbers of Molluscs, Crustaceans and Insects.

When the algae die, they decompose and the nutrients contained in that organic matter are converted into inorganic form by microorganisms. This decomposition process consumes Oxygen which reduces the concentration of dissolved oxygen. The depleted oxygen levels in-turn may lead to fish kills and a range of other effects reducing **biodiversity**. Nutrients may become concentrated in an **Anoxic Zone** and may only be made available again during autumn turnover or in conditions of turbulent flow. **Anoxic Zone** is defined as the areas of freshwater or ground water that is depleted of dissolved oxygen and has a **Hypoxic** condition, a condition where there is an acute deficiency of oxygen. Enhanced growth of aquatic vegetation or Phytoplankton and Algal bloom disrupts normal functioning of the ecosystem causing a variety of problems such as lack of **Oxygen** for the survival of aquatic organisms.

Anthropogenic activities can accelerate the rate at which nutrients enter the Ecosystem. Elevated levels of the atmospheric compounds of Nitrogen can increase the Nitrogen availability. It is converted into the utilizable form by the **blue-green algae**. Accumulation of greater numbers of blue- green algae result in more amounts of accumulations of reactive Nitrogen which may prove to be as dangerous as excess amount of Carbon dioxide put into nature.

Phosphorus is often regarded as the main culprit of Eutrophication in lakes and other water bodies, subjected to point-source pollution from sewage pipes. The concentration of algae and the trophic state of water bodies correspond well to Phosphorus levels in water. Continuous addition of Phosphorus into water bodies may lead to **Nitrogen depletion** in the **Photic Zone**. **Photic Zone** is the area of a water body in which sufficient amount of Sun rays enter, to support the process of photosynthesis by the aquatic plants. Under these conditions, the blue-green algae fix sufficient Nitrogen to enter the main Eutrophic conditions.

9. A STUDY ON EUTROPHICATION IN THE WATER BODIES OF RANCHI

Ranchi, the capital city of the state **Jharkhand** is well-known for its hills and waterfalls. Numerous small and large freshwater bodies can be seen here which are no more fresh due to certain anthropogenic activities. We have garnered some information about two of the most prominent water bodies, *viz.,* **RANCHI LAKE** and **KANKE DAM.**

At all events, anthropogenic activities play a major role in the deterioration of the environment including water, air, soil, etc. Kanke Dam is one of the most visited recreational spots of Ranchi. Due to various human activities around the periphery of the dam has resulted in the advent of various nutrients into the dam leading to nutrient enrichment and siltation. Due to the over-deposition of sediments the water storage capacity of the dam has greatly reduced in the past few years. Water from **Kanke dam** is used to quench the thirst of numerous people of Ranchi. Unfortunately due to various man made activities the water quality has deteriorated greatly and has become quite unfit for drinking.

Ranchi lake, situated behind the **Nagarmal Modi Seva Sadan** hospital, also known as the **Bada Talab**, is one of the largest lakes of Ranchi. It is a man-made lake dug by the British in the heart of the city. It is situated in the heart of the city near Upper Bazar. The Talab has a total area of 218592 km^2 with an average depth of 2.2 metres.

Ranchi Lake or Bada Talab is one of the spots for idol immersion and Chhath Parva. Though religious, but these activities tend to accelerate **Cultural Eutrophication** in the water body. Some other factors like excess use of detergents by the localites to wash their clothes, cars, cattle etc. on the banks of Ranchi lake and also the influx of sewage water from the surrounding areas, especially from the hospital, results to be the most important factors for deteriorating the water quality of Ranchi lake. On the basis of some prior researches done, we have garnered a few information regarding the deteriorating conditions of the Ranchi Lake and the Kanke Dam.

The quality of water has been badly affected due to Cultural Eutrophication. After becoming the capital there is a rapid increase in population, urbanization and industrialization which has led to severe problems of waste management in the city. Wastes are being directly dumped into the water bodies without any proper treatment, resulting in addition of unwanted particles into the water bodies leading to **Siltation**. **Siltation** is defined as the pollution of water by particulate terrestrial waste materials with a particle size of silt or clay. It increases both suspended matters and sediments at the bottom thus decreasing the water content of the water bodies. This ultimately has led to eutrophication which decreases the oxygen level of the surface of the water bodies. Due to Eutrophication and siltation and zero oxygen level there is always a foul smell from these water bodies. This has also led to the scarcity of fishes and other aquatic animals in the water bodies as they cannot acquire the desirable amount of oxygen required for proper respiration thus making oxygen a limiting factor.

Due to less oxygen level there is always a threat of growing of pathogenic microbes, viruses, protozoa and bacteria etc. especially on the sewage wastes dumped into the water. Consumption of such polluted pathogenic water may result in fatal water-borne diseases such as acute Diarrhoea, Dysentery, Typhoid, etc. These pose a great threat to the local poor people who unknowingly use this water for domestic purposes, especially for washing clothes and bathing.

Maximum part of the water bodies are filled with Water Hyacinth. **Water Hyacinth** mats degrade water quality by blocking the sun rays from reaching the underwater plants and phytoplankton thus restricting the photosynthesis, which greatly reduces oxygen levels in the water. This creates a cascading effect by reducing other underwater life such as fish and other plants. Water hyacinth also reduces biological diversity, impacts native submersed plants, alters immersed plant communities by pushing away and crushing them, and also alter animal communities by blocking access to the water and/or eliminating plants, the animals depend on for shelter and nesting.

The buildup of the nutrients through these activities gradually results in the growth of algal communities on the surface of the water bodies, especially in waters of **Kanke Dam**. Though algae help in water purification by removing carbon dioxide and adding oxygen during photosynthesis but certain species of algae are harmful to health. Algae are considered to be indirectly responsible for **Gastroenteritis** in humans. Although nutrients should not be considered solely responsible for Eutrophication in the water bodies because algal growth may also be influenced by other factors like Temperature, Light intensity, Geographical Features and Physico-chemical characteristics of the water. The algal growth in the water bodies is dominated by some blue-green algae which have very low nutritional values in food chain and many of them are responsible for producing the blooms. Some of the important bloom forming blue-green algae are Microcystis sp., ***Anabaena*** sp., ***Oscillatoria*** sp., etc.

As the change occurs in water due to Eutrophication, the characteristics of the sediments also change. There is an accumulation of organic matter which affects the benthic communities. They become dominated by **Chironomous larvae, Polycheates like earthworms,** with fewer **Molluscs like snails, Crustaceans** and **Insects**. When the algae die and decompose, the locked nutrients are again made available to the fresh algal growth.

Increased algal growth leads to the death of several plankton present in these water bodies. Accumulation of dead plankton in sand filters offers a substrata for the growth of ***Pseudomonas*** sp. which causes Gastroenteritic troubles. Algae poison is considered to be one of the most virulent poison which produces cirrhosis of the liver in humans. It also reduces the resistant power against the diseases in man. Dead algae form a mat on the surface of the water and act as an oxygen barrier.

The main cause of Eutrophication in the water bodies of Ranchi is the addition of nutrients like **Nitrates** and **Phosphates** from the nearby local habitats and from the Hospital. **Nitrates** and **Phosphates** along with desirable climatic conditions are quite responsible for algal growth in the water bodies. The over accumulation of these nutrients has resulted in the formation of a mat-like structure over the surface of the water which actually is the bloom of certain algal communities.

In some parts of the **Ranchi Lake** and the **Kanke Dam** the algal growth has increased to such an extent that the aquatic ecosystem of those water bodies has completely disturbed. The excessive growth of water weeds like ***Salvinia molesta*** in some parts of the Ranchi Lake has resulted in the death of a large number of fishes and also has increased the thickness of the benthic layers resulting in shallowness in those parts of the water body.

The scenario of **Kanke Dam** has worsened over the years. It is situated near the Rock Garden in Kanke road and lies at an elevation of 611 metres above the sea level. In some parts of the Kanke Dam, the growth of water hyacinth, sedge-grass and other water weeds has increased in such an extent that the particular area looks totally covered in those weeds giving an impression of bush. During rainy season the flow of water in Kanke Dam increases to a great extent. This is because of the increment in sediments in the benthic layer of the dam which has decreased the depth of the dam.

Algal growth of certain species of algae at a limited rate, in the water bodies, is good for better fish production as it serves as their food and also helps in reducing the amount of carbon dioxide present in the water by consuming it for the process of photosynthesis. But the algal growth has increased beyond extent and thus the cleaning of these water bodies is necessary for a balanced aquatic ecosystem and also for maintaining proper health and hygiene of the people consuming water from those bodies for the household purposes.

We have studied a few parameters of these two water bodies which are as follows:

9.i) <u>pH</u>

<u>THEORY:</u>

pH of water is a measure of amount of hydrogen ions that is present in the water. It determines if the water is alkaline or acidic in nature. pH stands for potential of hydrogen. As per the World Health Organization (WHO), value of pH for the water is 6.5 to 8.5. This scale was developed by the scientist Sorenson in the year 1909. The below reaction implies that the water shows that the number of H^+ and OH^- ions are equal in amount experimentally.

Eutrophication increases the photosynthetic rate which leads to the consumption of greater quantities of bicarbonates resulting in the formation of more and more carbonates, raising the pH of water bodies. During the winter season, when photosynthetic activity subsides, the pH is decreased owing to the excessive accumulation of free carbon dioxide in water. At this time, the previously precipitated carbonates may get re-dissolved.

<u>METHOD:</u> <u>ELECTROMETRIC METHOD FOR pH OF WATER</u>

- One of the most widely accepted method for the hydrogen ion determination (pH) is the electrometric method. This method is highly accurate and used in laboratory work and by researchers. The accuracy of the pH value is 0.1 to 0.0001.
- pH is measured using pH meter, which comprises a detecting unit consisting of a glass electrode, reference electrode, usually a calomel electrode connected by KCl Bridge to the pH sensitive glass electrode and an indicating unit which indicates the pH corresponding to the electromotive force is then detected.
- Before measurement, pH meter should be calibrated by using at least two buffers. Also it is recommended to use hydrated silica gel for the glass electrode, and the electrodes must be soaked with water or in suitable buffer followed by rinsing in water.
- Electrode tips should be cleaned after use of wiping with tissue paper to remove adhering substances. Potassium level in the calomel electrode is maintained and the cap should be removed during measurement.
- For the accurate measurement of pH, the temperature of the buffer should be maintained for standardization of pH meter is same.

<u>APPARATUS:</u>

- A 0.1pt. (50mL), wide-mouth glass beaker with a watch glass for cover. If lightweight material is to be tested, it may be necessary to increase beaker size up to a maximum of 0.5 pt. (250mL).
- A pH meter, suitable for laboratory or field analysis, with either one or two electrodes.
- Standard buffer solutions of known pH values - standards to be used are pH of 4.0, 7.0, and 10.0.
- Distilled water.

- **pH DATA OF RANCHI LAKE:**

Sr. No.	DATE OF SAMPLING	pH
1.	08.11.2018	9.32
2.	26.11.2018	9.41
3.	08.02.2019	8.314
4.	26.02.2019	8.12

- **pH DATA OF KANKE DAM:**

Sr. No.	DATE OF SAMPLING	pH
1.	08.11.2018	9.02
2.	26.11.2018	9.74
3.	08.02.2019	9.21
4.	26.02.2019	9.52

9.ii) CONDUCTIVITY

THEORY:

- Conductivity is a measure of water's capability to pass electrical flow. This ability is directly related to the concentration of ions in the water. These conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulphides and carbonate compounds. Compounds that dissolve into ions are also known as electrolytes. The more ions that are present, the higher the conductivity of water. Likewise, the fewer ions that are in the water, the less conductive it is. Distilled or de-ionised water can act as an insulator due to its very low (if not negligible) conductivity value.

- How well a solution conducts electricity depends on a number of factors:
• Concentration of ions
• Mobility of ions
• Valence of ions
• Temperature
• Turbidity
• Dissolved CO2

- Conductivity of water allows measuring ionic constituents of all types of water including surface waters, process waters in water supply and treatment plants.

METHOD:

To determine conductivity the capacity of the water to conduct an electric current is evaluated. This is an indirect measurement of the quantity of ions in solution (mainly chloride, nitrate, sulphate, phosphate, sodium, magnesium and calcium). The basic unit for measuring conductivity is Siemens/meter or µ Siemens/cm. The conductivity will be measured using an electronic conductivity meter, which generates a voltage difference between two electrodes submerged in the water. The drop in voltage due to the water resistance is used to calculate the conductivity per centimeter.

- **CONDUCTIVITY DATA OF RANCHI LAKE:**

Sr. No.	DATE OF SAMPLING	CONDUCTIVITY (mS/cm)
1.	08.1102018	0.411
2.	26.11.2018	0.424
3.	08.02.2019	0.389
4.	26.02.2019	0.392

- **CONDUCTIVITY DATA OF KANKE DAM:**

Sr. No.	DATE OF SAMPLING	CONDUCTIVITY (mS/cm)
1.	08.1102018	0.409
2.	26.11.2018	0.429
3.	08.02.2019	0.471
4.	26.02.2019	0.478

9.iii) DISSOLVED OXYGEN:

THEORY:

Dissolved oxygen refers to the free, non-compound oxygen present in water. A dissolved oxygen level too high or too low can affect the water quality. The solubility of atmospheric oxygen in fresh water ranges from 14.6mg/L at 0^0C to about 7.0mg/L at 35^0C under 1 atmospheric pressure. When respiration exceeds photosynthesis, the dissolved oxygen level gets rapidly exhausted, forcing reduction of several oxidized chemical species. They are harmful for several aquatic species and are also responsible for the foul odour.

Most samples for dissolved oxygen are collected in the field where it is not convenient to perform the entire determination. So it is customary to fix the samples immediately after collection to avoid the change in oxygen values because of various biological activities.

INTERFERENCE:

The Nitrite ions present in polluted water is one of the most common interferences in dissolved oxygen analysis.

METHOD: WINKLER AZIDE METHOD

- This method is used to determine the dissolved oxygen of polluted water. Oxygen present in sample rapidly oxidizes the dispersed divalent manganous hydroxide to its higher valency which precipitates as a brown hydrated oxide after addition of NaOH and KI. Upon acidification, manganese reverts to divalent state and liberates iodine from KI equivalent to the original dissolved oxygen content. The liberated iodine is then titrated against Sodium thiosulphate using starch as an indicator.

APPARATUS:

- 1 BOD bottle of 300mL for preparing the sample to be used for titration.
- Burette set-up for titration.
- 500mL conical flask for titrating the prepared sample.
- Two 5mL pipette for pipetting $MnSO_4$ and Alkali Azide Iodide and another 5mL pipette for pipetting H_2SO_4.
- 500mL measuring cylinder for measuring the prepared sample.
- 10mL measuring cylinder for measuring starch solution.

CALCULATION:

$$\text{Dissolved oxygen of the sample water} = \frac{\text{Titrant consumed x N of } Na_2S_2O_3 \text{ x } 8000}{\text{Volume of sample taken for titration}} \text{ mg/L}$$

- **DISSOLVED OXYGEN DATA OF KANKE DAM:**

Sr. No.	Date of Sampling (Vol=203mL)	Initial reading of burette (I.R.)	Final reading of burette (F.R.)	Difference (F.R. – I.R.)	Calculation (mg/L)
01	08.11.2018	1.0	9.7	8.7	8.57
02	26.11.2018	5.2	14.0	8.8	8.65
03	08.02.2019	2.1	11.0	8.9	8.83
04.	26.02.2019	1.5	10.5	9.0	8.87

- **DISSOLVED OXYGEN DATA OF RANCHI LAKE:**

Sr. No.	Date of Sampling (Vol=203mL)	Initial reading of burette (I.R.)	Final reading of burette (F.R.)	Difference (F.R. – I.R.)	Calculation (mg/L)
01	08.11.2018	9.4	21.1	11.7	11.51
02	26.11.2018	14.2	26.0	11.8	11.63
03	08.02.2019	11.0	21.7	10.7	10.50
04.	26.02.2019	10.5	21.4	10.9	10.72

9.iv) BIOCHEMICAL OXYGEN DEMAND (BOD)

THEORY:

Biochemical oxygen demand (BOD) is defined as the amount of oxygen required by microorganisms while stabilising biologically decomposable organic matter in a waste under aerobic conditions. The BOD test is widely used to determine :-

- The pollution load of waste waters.

- The degree of pollution in lakes and streams at any time and their self-purification capacity.

- Efficiency of waste water treatment methods.

Since the test is mainly a bio-assay procedure, involving measurment of oxygen consumed by bacteria while stabilizing organic matter under aerobic conditions, it is necessary to provide standard conditions of nutrient supply, pH, absence of microbial growth inhibiting substances and temperature. Because of the low solubility of O2 in water, strong wastes are always diluted to ensure that the demand does not increases the available oxygen. A mixed group of organisms should be present in the sample; if not, the sample has to be seeded artificially. Temperature is controlled at 20^0 C. The test is conducted for 5 days as 70 to 80% of the wastes oxidized during this period.

INTERFERENCES:

Since DO estimation is the basis of BOD test, sources of interference in BOD test are the same as in the DO test. In addition, lack of nutrients in dilution water, lack of an acclimated seed organisms and presence of heavy metals or other toxic materials such as residual chlorine are other sources of interference in this test.

APPARATUS:

- BOD bottles 300 ml capacity

- Incubator, to be controlled at 20^0 C

PROCEDURE:

A) Preparation of dilution water

- Aerate the required volume (say 1L) of distilled water in a container by bubbling compressed air for 1-2 days to attain DO saturation. Try to maintain the temperature near 20^0 C.

- Add 1 ml each of phosphate buffer, magnesium sulphate, calcium chloride, ferric chloride solutions for each litre of dilution water. Mix well.

- In the case of the wastes which are not expected to have sufficient bacterial population, add 2 ml seed to the dilution water. Generally, 2 ml settled sewage is considered sufficient for 1000 ml of dilution water.

B) Dilution of sample

- Neutralize the sample to pH around 7.0 if it is highly alkaline or acidic.

- Dilute the sample with prepared dilution water i.e. 300 ml of sample water and 700 ml of dilution water.

Step 1- Fill two BOD bottles with 300 ml of dilution water. Also fill another two BOD bottles with 300 ml of sample water.

Step 2- Put the two BOD bottles in an incubator, one of which contains sample water while the other bottle has dilution water at a temperature of 20^0 C.

Step 3- Now measure the dissolved oxygen (DO) of the remaining two BOD bottles immediately by Winkler method.

Step 4- After 3 days, take out the BOD bottles and measure the DO of these two bottles.

OBSERVATION TABLE:

Table 1. DO measured on 0th day

Sl. No.	SAMPLE TYPE	Initial reading of burette(I.R.)	Final reading of burette(F.R.)	Difference (F.R – I.R.)
1	Dilution water	6.3	13	6.7
2	Sample water	13	20.3	7.3

Table 2 . DO measured on 3rd day

Sl. No.	SAMPLE TYPE	Initial reading of burette(I.R.)	Final reading of burette(F.R.)	Difference (F.R – I.R.)
1	Sample water	7.1	10.7	3.6
2	Dilution water	10.7	16.7	6

CALCULATION:

Let D_0 = DO of sample bottle on 0th day

D_1 = DO of sample bottle on 3rd day

C_0 = DO of blank bottle on 0th day

C_1 = DO of blank bottle on 3rd day

$C_0 - C_1$ = DO depletion in the dilution water alone

$D_0 - D_1$ = DO depletion in sample + dilution water

$(D_0 - D_1) - (C_0 - C_1)$ = DO depletion due to microbes

So,

BOD (mg/L) = $\{(D_0 - D_1) - (C_0 - C_1)\}$ **x decimal fraction of sample taken**

We have taken 30 ml of sample so decimal fraction = $\frac{100}{3} = \frac{10}{3}$

On putting the values of DO from above tables in the formula we get,

$$\text{BOD (mg/L)} = (7.3 - 3.6) - (16.7 - 6.0) \times \frac{10}{3}$$

$$= (3.7 - 0.7) \times \frac{10}{3}$$

BOD = 10 mg /L for the water of **Kanke Dam**

- **BOD DATA OF RANCHI LAKE:**

Sr. No.	DATE OF SAMPLING	BOD (mg/L)
1.	08.11.2018	16.16
2.	26.11.2018	16.23
3.	08.02.2019	11.00
4.	26.02.2019	11.21

- **BOD DATA OF KANKE DAM:**

Sr. No.	DATE OF SAMPLING	BOD (mg/L)
1.	08.11.2018	9.77
2.	26.11.2018	9.35
3.	08.02.2019	10.24
4.	26.02.2019	10.00

9.v) TOTAL DISSOLVED SOLIDS (TDS)

THEORY:

The term solid refers to the matter either filterable or non-filterable that remains as residue upon evaporation and subsequent drying at a defined temperature. Further categorization depends upon the temperature employed for drying and ignition. Different forms of solids are defined on the basis of the method applied for their determination. All solids are determined by Gravimetric Method except Settleable Solids by volume.

"Total Dissolved Solids (TDS)" is the concentration of the dissolved chemicals in a sample of water. Before dissolving, these chemicals could have been a solid or a liquid." The total dissolved solids can be determined by using the filtrate and following the procedure mentioned below.

APPARATUS:

- Glass-fibre filters, with a 47 mm diameter, nominal pore size ≤ 2.0 µm and ≥ 1.0 µm, and no binders.
- Filtrations funnel assembly for a 47 mm size diameter filter.
- Beaker, for sample evaporation, made of borosilicate glass.
- Hot plate or heating block (optional) for evaporating samples in a pre-drying step and capable of maintaining a temperature.
- Convection oven operated at 80°C (optional) for evaporating samples in a pre-drying step.
- Convection oven operated at 180 ± 2°C for drying samples to a constant weight condition.
- Desiccators containing a desiccant that responds (colour change) to moisture or a hygrometer that measures moisture.
- Analytical balance capable of weighing to the nearest 0.1 mg or less.

METHOD: GRAVIMETRIC METHOD

- Gravimetric means "by weighing". Balances require gravity to weigh something. It will weigh the total dissolved solids after water is boiled away. This will be done using just one water sample.
- A total dissolved solid is a measure of the dissolved matter in water that remains after all the water has been evaporated. A higher level of dissolved solids is typically accompanied with a higher level of hardness. Dissolved solids affect water quality by making it unfit or unpalatable to drink,
unsuitable for use in many industrial applications, and unsuitable for cooking or other applications where water is heated.- A known volume of a well-mixed sample is filtered through a standard glass-fibre filter and the filtrate collected. The filtrate is evaporated to a constant weight condition in an oven maintained at a temperature of 180°C to remove mechanically occluded water.

- The mass of the dried sample's dissolved solids is determined and used to calculate the concentration of total dissolved solids in the sample. This method is applicable for measurement of total dissolved solids in all natural waters, in raw, process and treated agricultural, municipal and industrial wastewaters and in treated drinking water.

CALCULATION:

To calculate the concentration of total dissolved solids;

$$\text{Total Dissolved Solids, as mg TDS/L} = \frac{(W2 - W1) \times 10^6}{\text{Vol. Sample in mL}} \text{ mg/L}$$

Where,
W2 = dry weight of solids plus beaker in mg, and
W1 = weight of beaker in mg.

- **DATA TABLE FOR TDS OF RANCHI LAKE:**

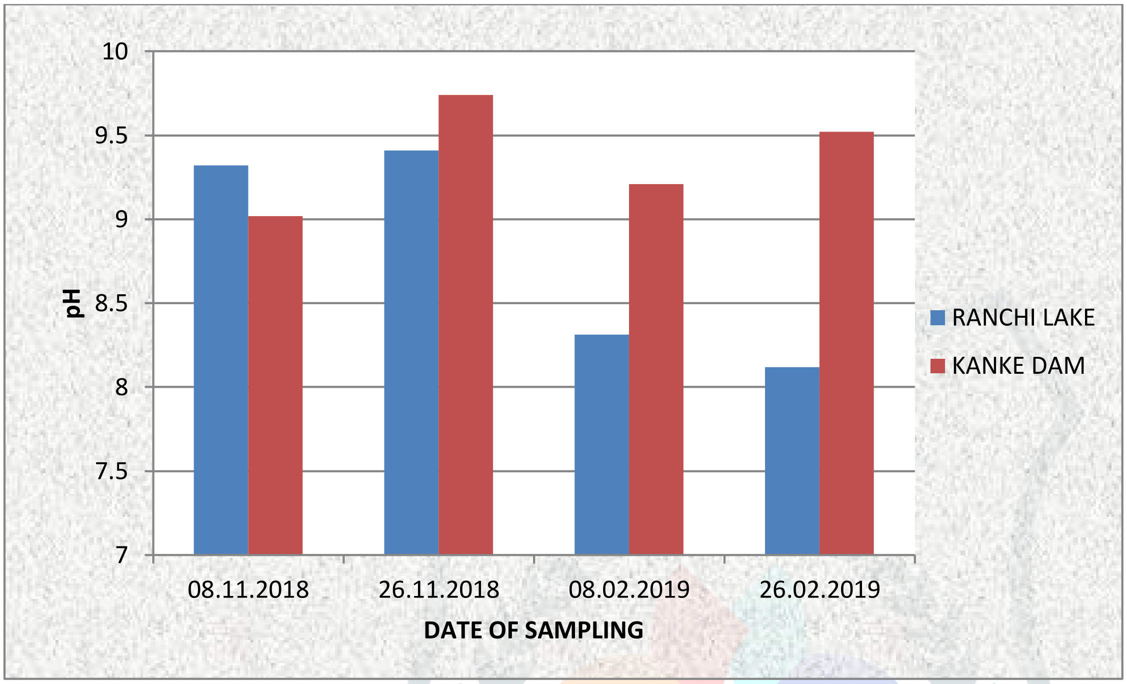
Sr. No.	Date of Sampling (Vol=50mL)	Initial weight of the beaker (W_1)	Final weight of the beaker (W_2)	Difference (W_2-W_1)	Calculation $\frac{(W_2-W_1)\times10^6}{\text{Vol. of sample}}$
01.	08.11.2018	28.45109	28.51769	0.06660	1332mg/L
02.	26.11.2018	28.45121	28.51941	0.06820	1364mg/L
03.	08.02.2019	28.45111	28.51366	0.06255	1251mg/L
04.	26.02.2019	28.45091	28.51311	0.06220	1244mg/L

- **DATA TABLE FOR TDS OF KANKE DAM:**

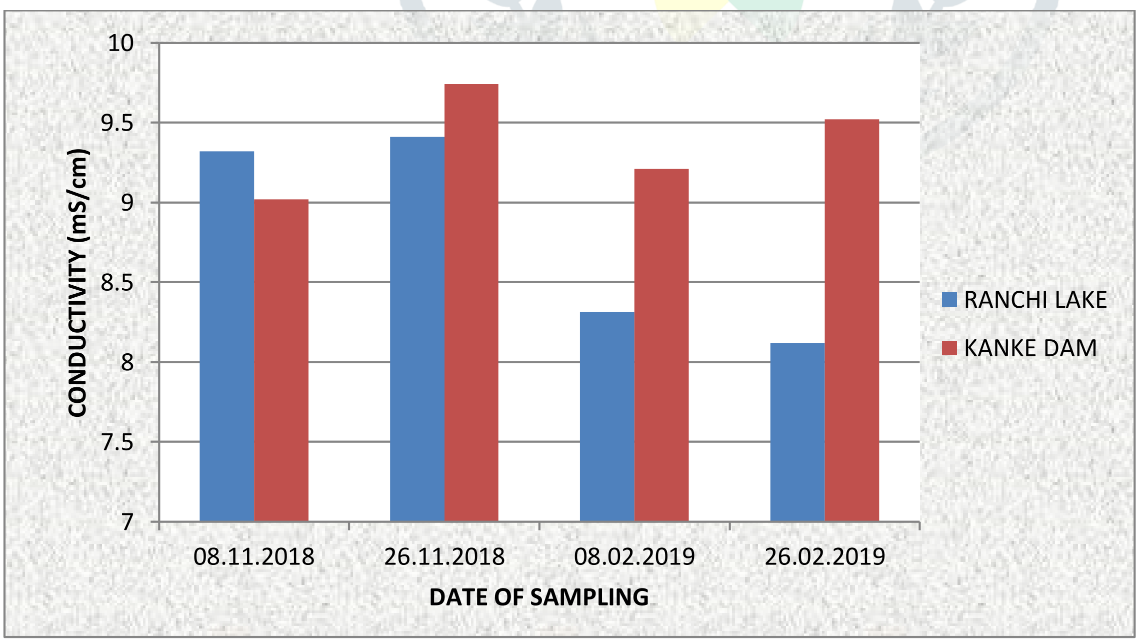
Sr. No.	Date of Sampling (Vol=50mL)	Initial weight of the beaker (W_1)	Final weight of the beaker (W_2)	Difference (W_2-W_1)	Calculation $\frac{(W_2-W_1)\times10^6}{\text{Vol. of sample}}$
01.	08.11.2018	28.45139	28.50989	0.05850	1170mg/L
02.	26.11.2018	28.45222	28.51167	0.05945	1189mg/L
03.	08.02.2019	28.45157	28.51297	0.06140	1228mg/L
04.	26.02.2019	28.45118	28.51188	0.06070	1214mg/L

- **COMPARISON OF THE PHYSICO-CHEMICAL CHARACTERISTICS OF KANKE DAM AND RANCHI LAKE**

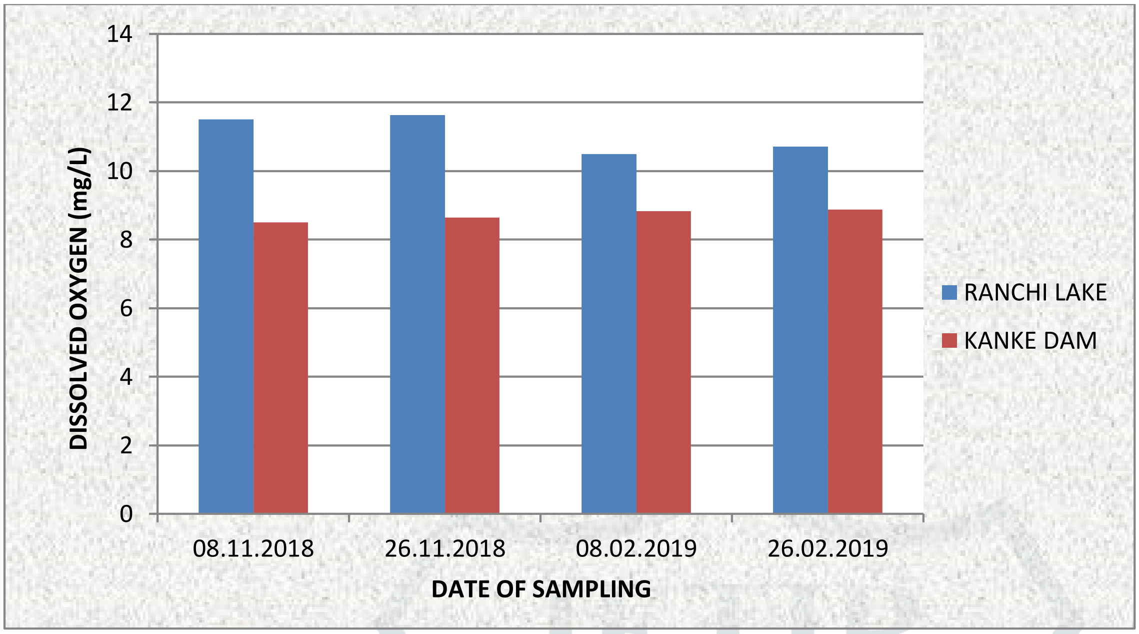
Picture A: Graph showing comparison of pH



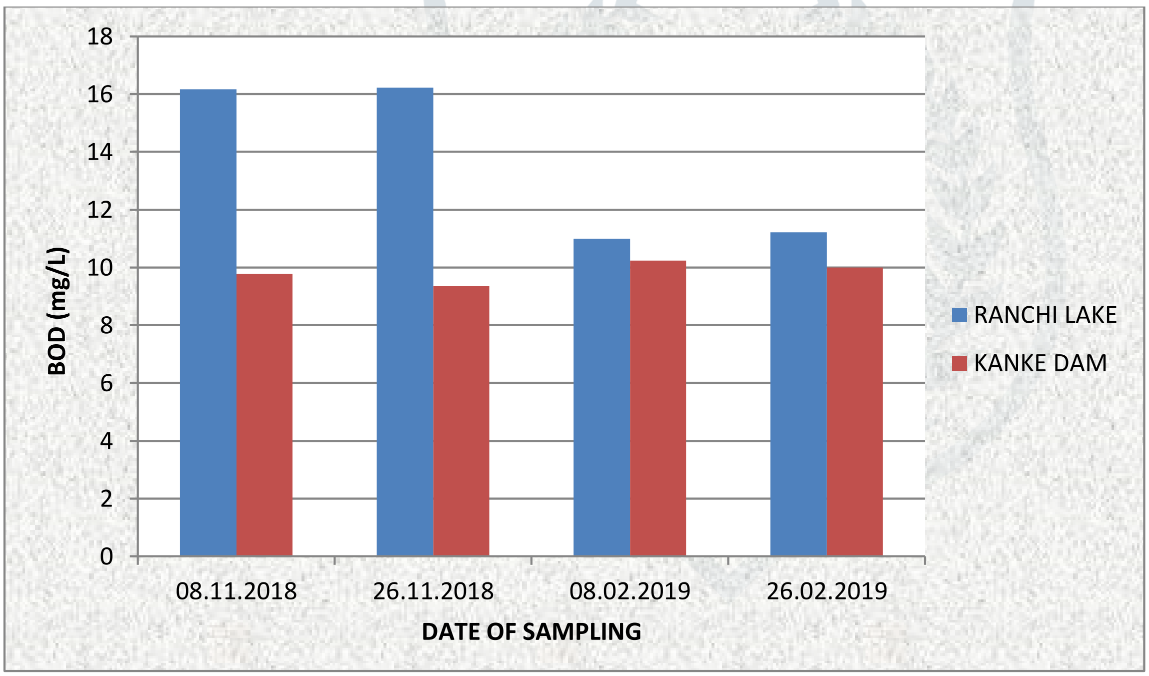
Picture B: Graph showing comparison of Conductivity



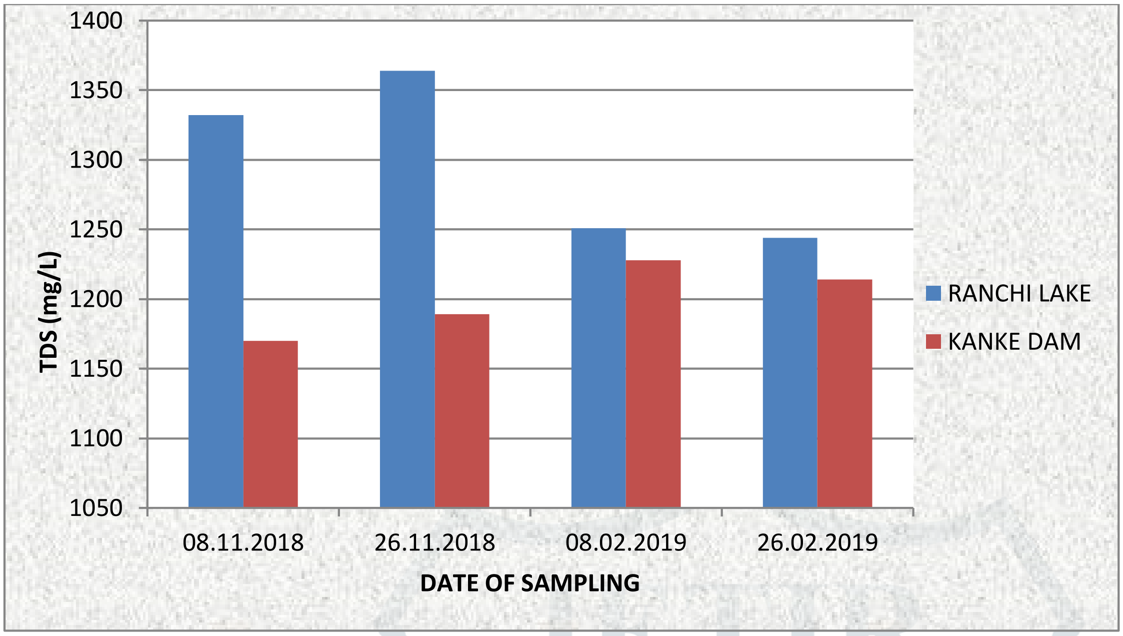
Picture C: Graph showing comparison of Dissolved Oxygen



Picture D: Graph showing comparison of Biochemical Oxygen Demand (BOD)



Picture E: Graph showing comparison of Total Dissolved Solids (TDS)



RESULT AND CONCLUSION:

The bar graphs (Picture A – Picture E) represent a clear comparison between the 5 typical physico-chemical parameters of the RANCHI LAKE and KANKE DAM over a certain period of time. It is clear from the comparison that comparatively Ranchi Lake or Bada Talab has always been more polluted than Kanke Dam.

Talking about the pH, the pH of both the water bodies has remained slightly alkaline due to the growth of various unwanted water weeds and extensive growth of algal bloom which increases the photosynthetic activity and thus the pH is also increased during the day time, as pH is directly related to the amount of free oxygen present in any water body.

The BOD of Ranchi lake has shown a sharp decrease over time. This is so because of the cleaning of the water body for inauguration of the new Vivekananda Statue. This resulted in cleaning off of the algal bloom and water weeds using various chemical as well as by manual removal processes.

On the whole, the other parameters of the two water bodies were not in desirable range to be suitable for drinki8ng purposes so various methods and suggestions of cleaning the Ranchi Lake and Kanke Dam has to be adopted. Various kinds of anthropogenic activities including washing of clothes bathing, etc. has caused the nuisance named Eutrophication.

The Bada Talab is basically dumped with the discharge of Seva Sadan Hospital which has a great impact on the aquatic organisms as the toxic chemicals of the bio medical wastes are directly dumped into the Ranchi Lake or the Bada Talab without proper treatment.

Although the disposal OF wastes into the Ranchi lake has somewhat been checked by the Jharkhand Government still the idol immersion process continues which also poses a great threat to the aquatic organisms' survival. The intense fishing practices done in the Kanke dam is one of the major causes of the deterioration of its water quality. Aquaculture releases around tons of phosphorus into the water body which is trusted to be the main precursor of eutrophication. Phosphorus is needed for photosynthesis to take place properly but excessive amounts of phosphate ions produced by various chemical reactions are responsible for the formation of the algal mat over the surface of Kanke Dam which has turned the colour of the water to moss green. This has resulted in the death of fish and other aquatic organisms. Hence proper measures should be taken by the Governmebt to somewhat control the various activities causing such degradation of the two water bodies.

10. IMPACT OR EFFECTS OF EUTROPHICATION

Eutrophication is a concern because it has numerous negative impacts. The higher the nutrient loading in an ecosystem, the greater the potential ecological impacts. Increased productivity in an aquatic system can sometimes be beneficial. Fish and other desirable species may grow faster, providing a potential food source for humans and other animals.
However, detrimental ecological impacts can in turn have other adverse impacts which vary from aesthetic and recreational to human health and economic impacts.

This is summarised in the following figure:

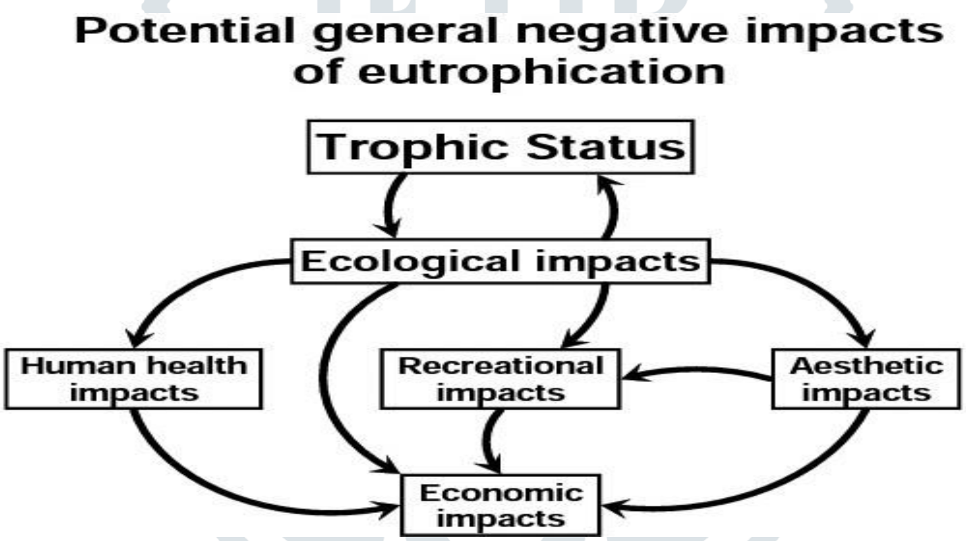


Fig: Summary of potential general negative impact of eutrophication.

10.1 Ecological impact

Macrophyte invasions and algal and cyanobacterial (blue-green) blooms are themselves direct impacts on an ecosystem. However, their presence causes a number of other ecological impacts. Of critical concern is the impact of eutrophication. Macrophyte invasion prevent the growth of other aquatic plants.

Similarly, algal and cyanobacterial blooms consist of species that have out-competed other species for the available nutrients and light. Their impact on animal biodiversity is also of concern. By generally lowering the ecological integrity of an ecosystem, only the more tolerant animal species can survive. Cyanobacteria (also known as blue-green algae) and algae require water, carbon sdioxide, inorganic substances and light for their life processes. Cyanobacteria are found widely in nature and flourish in water that is salty, brackish or fresh, in cold and hot springs and in environments in which no other algae can exist. The basic forms and structure include unicellular, colonial and multicellular filamentous forms. The growth rate of cyanobacteria is usually much lower than that of many algal species.

10.2 Aesthetic impact

Algal and cyanobacterial blooms, and particularly surface scums that might form, are unsightly and can have unpleasant odours. This is often a problem in urban impoundments where people live close to the affected water body. If the water is being used for water treatment purposes, various taste and odour problems can occur. These lower the perceived quality of the treated water, although do not cause human health problems.

10.3 Economic impact

Nearly all of the above mentioned impacts have direct or indirect economic impacts. Algal or cyanobacterial scums increase the costs of water treatment in order to avoid taste, odour and cyanotoxin problems in the treated water. Excessive blooms can clog filters and increase maintenance costs.Human and domestic and wild animal health impacts due to cyanotoxins in water have obvious direct economic impacts.Once significant eutrophication has occurred, the costs of corrective action can be enormous. Macrophytes may need to be sprayed or brought under control by biological or other costly treatment processes.

10.4 Threatens the survival of fish and other aquatic life forms

When aquatic ecosystems experience increased nutrients, the phytoplankton and other photosynthetic plants grow explosively, commonly known as algal blooms. As an outcome the algal blooms limit the amount of dissolved oxygen required for respiration by other animal and plant species in the water.

Oxygen depletion happens when the algae or plant die and decompose. When the dissolved oxygen reaches hypoxic level, the animal and plant species under the water such as shrimp, fish and other aquatic biota suffocate to death. In extreme cases, the anaerobic conditions encourage the growth of bacteria that produces toxins that are deadly to marine mammals and birds. This can bring about aquatic dead zones and lessens bio-diversity.

10.5 Deterioration of water quality and limits access to safe drinking water

Algal blooms are highly toxic and once the water reaches the anaerobic conditions, the growth of more toxic bacterial is promoted. This consequence is extensive deterioration of water quality and decline in the availability of clean drinking water. The dense growth of algal blooms and photosynthetic bacteria in surface waters can also block water systems, hence limiting the availability of piped water. On this regard, toxic algal blooms have shut down numerous water supply systems across the globe.

10.6 Impact on human health

The **Cyanobacteria** , also referred to as **Dinoflagelates** , which generates red tide, releases very powerful toxins with high poison levels in the water even at very low concentrations. The anaerobic conditions created by explosive plant growth in the water also results in the doubling of the toxic compounds. It can cause death in humans and animals even at the least concentration when ingested in drinking water. Freshwater algal blooms can threaten livestock health. The toxic compounds can also make up their way up the food chain, contributing to various negative health impacts such as cancers. **Biotoxins** are linked to increased incidence of neurotoxic, paralytic, diarrhoetic shelfish can lead to death. High concentration in drinking water is associated with the ability of inhabiting blood circulation in infants, a condition known as **blue-baby syndrome**.

10.7 Endangers fishing

The minute floating plants such as algae and photosynthetic bacteria and the development of extensive and dense mats of floating plants such as Nile cabbage water hyacinths grows. Whenever this happens on a water body, fishing is endangered. It simply becomes difficult to set the fishing nets in water and plant floating on water limits the mobility of boats and other fishing equipment.

10.8 Degradation of recreational opportunities

The main problem of eutrophication is the algal blooms and other aquatic plants that float on an extensive area of the water surface. It reduces the transparency and navigation in the water which lessens the recreational values and opportunities of the lakes, especially for boating and swimming. Nile cabbage, algal blooms and water hyacinth can spread over an extensive area along the shores and can sometimes float over the entire surface into the land area.

11. CONTROL OF EUTROPHICATION

Out of all the factors promoting eutrophication, only nutrient supply is within the scope of human intervention. Rest of the factors are essentially natural and only very little can be done to manipulate them. The first step in any control programme should be a regular monitoring of certain parameters [nutrients, algal species, productivity, etc. in the water body to evaluate the level of eutrophication and its trends.

The next step would be to prepare an inventory of inflows, especially to know the source wise contribution of nutrients. The reduction of nutrient supply to a water supply to a water body can be brought about by a number of methods involving either prevention of the entry of nutrients or by some in situ water treatment procedures to curtail the nutrient availability to algae.

12. PREVENTION OF EUTROPHICATION

There is a proverb, 'Prevention is better than Cure'. So we should try to prevent the factors which generally accelerate or results in eutrophication. Some of them are listed below.

12.1 DISPERSION OF NUTRIENTS FROM LAKES

The diversion of nutrient bearing flows away from lakes can keep them free from nutrients. This can be achieved when the nutrients enter the lake mainly through point sources such as domestic sewage and industrial wastes. The wastes can be diverted directly to somewhere else like downstream, estuary or oceans, which have comparatively greater self purification capacities than stagnant waters.

12.2 REMOVAL OF NUTRIENTS FROM WASTE WATERS

Any degree of treatment to remove the nutrients and the organic matter can be given to wastes depending upon the process selected. Secondary treatment usually removes only organic matter and is not effective in controlling eutrophication. Though, tertiary treatment methods are fairly well known to remove practically all nutrients, interest often lies in removal of only phosphorus for control of eutrophication.

12.3. ZONING AND WATERSHED MANAGEMENT

Many of the water pollution problems arise due to lack of proper management of watershed areas leading to excessive erosion and entertainment of nutrients and organic matter in run-off. The land use pattern in the watershed or catchment area will determine the nature of drainage.

A check on deforestation and erosion will help reducing the nutrient load of the water resources. Selection of suitable sites for industries, agriculture, urban development and so on will also help in controlling the water quality.

SOME MORE PREVENTIVE MEASURES:

- **a.** Reduction of Phosphorus in detergents.
- **b.** Implementation of effective filter eco-systems to remove nitrogen and phosphorus present in the run-off water such as phyto-purification plants.
- **c.** Rationalisation of agriculture techniques through proper planning of fertilization and use of slow release fertilizers.
- **d.** Use of alternative practices in animal husbandry to limit the production of waste water.

13. CURATIVE MEASURES OF EUTROPHICATION

In cases where water quality is already so compromised as to render any preventive initiative ineffective, curative procedures can be implemented such as,

13.1 FLUSHING OUT OF POLLUTED WATER BY NUTRIENT POOR WATER

The technique is useful for relatively small and highly polluted waters where the existing water can be removed to a convenient place and a supply of high quality water is readily available. Two approaches are usually followed for this, in one, the incoming water shall displace an equivalent amount of polluted water is removed first to be replaced later by the water of low nutrient content. The quantity of water requirement for flushing can be reduced if it is preceded by the removal of nutrients by some other methods, and by preventing further influx of nutrients to the water body.

13.2 REMOVAL OF LOCKED-UP NUTRIENTS

Nutrients in aquatic ecosystems are locked-up in the tissues of fish, other animals, vegetation {macrophytes} and of course, in the algae besides being in the water and sediments. Periodical removal of macrophytes and fish, especially when the water level is low, would help in removing a quantity of nutrients from water. The further entry of the nutrients should be checked, since their built up in water can start again after recovery.

13.3 DREDGING OF SEDIMENTS

A large proportion of nutrients can also be removed by dredging the sediments out of lake. Dredging may be feasible where simultaneous deepening of the lake is also desired. It is often possible that the quality of water may deteriorate temporarily due to disturbance of well consolidated sediments causing the release of these nutrients in water mass and decrease in capacity of the remaining sediments to bind them. Proper considerations should be given to given to these impacts on the water quality.

13.4 COVERING OF SEDIMENTS

The nutrients and organic matter present in upper sediments of a lake, under proper conditions. In other words, the sediments work as a store house of nutrients from where they may be periodically released into the water mass. The retardation of release of these nutrients shall check the internal fertilisation. This can be performed by covering the sediments with some suitable material such as rubber or polythene sheets or some other inert material like clay or fly-ash.

13.5 OXYGENATION AND MIXING

Mixing of water column de-stratifies the lakes and eliminates the anaerobic reducing conditions in hypolimnetic waters, promoting the development of uniform profiles of dissolved oxygen, temperature, phosphorus and other such parameters. It is known that the release of nutrients from the sediments is about 10 times more in anaerobic conditions than that in aerobic conditions. Oxygenation by way of mixing of elements anaerobic conditions and lowers the nutrient release from sediments. A proper mixing and aeration in water column can be carried out by using compressed air pumps releasing air near the bottom of the lake.

13.6 NUTRIENT INACTIVATION

The technique involves eliminating the nutrients from their natural cycles in water bodies by various physical and chemical means, in order to make them unavailable for the growth of algae. Phosphorus is the most important nutrient, controlled in this manner. The use of calcium hydroxide or aluminium sulphate co-precipitates phosphorus with them which settles down to the bottom. A proper mixing of the water is required to disperse the chemical uniformly. Phosphorus has also been controlled by its adsorption on some inert material such as clay or fly-ash. The use of these materials serves dual purpose as they, besides adsorbing phosphorus, also cover and seal the sediments preventing the nutrient release.

14. MANAGEMENT OF EUTROPHICATION

The basis of eutrophication management is often the 'limiting nutrient concept. The rate and extent of aquatic plant growth is dependent on the concentration and ratios of nutrients present in the water. Plant growth is generally limited by the concentration of that nutrient that is present in the least quantity relative to the growth needs of the plant. Minimisation of eutrophication-related impacts therefore tends to be focussed on efforts to reduce nutrient (particularly phosphorus) inputs. This approach therefore deals directly with the primary cause of eutrophication (namely, nutrient enrichment).Typically, limiting nutrients entering an impoundment exhibiting a high degree of eutrophication will first focus on point sources. These are easier to quantify, simpler to manage and often contribute the highest nutrient load.

Following this, non-point sources are managed and then internal ("in-lake") management options can be implemented. The successful eutrophication management depends on the acceptance of certain perspectives. These include the following:

a) *Cultural eutrophication is reversible.*
b) *There is no quick fix. Long term approaches are required to solve the problem.*
c) *Collaboration is required between government, business and communities. However, government must play the lead facilitation role.*
d) *The problem cannot be solved by a single technical intervention. It requires a suite of social, economic and technical actions.*
e) *Transparent research and monitoring activities are prerequisites to the decision making that is required.*

15. CONCLUSION

Water is not a commercial product like any other, but rather a heritage which must be defended and protected, especially in the presence of a global decline in the availability of drinking water and increase in its demand. From the discussions and the analysis done, it can be concluded, now-a-days, eutrophication has become a great cause of distress for the aquatic organisms.
The parameters discussed depict that a great commotion has taken place within the water bodies due to the various anthropogenic activities taking place on a large scale. The quality of the water can be retained if these activities are checked and implementations of various environmental laws are done.

Natural as well as cultural eutrophication , both are equally harmful as it decreases, the dissolved oxygen content of water and we all know oxygen is the most important gas to stay alive for the aerobic organisms.
Due to various anthropogenic activities the addition of more and more nutrients to the water bodies has caused an enrichment beyond limit which promotes algal bloom and other harmful mat formation of various micro-organisms over the surface of the water body then cancelling the direct contact of atmospheric oxygen with the water organisms.

Despite of the considerable effects made to improve the quality by limiting nutrient enrichment, cultural eutrophication and the resulting algal blooms continues to the main cause of water pollution. Although, eutrophication process, which involves a natural sequence of events, is difficult to halt, yet it can be controlled by direct killing of aquatic plants and weeds. **Copper sulphate** is used to kill algae and **Sodium arsenite** is used to kill the rooted plants of the water body.
The prevention and protection action that countries must adopt to safeguard the quality of surface water as requested not only by the scientific community and other experts, but to an increasing extent, also by citizens and environment organizations, is therefore increasingly important. We need to manage, maintain and clean the water resources properly to provide safe drinking water to the people and save them from dreadful water-borne diseases to some extent

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